ACTEW CORPORATION

MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 3: MURRUMBIDGEE PUMP STATION

Autumn 2010

The ALS Water Sciences Group is part of the Environmental Division of ALS, one of the largest and most geographically diverse environmental testing businesses in the world.

CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Client: ACTEW Corporation
Project Title: **Murrumbidgee Ecological Monitoring Program**
Report Title: PART 3: Murrumbidgee Pump Station
Document No: MPS_A10_R5
Document Status: Final
Date of Issue: 22/12/10
Comments:

	Position	**Name**	**Signature**	**Date**
Prepared by:	Environmental Project Officer	Phil Taylor		11/10/10
Internal Review by:	PRINCIPAL SCIENTIST (GROUNDWATER ECOLOGY)	PETER HANCOCK		18/11/10
Peer Review by:				
Approved by:	Manager - Water Sciences	Norm Mueller		20/12/2010

For further information on this report, contact:

Name: Phil Taylor
Title: Environmental Project Officer
Address: 16b Lithgow Street, Fyshwick, 2609. ACT.
Email: phil.taylor@alsglobal.com

Document Revision Control

Version	**Description of Revision**	**Person Making Issue**	**Date**	**Approval**
1	Draft	Norm Mueller	09/08/2010	

TABLE OF CONTENTS

List of Tables

List of Figures

List of Plates

List of Appendices

List of Abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Free Dry Mass (periphyton)
ALS – Australian Laboratory Services
ANZECC –Australian and New Zealand Environment and Conservation Council
ANOVA – Analysis of Variance (statistics)
APHA – American Public Health Association
ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand
ARI – Average Recurrence Interval
AUSRIVAS – Australian River Assessment System
BACI – Before After Control Impact
CI – Confidence Interval
CMA – Catchment Management Authority
EC – Electrical Conductivity
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
GL/a – Gigalitres per annum
GPS – Global positioning system
IBT- Inter-Basin Water Transfer
M2G – Murrumbidgee to Googong
MEMP – Murrumbidgee Ecological Monitoring Program
ML/d – Megalitres per day
NATA – National Association of Testing Authorities
NMDS – Non-metric Multidimensional Scaling (statistics)
NSW – New South Wales
NTU – Nephlelometric Turbidity Units
QA – Quality Assurance
QC – Quality Control
SD – Standard Deviation
TN – Total Nitrogen
TP – Total Phosphorus

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 to assist in the characterisation of 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 autumn 2010. Sampling was completed in May 2010 and was based on the AUSRIVAS sampling protocols. Sampling was extended to include multiple replicates from each site and 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 autumn 2010 sampling of the MPS indicate that:

- *Water quality was good overall, with most water quality parameters at levels within ANZECC (Australian and New Zealand Conservation Council) guidelines. The exceptions to this were Total Nitrogen, which was over the recommended guidelines at all sites and TP, which was at the upper threshold level recommended for healthy ecosystems. Despite exceeding the trigger values, TN concentrations were the lowest recorded since the inception of this program. The water quality results from autumn 2010 represent stable, low flow conditions, while the higher concentrations recorded in previous runs are likely a result of the timing of the sampling – which was conducted within 3 weeks of the last runoff event meaning that nutrient loads were still being conveyed through the system.*

- *Chlorophyll-a and ash free dry mass from the periphyton samples did not differ between upstream and downstream sites of the MPS. The implications of these results are that any seasonal fluctuations in flow and water quality appear to occur at the macro-reach scale and are not restricted to sites downstream of the MPS. This is because first order changes such as those to flow and/or water quality can influence rates of primary production. If the MPS upgrade caused these "first order" changes, it is likely that there would be: a) notable differences in the chlorophyll-a and AFDM from the periphyton samples and b) notable differences in water quality analytes between locations. However, in this study no differences in either case were found.*

- *All sites were categorised as Band-B ("significantly impaired") by the AUSRIVAS assessment which is consistent with the previous two sampling runs. The absence of certain taxa predicted by the AUSRIVAS model is likely to be due to pre-existing disturbances (specifically urban and agricultural landuse) of this part of the upper Murrumbidgee Catchment rather than MPS related activities. This is because the same community patterns and same suite of missing taxa are seen at all of the sampling sites rather than just downstream of the MPS, as would be expected if there was an obvious impact.*

- *Stable flows in late autumn (and during sampling) have facilitated the recolonisation of sensitive EPT taxa in the riffle samples and increased the abundance of free-living taxa in the edge habitat. Previous sampling runs have shown declines or even absence of these, usually very common, taxa due to drought related impacts and on the conversely, high flow events. This suggests that following such disturbances, recolonisation can be rapid, but requires periods of stability to reach pre-disturbance conditions.*

- *This autumn 2010 assessment shows no evidence of physico-chemical or biological changes resulting from the construction works associated with the MPS development. This is supported by no location-specific impacts to water quality, periphyton or macroinvertebrate communities seen in this assessment.*

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 autumn 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 (ALS, 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 ALS's NATA accredited laboratory.

1.3 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most commonly used biological indicators in river health 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 floral and microbial 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 and 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 flow, and this makes them a valuables indicator of river health.

2 Materials and Methods

The types of impacts that may arise during the implementation of M2G, depends on 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 and 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 Study sites

Site selection was based upon the recommendations outlined in ACTEW's Licence to take water WU67 section D6 (Figure 1; Table 1: see photographs in APPENDIX A). 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 1. 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

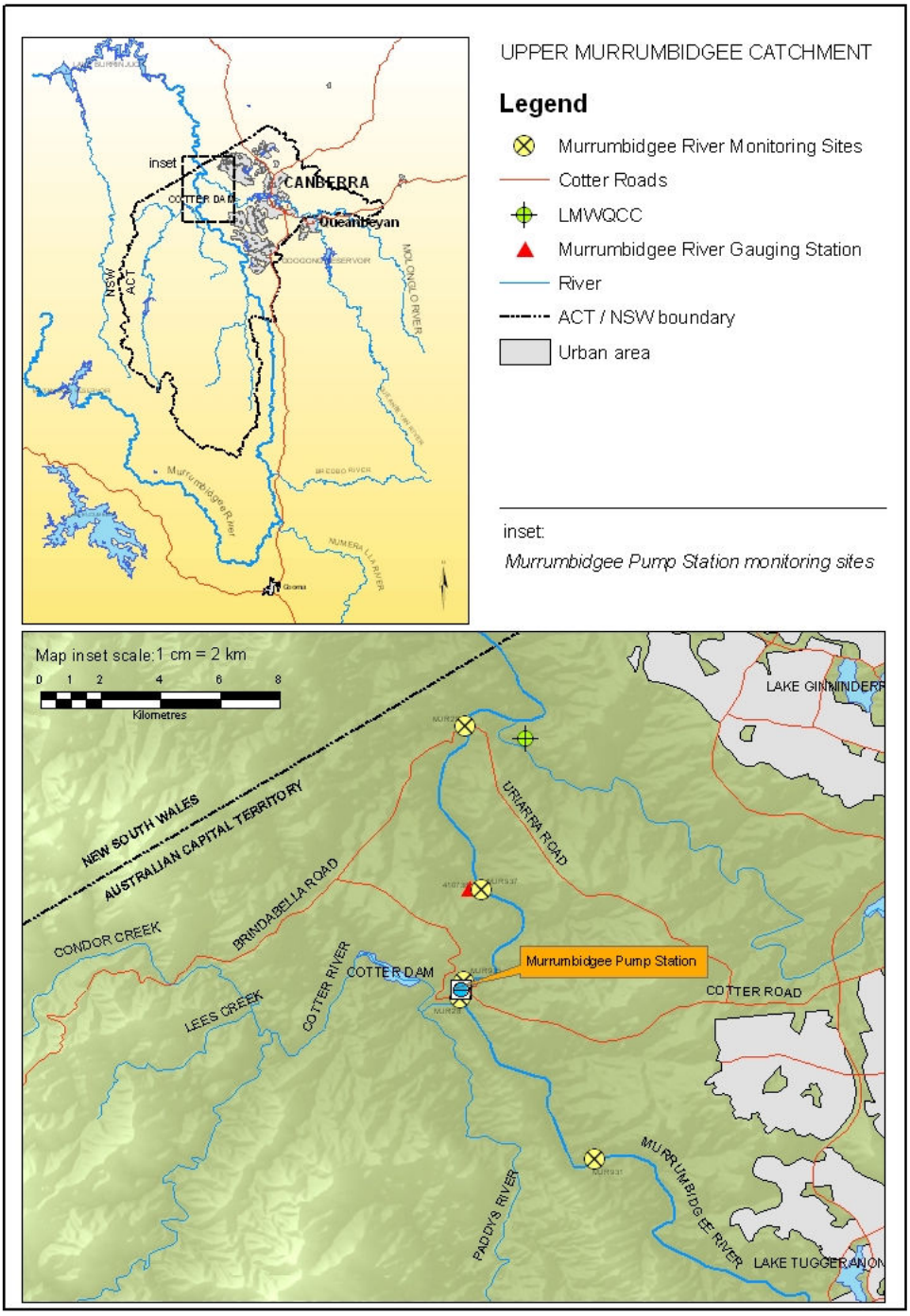


Figure 1. Location of the monitoring sites and gauging stations for the MPS monitoring program

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS gauging stations at Burra Road (410774, downstream of the Burra Road Bridge) and the Queanbeyan River (410781, upstream of Googong reservoir). Site locations and codes are given in Table 2 (below).

Table 2. Stream flow and water quality monitoring site locations. WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity

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

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 Hydrolab® Minisonde 5*a* Surveyor. The Surveyor was calibrated in accordance with ALS QA procedures and the manufacturer's requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols (Coysh *et al.*, 2000b) for Hydrolab® verification, nutrient analysis and given that all of the Burra Creek sites could be sampled on this occasion a full metals screen and anion: cation balance was carried out to provide a baseline for comparisons against samples during the construction and operational phases of this project.

All samples were placed on ice, returned to the ALS laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in APHA (2005). This information will assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to increased flow and potential changes in the Burra Creek system due to inter-basin water transfers from the donor (Murrumbidgee) system.

2.4 Macroinvertebrate sampling

Riffle and edge habitats were sampled for macroinvertebrates (May 24th and 25th) and analysed using the ACT autumn riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000b).. 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 10 cm; (Coysh *et al.*, 2000b) using a framed net 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 code and date, then stored on ice and placed in a refrigeration unit until laboratory sorting commenced.

The edge habitat was also sampled according to the ACT AUSRIVAS protocols. Two samples were taken from the edge habitat. 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.

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) measurements (Biggs, 2000).

The five sampling sites selected for this project (Table 1) were sampled for periphyton in spring in conjunction with the macroinvertebrate sampling. All periphyton (i.e. adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix) samples 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), and chlorophyll-a. Samples for Ash Free Dry Mass and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing followed the methods outlined in APHA (2005).

2.6 Data analysis

Data were analysed using both univariate and multivariate techniques using R 2.10.1. (R Development Core Team, 2008) and PRIMER v6 (Clarke and Gorley, 2006) . Details of these analyses are provided below.

2.6.1 Water quality

Water quality parameters were examined for compliance with ANZECC & ARMCANZ (2000) water guidelines for healthy ecosystems in upland streams. Trend analyses of water quality parameters will be 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 at this stage. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006).

Processing of the aquatic 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 dataset prior to analysis.

For the ACT AUSRIVAS model, all taxa were analysed at the family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order). Animals were identified using taxonomic keys listed in Hawking (2000). All animals within the cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

Non-metric multidimensional scaling (NMDS) was performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data by describing trends in the joint occurrence of taxa and aids with interpretation. 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 and Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions is reduced to two. How well the patterns in the 2-dimensional NMDS plot represents the multivariate data is indicated by the stress value of each plot. 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. Stress can be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964), and when near zero suggests that NMDS patterns are very representative of the multidimensional data. Stress greater than 0.2 indicates 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 proposed discharge point. Sites were unable to be nested with location in the two-way design due to a lack of replication at several of the sites. Instead, a one-way analysis examined the differences between location (up and downstream of the proposed discharge point, using site as the unit of replication) and differences between systems (Burra and Queanbeyan).

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 and Warwick, 2001)

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 4) 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).

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.

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.

Table 1. AUSRIVAS band-widths and interpretations for the ACT autumn riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	O/E Band width	Explanation
X	>1.12	>1.17	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.88-1.12	0.83-1.17	Similar to reference. Water quality and / or habitat in good condition.
B	0.64-0.87	0.49-0.82	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.40-0.63	0.15-0.48	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0.-0.39	0-0.14	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.6.5 Periphyton

The raw Chlorophyll-a and Ash Free Dry Mass data were converted to estimates of concentrations and biomass per square metre respectably following the methodology outlined in Biggs and Kilroy (2000).

These data were used to test for differences between upstream-control locations versus downstream impact locations. Log transformed Chlorophyll-a and raw ash free dry mass data were fitted to a mixed effects, nested analysis of variance (ANOVA). Site was nested within location and was treated as a random effect and location was considered a fixed effect. For the purposes of graphical visualisation, 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 confirmed 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 Licenses 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)).

ALS field staff maintain current ACT AUSRIVAS accreditation.

3 Results

Sampling commenced on the 25th of May and was completed on the 26th. During this period, sampling conditions were overcast but otherwise fine. Sampling occurred during a period of low (<40ML/d) but stable flow conditions in the Murrumbidgee River (Plate 1; APPENDIX A).

3.1 Hydrology and rainfall

The flows recorded for the autumn 2010 period indicate that the 50th percentile flows for March are the highest since 1993 and for both Mt. MacDonald and Lobb's Hole and the 50th percentile flows recorded in May were the highest since 1995 at Lobb's Hole.

There were two events of significance occurring between the spring 2009 (October/November) and autumn 2010 (May) sampling periods. The first occurred in mid February and peaked at 274174 ML/d (Plate 2), while the second occurred in early March and peaked at 5506 ML/d.

March was the wettest month in autumn, with 114 mm of rainfall recorded at Lobb's Hole – 31.6 mm more than for the entire 2009 autumn period. There were 23 wet days for the period, averaging 7.6 per month. Daily rainfall for the autumn period ranged from 0.2 (detectable minimum) to 39.6 mm in early March. Four consecutive wet days contributed to 65% of March's rainfall resulting in a peak in the hydrograph early in the month (instant maximum = 5506 ML/d) (Figure 2). A second event, with an average recurrence interval (ARI) of 5 years (32855 ML/d) occurred on the 31st of May, five days after the completion of autumn sampling (Figure 2). Rainfall and flow data for autumn are summarised in Table 2.

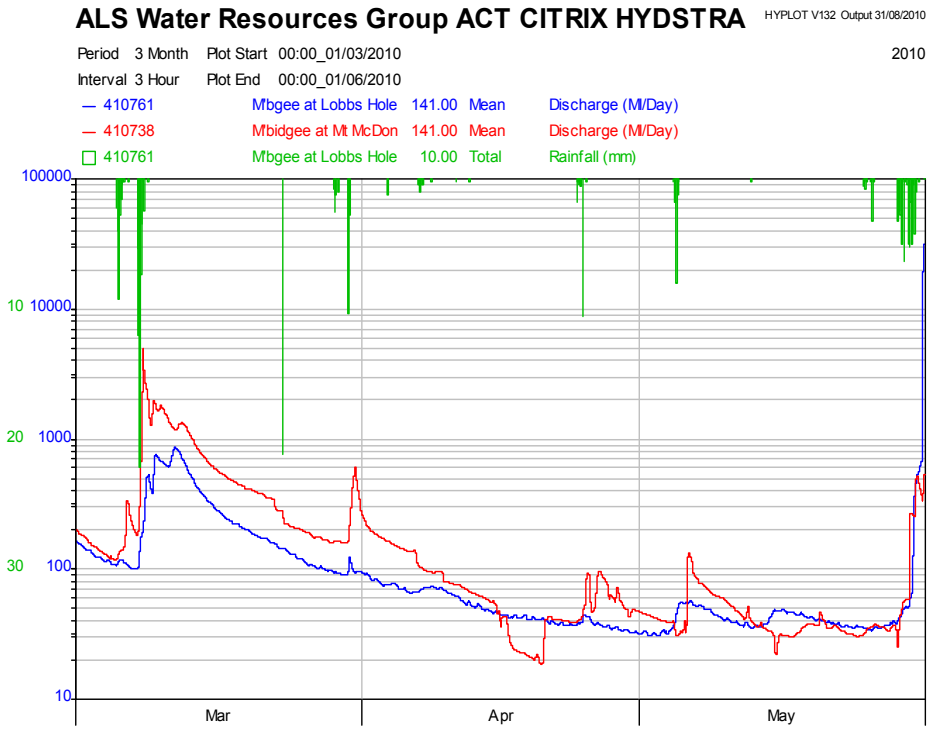


Figure 2. Autumn hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738). Total rainfall was recorded at the Lobb's Hole station. Note the log-scale on the y-axis.

Plate 1. The Murrumbidgee River from the Cotter Road Bridge. Top: looking upstream towards the Cotter River confluence. Bottom: looking downstream with the MPS pump intake on the right and the Coffer dam wall on the left hand side*.* At the time these photographs were taken (26/05/2010), the mean daily flow at Mount MacDonald (410738) was 36.7 ML/d.

Plate 2. The Murrumbidgee River from the Cotter Road Bridge. Top: looking upstream towards the Cotter River confluence. Bottom: looking downstream with the MPS pump intake on the right hand side. At the time these photographs were taken (17/02/2010), the mean daily flow at Mount MacDonald (410738) was 12938 ML/d; peak flow was measured as 27417 ML/d.

Table 2. Monthly flow and rainfall statistics for autumn 2010 at Lobb's Hole (410774) and Mount MacDonald (410761). * The average flow for May is skewed due to a high flow event passing through Lobb's Hole as a result, flows appear lower at Mt. MacDonald to the travel time lag between the two sites.

Station	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
March	114	245.4	551.4
April	18.2	52.75	78.9
May	63.4	263.9*	60.8*
Autumn	195.6	187.3	230.3

3.2 Water quality

Data are missing from the continuous records for the first three weeks of March, due to the essential repairs to water quality probes. No records were taken during repairs, so it is unclear of the water quality responses to the event in early March (Figure 2). The data that is available shows that all of the physico-chemical parameters were within ANZECC and ARMCANZ guidelines (figures based on daily means) for the autumn period. The one exception was a turbidity spike in late March corresponding to a small rainfall event (10mm) on the 30th.

The overall patterns in the continuous water quality data show a gradual decline in temperature, which corresponds to ambient temperatures decreasing leading into winter (Figure 3). EC tended to fluctuate with changes in flow. The monthly average EC values were highly consistent over the three month period ranging between 115-121 µs/cm^{-2}; monthly means ranged form 115 - 118 µs/cm^{-2} (Table 3). Both pH and DO (% sat.) showed strong diurnal trends. pH fluctuated more as the hydrograph was receding and as flows became more stable in May, the daily variation in pH became less apparent (Figure 3). DO trends were constant throughout autumn, which is emphasised by the similarity in the monthly mean values (Table 3). Daily maximums did not exceed the upper 110% trigger value while the minimums stayed above the minimum threshold of 80% in autumn.

During the current stage of the MPS upgrade, there is little evidence from the grab samples or the continuous records to suggest any impact from the works on water quality. Upstream of the MPS, total suspended solids were negligibly lower than the readings downstream and on average turbidity readings were almost equivalent between locations (Table 4)

Nitrogen oxides were below detectable levels for all sites. Total phosphorus concentrations were on the ANZECC & ARMCANZ threshold of 0.2 at all sites. Total nitrogen was exceeded at all sites with the highest values (0.41 mg/L) being recorded at Mount MacDonald (MUR 937). The remaining physico-chemical parameters were similar across all sites. EC was slightly lower at MUR 937 (111.7 µs/cm^{-2}) and MUR 29 (111.4 υs/cm^{-2}) than the upstream sites (Table 4).

Table 3. Monthly water quality statistics from Lobb's Hole (410761)

All values are means. Monthly maximum turbidity values are in parentheses

Station	Lobb's Hole (410761)				
Analyte	temp.	EC	pH	turbidity	D.O. (% Sat.)
March	20.8	115.9	7.7	6 (41)	98
April	17.5	118.7	7.7	6.8 (15)	96
May	11.5	115.8	7.7	7.7 (16)	97
Autumn	**16.6**	**116.8**	**7.7**	**24 (41)**	**97**

Figure 3. Continuous water quality records from Lobb's Hole (410761) for autumn 2009

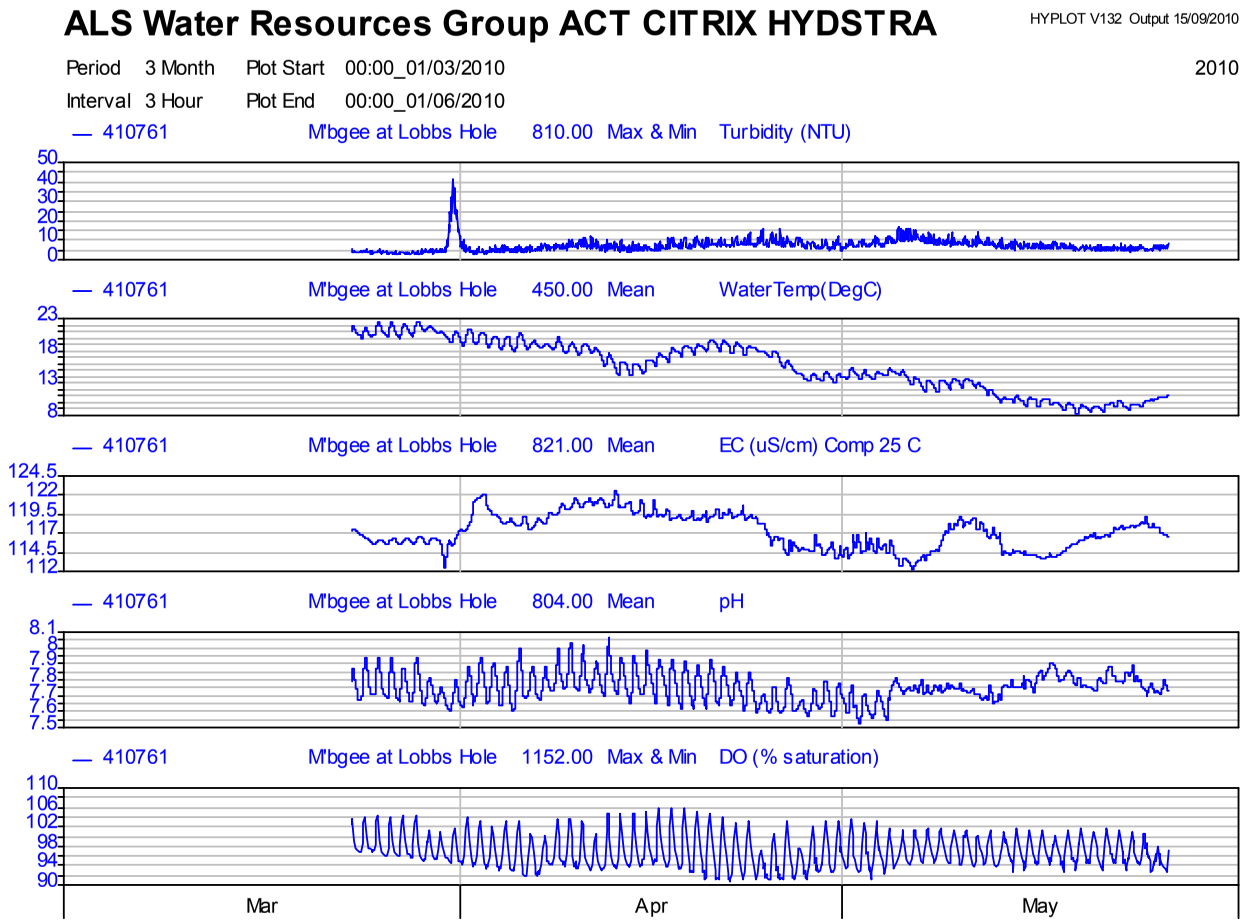


Table 4. Water quality results for autumn 2010. ANZECC & ARMCANZ guidelines are in red. Yellow cells indicate values outside guidelines. † Indicates water sample taken from pool/edge.

Location	Site	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS (mg/L)	pH (6.5-8)	D.O. (% Sat.) (90-110)	D.O. (mg/L)	Alk.	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Upstream	Mur 0931	0830	10.7	114.6	7.6	6	7.8	99.70	10.20	54	<0.01	<0.01	<0.01	0.03	0.02	0.39
	Mur 28	1200	11.2	115.4	7.0	7	7.8	99.30	11.00	54	<0.01	<0.01	<0.01	0.03	0.02	0.39
Downstream	Mur 0935	1145	10.9	116.8	5.5	7	7.8	100.00	11.18	52	<0.01	<0.01	<0.01	0.01	0.02	0.40
	Mur 0937	0930	9.25	111.7	9.1	10	7.5	99.00	11.50	53	<0.01	<0.01	<0.01	<0.01	0.02	0.41
	Mur 29	1135	10.7	111.4	6.8	7	8.04	104.1	11.66	53	<0.01	<0.01	<0.01	0.02	0.02	0.38

3.3 Periphyton

Chlorophyll-a concentrations showed considerable variation both within, and between all sites (Figure 3). The average concentration upstream of the MPS (MUR 931 and MUR 28) was 35 662 µg/m^{-2} ± 19 078 µg/m^{-2} (95% CI) µg/m^{-2} compared to 29 203 µg/m^{-2} ± 11 419 µg/m^{-2} (95% CI) downstream of the MPS. These differences were determined as not significantly different between locations ($F_{1,3}$=2.56; P=0.21; Table 5). These concentrations are higher than previous sampling runs, but the overall pattern is consistent also with the previous runs, where a sharp increase occurs at MUR 28 and declines downstream to MUR 937, which again increases at MUR 29 (Figure 3). The absence of such a pattern in the AFDM data (Figure 4), combined with a weak correlation between the AFDM and chlorophyll-a data (Pearson's R = 0.247; $F_{1,28}$=1.83; P=0.18) suggests that the chlorophyll-a might not be algal derived and that the observable site differences could be due to differences in riparian vegetation and cover between sites.

The average AFDM for the upstream sites was 19 914 mg/m^{-2} ± 16 317 mg/m^{-2} (95% CI) compared to 12 562 ± 11 388 mg/m^{-2} (95% CI) for the downstream sites. Despite the lower mean mass downstream of the MPS, the ash free dry mass estimates from the periphyton samples did not differ between upstream and downstream locations ($F_{1,3}$=1.03; P=0.38; Table 5). There were higher maximum values (>5 0000 mg/m^{-2}) at the two sites upstream of the MPS and at MUR 935 – approximately 380 m downstream of the Cotter Road bridge. The high maximum values at the upstream sites (MUR 28 and MUR 931) explain the larger mean at the upstream locations (Figure 4).

Table 5. One-way nested analysis of variance results for chlorophyll-a and ash free dry mass densities

Response	Source	DF	F-value	P-value
Chlorophyll-*a* (log)	Location	1	2.56	0.21
	Site [Location]	3	4.84	0.008
	Residual	29		
AFDM (log)	Location	1	1.027	0.38
	Site [Location]	3	2.37	0.09
	Residual	29		

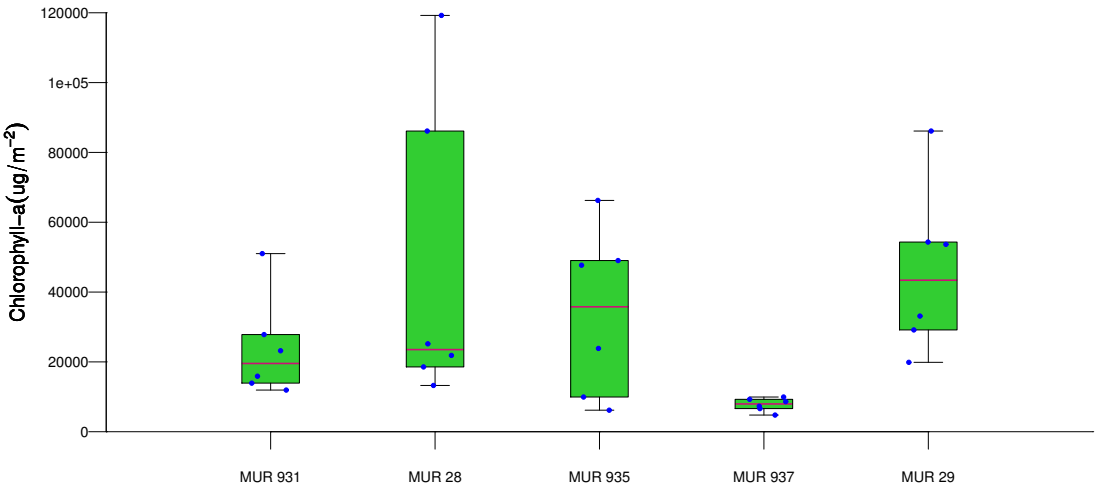


Figure 4. Periphyton chlorophyll-a concentrations from upstream and downstream of the MPS

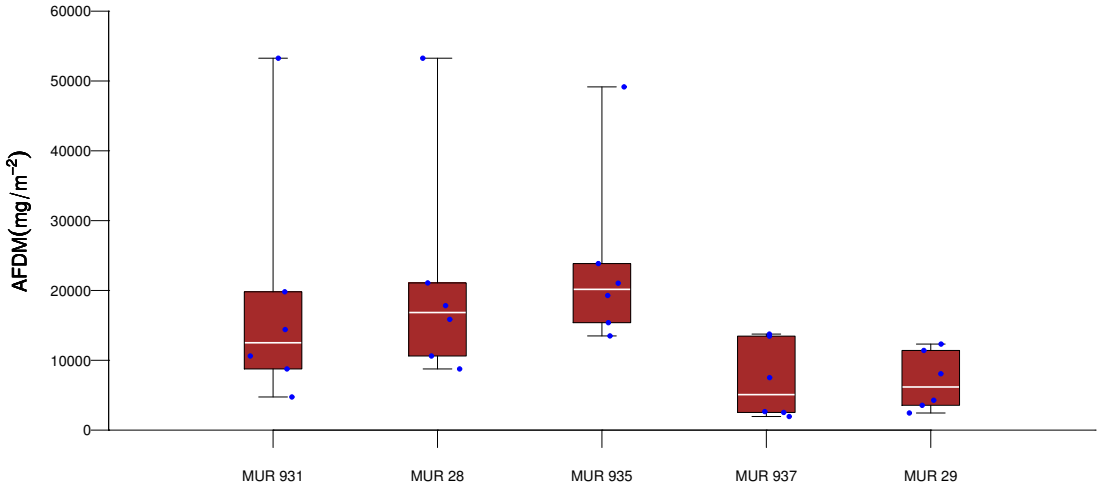


Figure 5. Periphyton Ash Free Dry Mass (AFDM) from upstream and downstream of the MPS

Strip chart values in blue represent raw data points. See **APPENDIX E** for and explanation on how to interpret box and whisker plots

3.4 Macroinvertebrate communities

3.4.1 Patterns in community structure

3.4.1.1 Riffle

The macroinvertebrate communities split into two main groups with 65% similarity based on the cluster analysis (Figure 5). Within the two main groups the highest degree of similarity was generally between samples from the same site, but not always. For example, subsamples from MUR 29 were more similar to samples from MUR 931, which is more easily seen in Figure 6 by the high degree of overlap between sites in ordination space.

The NMDS analysis (Figure 6) indicates a lack of separation between locations based on the macroinvertebrate community data. This is confirmed by the ANOSIM results which show no significant difference in the macroinvertebrate community structure between upstream and downstream locations (R=-0.417; P=0.9). The negative R-value suggests that many of the within-group samples are more similar to between groups samples. This can be seen by the positions of the upstream and downstream sites in Figure 5.

The superimposed groups at 65% similarity indicate that MUR 937 differs from the main group. Patterns in the community structure, causing this separation from the other four sites include: 1) up to a five-fold increase in the total abundance of black fly larvae (Simuliidae); 2) much fewer Oligochaetes (up to ten times fewer than recorded at all other sites); 3) on average, a higher abundance of Caenidae mayflies and fewer Trichopterans (specifically in the families: Hydropsychidae and Hydroptilidae) and 4) there was also several *Macrobrachium* sp. (freshwater prawns) collected from the riffle habitat – an animal that is usually collected from deeper water such as pools and edge habitat and often in association with vegetation. Although *Macrobrachium* sp. were collected at MUR 28 and MUR 935, they were more abundant at MUR 937.

Taxa richness at the genus level (TR*g*) ranged from 40 at MUR 931 and MUR 935 to 29 at MUR 28 (Figure 7); while family richness (TR*f*) ranged from 25, again at MUR 931 and MUR 935 to 20 at MUR 28. These results show no discernable pattern between locations, although the temporal pattern is consistent since autumn 2009, where MUR 931 and 935 have shown the highest number of taxa and MUR 28 has consistently had the lowest number of families and genera collected.

All sites were dominated by four main groups of pollution tolerant taxa: Chironomids (SIGNAL = 3); Oligochaetes (SIGNAL =2); Simuliidae (SIGNAL =5) and Orthocladiinae (SIGNAL =4). Combined, these taxa made up to 75% of the total number of individuals from the macroinvertebrate communities. MUR 931 had the highest abundance of these four key groups, particularly in the Simuliidae family where 61% of the total were comprised of genera from this family. There appeared to be no apparent trend in the percentage of tolerant taxa across sites; although there was a slight increase at MUR 937 and MUR 29. This slight increase is caused by higher numbers of Simulids at both sites (Figure 8).

EPT taxa richness ranged from 15 genera at MUR 28 and MUR 931 to 13 at MUR 29. The number of EPT families ranged from 7-9. MUR 931 had the most families (9); while MUR 28 and MUR 29 had the least (7 at each site). Stoneflies were not collected from the riffle habitat at any of these monitoring sites despite being collected at MUR 931, MUR 28 and MUR 935 in spring 2009. However for autumn 2009, Plecoptera (Stoneflies) were also absent from all of the MPS monitoring sites.

3.4.1.2 Edge

The relationship between the edge samples can be seen in Figures 9 and 10. The cluster analysis displays two main groups which are separated at approximately 55% similarity (Figure 9), consistent with the NMDS analysis (Figure 10). Both groups contain sites from upstream and downstream locations which suggests that there is no location effect on the macroinvertebrate communities. The ANOSIM results confirm this hypothesis (R=0; P=0.4). The R-value of 0 indicates that the similarity between locations is, on average, equivalent (Clarke and Warwick, 2001).

The highest number of families from the edge samples were recorded from MUR 29 (Uriarra Crossing). MUR 29 had a total of 48 genera and 39 families collected in autumn 2010, representing a 56% increase in the number of genera collected in spring 2009 and a 38% increase in the number of taxa collected in autumn 2009. The lowest number of taxa were collected from MUR 935 (immediately downstream of the MPS) with 26 families and 32 genera collected. Increases in the number of taxa since the previous two sampling runs were found across all sampling sites.

The edge samples contained a rich EPT fauna, particularly the in the order Trichoptera. The EPT fauna was richer than the riffle samples but contained less individuals. Across the MPS monitoring sites, *Tasmanocoenis* sp. (Caenidae: SIGNAL =4), *Triplectides* sp. (Leptoceridae: SIGNAL = 6) and *Orthotrichia* sp. (Hydroptilidae: SIGNAL = 4) were the most abundant EPT taxa. Chironominae (SIGNAL=3) was the most abundant taxa across all sites, contributing up to 52% of the total individuals (at MUR 28). Other abundant taxa included Acarina (SIGNAL =6) Orthocladiinae (SIGNAL = 4) and Oligochaeta (SIGNAL =2).

Micronecta sp. were the mot abundant taxa in the edge samples in autumn 2009, except at MUR 937, where they were not collected. In this sampling run, there were very few individuals collected and most of these were only found in one of the subsamples. Similar abundances of Baetids, Chironominae and Orthocladiinae were collected in this sampling run compared to autumn 2009, but there has been an increase in the number of taxa collected which has affected these common taxas' ranked abundance.

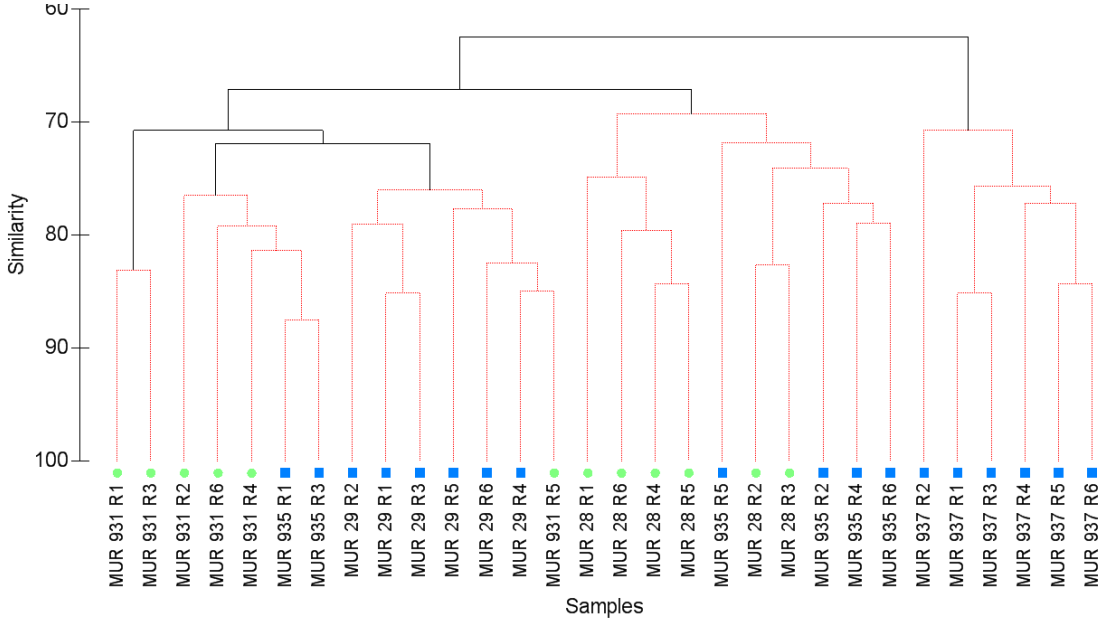


Figure 6. Cluster analysis of riffle samples from autumn 2010 Green circles are upstream of the MPS, blue squares are downstream.

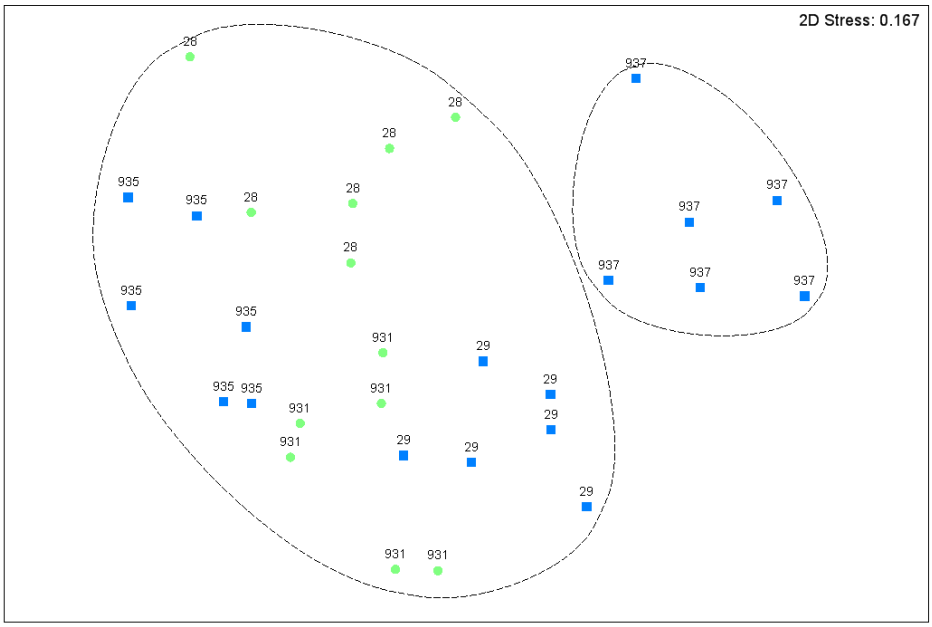


Figure 7. NMDS plot of riffle samples taken in autumn 2010. Green circles are upstream of the MPS, blue squares are downstream. Ellipses represent the 65% similarity groups superimposed from the cluster analysis

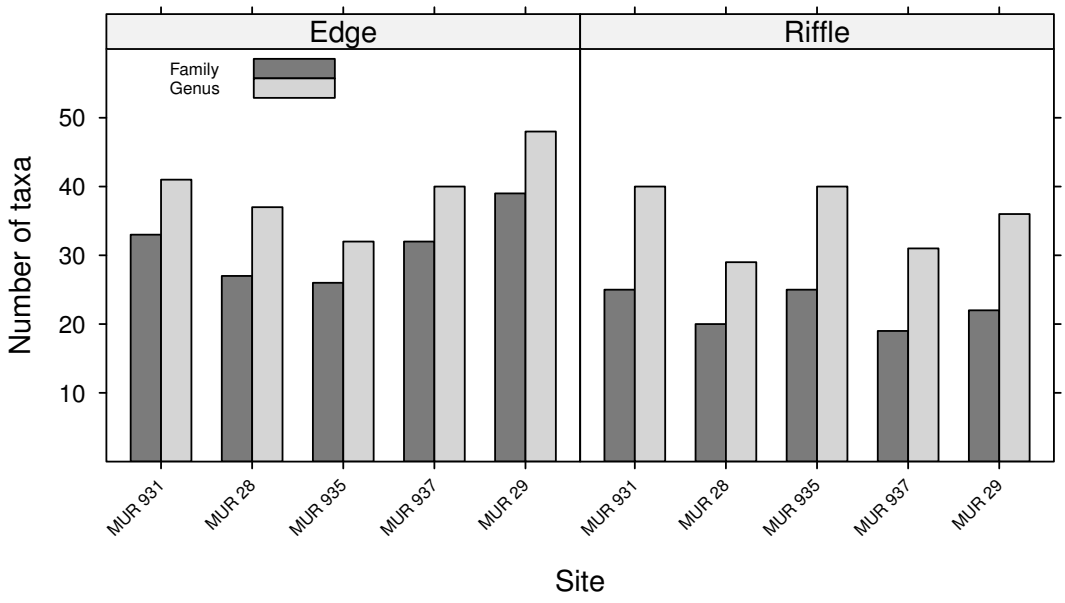


Figure 8. Family and genus richness from riffle and edge habitats

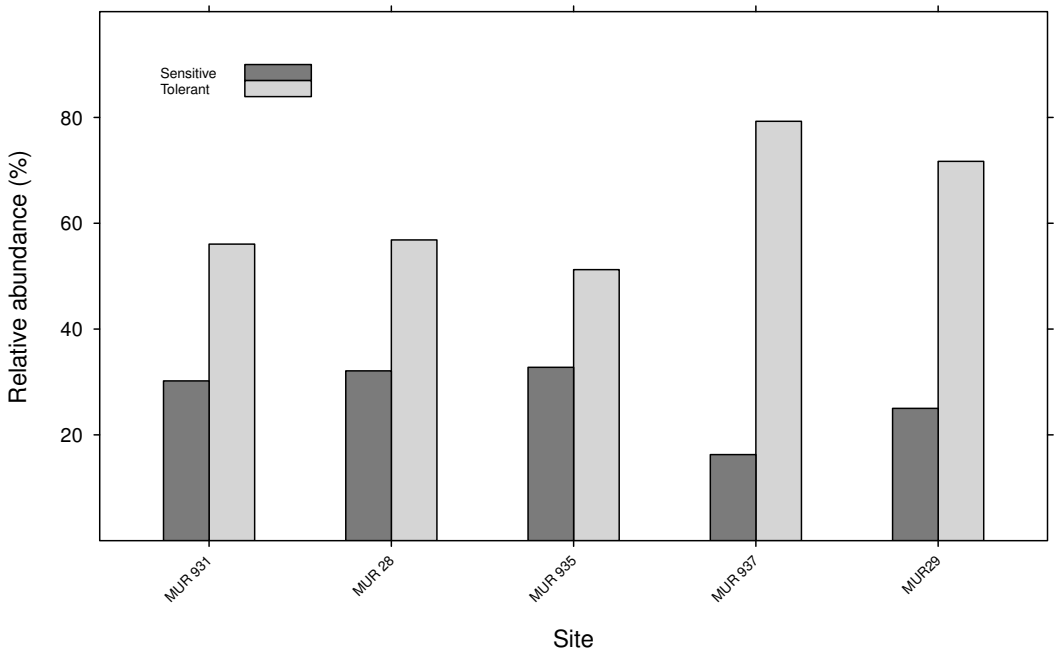


Figure 9. Relative abundance of sensitive (EPT) and tolerant taxa. EPT is a commonly used metric comprising the relative abundance of Ephemeroptera (mayflies); Plecoptera (stoneflies) and Trichoptera (Caddisflies). Tolerant taxa are comprised mainly of Oligochaeta (worms); Chironomids (non-biting midges) and other Diptera (true flies).

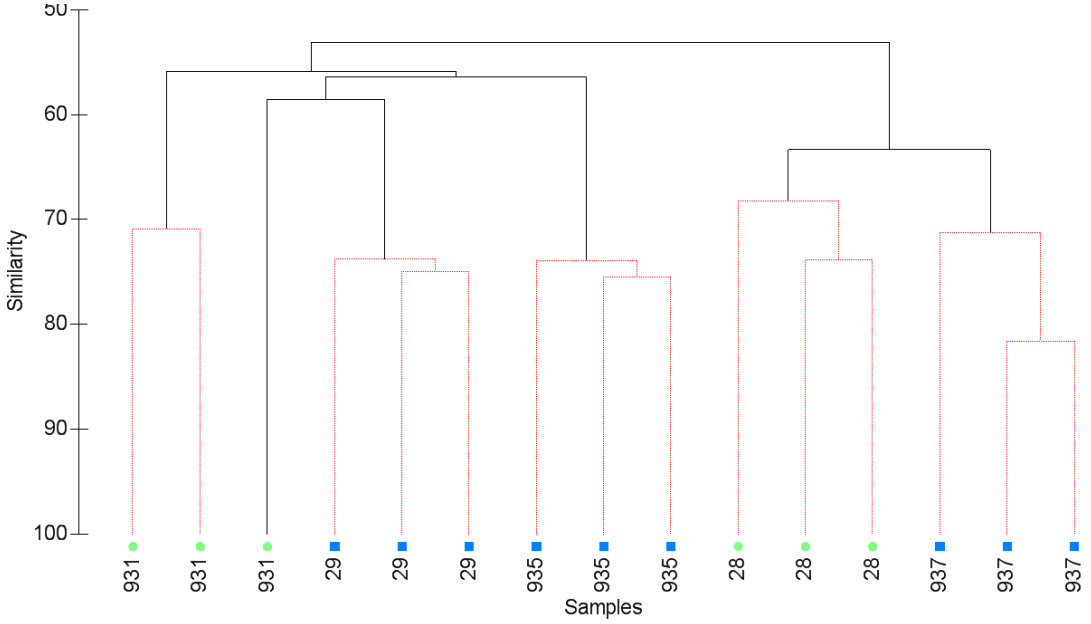


Figure 9. Cluster analysis of edge samples from autumn 2010. Green circles are upstream of the MPS, blue squares are downstream

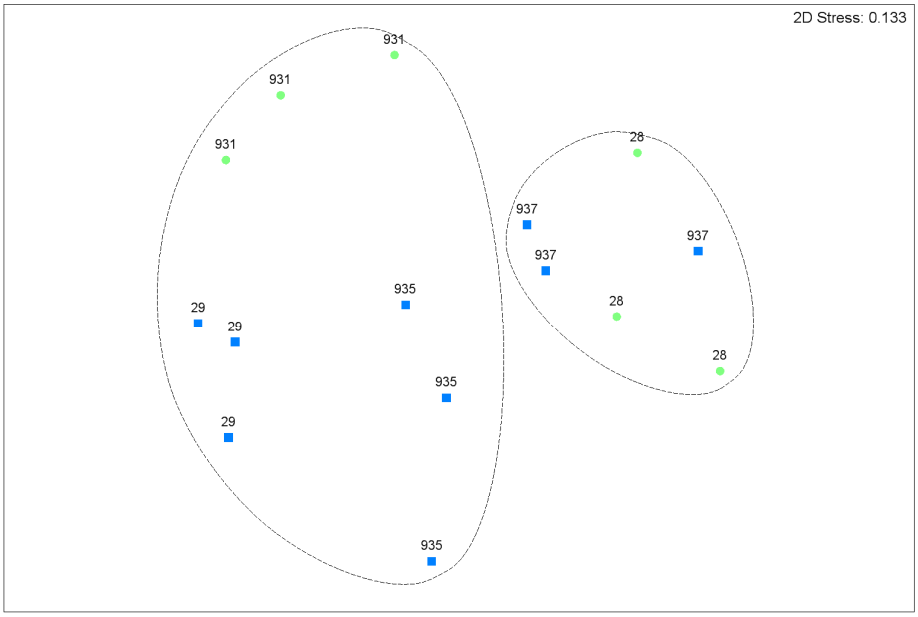


Figure 10. NMDS plot of edge samples taken in spring 2009. Green circles are upstream of the MPS, blue squares are downstream Ellipses represent the 55% similarity groups superimposed from the cluster analysis

3.4.2 AUSRIVAS assessment

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

The AUSRIVAS assessment for autumn 2010 shows that the overall site assessments (i.e. the combined riffle and edge assessments) were the same (BAND –B) across all of the sites (Table 6). Compared to previous sampling runs, there have been few detectable changes in the banding scheme assigned to each site by the AUSRIVAS methodology, despite some obvious changes in the communities in terms of their dominant taxa, estimated abundance and presence absence of certain taxa.

Comparisons to previous sampling events indicate that the riffle habitat has been assessed as BAND-B since the program began in autumn 2009; with the exception of MUR 931 in spring 2009. Similarly, apart from MUR 29 and MUR 937 in spring 2009 and autumn 2009 respectively, the edge habitat has also been assessed as BAND- B across all sites for the duration of the project to date.

In this sampling run, there was an improvement in the assessed condition in the edge habitat at MUR 29, moving from BAND-B to BAND –A since autumn 2009. Taxa that were not collected at this site in autumn 2009 but were recorded in the current sampling run include: Corixidae (SIGNAL =2); Leptophlebiidae (SIGNAL=8) and Leptoceridae (SIGNAL=6).

The average observed to expected ratios (O/E 50) from the riffle samples that were calculated for the upstream sites were slightly lower upstream (mean =0.83; n=12) of the MPS than downstream (mean=0.84; n=18) and were not statistically different ($F_{1,3}$ = 0.08; P=0.79) (Table 7). The O/E 50 scores for the edge habitat were statistically higher downstream of the MPS (mean = 0.85; n=9) compared to the upstream sites (mean =0.75; n=6) ($F_{1,3}$ = 15.31; P=0.02) (Table 8) which is consistent with a lower number of missing taxa (on average) from the edge samples downstream of the MPS (**APPENDIX C**).

The one–way ANOVA results indicate that the average SIGNAL-2 scores for the edge and riffle samples were not statistically different between upstream and downstream locations (Table 7 and 8). For the riffle samples the average SIGNAL-2 score for the upstream sites was 4.2, while downstream it was 4.4. Average SIGNAL -2 scores for the edge samples were higher upstream (mean = 4.5) compared to the downstream sites (mean =4.2) indicating that while the edge samples downstream contained more taxa that were predicted by the AUSRIVAS model, compared to the upstream sites, these taxa tended to have lower SIGNAL-2 tolerance scores.

The number of missing taxa form the riffle samples ranged from 1 (at MUR 28, MUR 935 and MUR 29) to 4 (MUR 937). These missing taxa were the same at each site and included: Elmidae (SIGNAL=7); Tipulidae (SIGNAL=5); Gripopterygidae (SIGNAL =8) and Oligochaeta (SIGNAL=2). Gripopterygidae (SIGNAL =8) was missing from all of the riffle samples and to date, this family has not been collected at any of the sampling sites in autumn. Other taxa that were absent in the majority of the samples included: Elmidae (SIGNAL=7) and Tipulidae (SIGNAL=5), although both were present in more subsamples in previous runs. MUR 29 in particular had more Elmidae than in previous seasons as did MUR 931.

There were more taxa recorded in the edge samples than in the previous autumn sampling run. Three taxa: Gripopterygidae (SIGANL =8), Synlestidae (SIGNAL=7) and Conoesucidae (SIGNAL=7) were absent from all samples. These taxa were not collected in autumn 2009 either. Sites showing particular improvements since autumn 2009 were MUR 29, MUR 935 and MUR 937. Previously these three sites had up to ten missing taxa from at least one sub-sample, including a range of sensitive and tolerant taxa. In this sampling run, the number of missing taxa ranged from 4 to 6 (**APPENDIX C**) with a re-appearance of some common mayfly taxa (Baetidae and Leptophlebiidae) at MUR 935 & MUR 29 and at MUR 937, Elmidae, Corixidae and Leptophlebiidae were collected, albeit in low (<20) numbers.

Table 6. AUSRIVAS and SIGNAL-2 scores for autumn 2010

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	4.14	4.18	0.78	0.85	B	A	B	B	B
Mur 931	2	4.14	4.67	0.78	0.7	B	B			
Mur 931	3	4.14	4.5	0.78	0.62	B	B			
Mur 931	4	4.14		0.78		B				
Mur 931	5	4.14		0.78		B				
Mur 931	6	4.25		0.89		A				
Mur 28	1	4.25	4.4	0.89	0.78	A	B	B	B	B
Mur 28	2	4.25	5	0.89	0.7	A	B			
Mur 28	3	4.25	4.64	0.89	0.85	A	A			
Mur 28	4	4.14		0.78		B				
Mur 28	5	4.14		0.78		B				
Mur 28	6	4.56		1		A				
Mur 935	1	4.14	4.2	0.89	0.78	A	B	B	B	B
Mur 935	2	4.25	4	0.78	0.78	B	B			
Mur 935	3	4.14	4	0.89	0.93	A	A			
Mur 935	4	4.25		0.89		A				
Mur 935	5	4.5		1		A				
Mur 935	6	4.56		0.78		B				
Mur 937	1	4.14	4.4	0.67	0.78	B	B	B	B	B
Mur 937	2	4.5	4.18	0.67	0.85	B	A			
Mur 937	3	4.5	4.17	0.89	0.93	A	A			
Mur 937	4	4.25		0.89		A				
Mur 937	5	4.5		0.78		B				
Mur 937	6	4.86		0.89		A				
Mur 29	1	4.5	4.45	0.89	0.85	A	A	B	A	B
Mur 29	2	4.5	4.45	0.89	0.85	A	A			
Mur 29	3	4.86	4.25	0.78	0.93	B	A			
Mur 29	4	4.14		0.78		B				
Mur 29	5	4.5		0.89		A				
Mur 29	6	4.56		1		A				

Table 7. One-way nested analysis of variance results for O/E 50 and SIGNAL-2 scores from the riffle samples

Response	Source	DF	F-value	P-value
O/E 50	Location	1	0.08	0.79
	Site [Location]	3	1.83	0.16
	Residual	29		
SIGNAL - 2	Location	1	5.84	0.09
	Site [Location]	3	1.61	0.21
	Residual	29		

Table 8. One-way nested analysis of variance results for O/E 50 and SIGNAL-2 scores from the edge samples

Response	Source	DF	F-value	P-value
O/E 50	Location	1	15.31	0.02
	Site [Location]	3	0.36	0.78
	Residual	29		
SIGNAL - 2	Location	1	6.02	0.09
	Site [Location]	3	1.95	0.18
	Residual	29		

4 Discussion

The Murrumbidgee Pump Station (MPS) is currently being constructed to increase the maximum water abstraction capacity from the Murrumbidgee River to 150ML/d. The increase in abstraction at the MPS may place additional stress on the downstream river ecosystem. Biological and water quality monitoring is underway to assess any changes associated with the pre-abstraction construction period and to monitor ecological and water quality changes that might eventuate as a result of this project. The sampling conducted in autumn 2010 is the third sampling run undertaken by ALS (formally Ecowise Environmental) and focuses on aquatic fauna, periphyton and water quality at five sites selected from recommendations in ACTEW's licence to take water (WU67 section D6).

4.1 Water quality

Water quality was collected in conjunction with the biological samples in late May (25th and 26th). The results show no obvious differences between upstream and downstream locations (Table 4) indicating that the works related to the MPS upgrade or the construction of the off-take weir on the true left bank (opposite the MPS) are having no impact on the water quality. However, during this period flows were low and stable (Figure 2) which might have masked any changes caused by construction work practices, such as: land clearing (for roads) stockpiles along or near the river bank or spillages along drainage lines. In saying this however, there has been no evidence from previous sampling runs to suggest that increased nutrient concentrations, suspended solids or physico-chemical analytes related to the MPS project have been found to have impacts on water quality and river health (e.g. Hedrick *et al.*, 2010).

Changes in the water quality parameters measured in this monitoring program can be linked to flow conditions, which are not specific to the downstream reaches as the case would be if the changes were related to the MPS project. For example, the increased nutrient loads in spring 2009 were attributed to runoff from surrounding agricultural and urban landuse upstream of the monitoring sites. During autumn 2009, the low flows and warm ambient temperatures may have concentrated nutrient levels, or concentrations could have increased because of decaying plant material in the warmer water temperatures. Differences in electrical conductivity were negligible between all of the sampling sites (Table 4) but were up to 6 times higher than recorded in spring. The slight decreases in EC downstream of the MPS are likely caused by a 10 ML/d increase in daily flow on the second day of sampling. Turbidity exceeded the ANZECC and ARMCANZ (2000) once in autumn, at the end of March in response to a short, intense rainfall event. During this event, NTU peaked at 41 and returned to guideline limits within two hours.

4.2 Periphyton

There was no difference in either chlorophyll-a concentrations or AFDM between upstream and downstream locations (Table 5; Figures 4 & 5). These concentrations were an order of magnitude higher than in previous sampling runs, which probably reflects a combination of two things. First, flows during the autumn sampling run were low and stable with low turbidity. Daily mean turbidity readings were 50% lower than the preceding sampling events, allowing higher light penetration and thus increasing growth rates. The combination of these factors has been shown to favor the growth of attached algae (Hynes, 1970; Biggs, 2000; Rutherford and Cuddy, 2005).

Despite the elevated levels of AFDM and chlorophyll-a, the patterns of variation on a site by site basis have remained consistent across seasons, and shows that MUR 28 has had the largest variation and average chlorophyll-a concentrations while MUR 937 has generally shown the lowest values on average (Ecowise Environmental, 2009a and 2009b). The high concentrations of chlorophyll-a at MUR 28 are possibly derived from riparian leaf material. Evidence for this is that the relationship between AFDM and chlorophyll-a from this site specifically, is low (R^2 = 0.07). Furthermore, the physical characteristics of this site suggest a higher input of riparian material due to a narrowing of the

main channel and consequently a higher proportion of riparian cover. This consistency within and between sites suggests that broad scale influences such as flow, light, nutrient concentrations and other factors as a function of seasonality are the key determinates of these changes, rather than site specific changes that may result from the MPS project.

4.3 River health and patterns in macroinvertebrate communities

There was no statistical difference found between upstream and downstream locations in the riffle habitat based on the ANOVA results for AUSRIVAS OE50, or SIGNAL -2 scores (Table 7). However, the OE50 scores from the edge samples were higher on average downstream of the MPS (downstream mean = 0.85) compared to the upstream sites (upstream mean = 0.75) (Table 8). The results from this sampling period also indicate that all sites upstream and downstream of the MPS are in moderate ecological condition, with all sites being assessed as "*significantly impaired*" (AUSRIVAS - BAND B). These results are equivalent to the health rating for the same sites in autumn 2009, with exception of MUR 937 which was assessed as BAND C.

The conservative approach when reporting multiple AUSRIVAS assessments from a given site is to take the AUSRIVAS "BAND" furthest from the reference condition (i.e. BAND-A) (Coysh *et al.*, 2000a).It should be noted therefore that, while MUR 29 was the only site assessed as BAND –A, all of the other sites under assessment had at least one sub-sample with a BAND-A assessment, but the final assessment was based on the lowest assessment given to that site. Despite the appearance that MUR 29 was the only site to show an improvement since the previous sampling runs, it should also be noted that across all of the sites sampled, there were less taxa missing than in previous seasons which was mainly due to an increase in the number of EPT families collected. The increase in EPT taxa also resulted in an overall increase in the average signal scores for each site compared to autumn 2009.

The higher OE50 scores downstream of the MPS edge samples (Table 8) were due to site MUR 931 having the most missing taxa (8) of all the sites sampled and correspondingly MUR 29 having the fewest (4). The taxa missing from MUR 931 included Corixidae (SIGNAL=2), Ecnomidae (SIGNAL=4), Hydroptilidae (SIGNAL=4) and the more sensitive Elmidae (SIGNAL=7). Despite the difference in edge OE50 scores, the multivariate analysis did not find any differences in the edge communities between up and downstream locations. The cluster analysis revealed significant structure in the two main groups (Figure 9) at 55% similarity indicating a high level of overlap in the structure of the macroinvertebrate between sites and locations (Figure 10). The multivariate NMDS analysis conducted on data from the riffle samples indicates an even higher similarity coefficient in the macroinvertebrate communities (Figures 7 & 10) and did not detect any statistical differences between the upstream and downstream communities. This is further supported by the univariate metrics (taxa richness, % EPT taxa and EPT richness) determined for each site which also showed no location specific differences (Figures 8 & 9).

The high degree of similarity in the macroinvertebrate community structure displayed between all of the sites and between sampling locations provides evidence that there was no point source related impact to the Murrumbidgee River resulting from the work carried out as part of the MPS upgrade and that the apparent changes in community composition are largely due to natural variation in the system, which we believe is driven by changes in river flow. The main consideration regarding the macroinvertebrate communities from this study is the degree of unevenness in the community structure (i.e. dominance by three Dipteran taxa) and the overall increase in EPT richness and by association taxonomic richness.

This pattern is apparent across all of the monitoring sites, and is likely to be a representation of the intermediate successional stages of recolonisation following two high flow events in February and March (Figure 2). Patterns of recolonisation have been shown to begin with the rapid occupation of substrate by early, opportunistic taxa such as Simuliidae and Chironomidae and other Dipterans; followed by Ephemeroptera, Trichoptera and Plecoptera (Niemi *et al.*, 1990; Collier and Quinn, 2003). Stubbington *et al.*(2009) for example, examined community dynamics following a high flow event of

similar magnitude to the high flow event registered in Feburary (>30 000 ML/d). They found that after rapid colonisation of mayfly recovery was similar to to pre-flood conditions after 132 days, and taxonomic richness reached comparible levels (19 families) to our study (mean = 22) after 90 days which is consistent with our findings after 93 days.

The key difference between the spring communities and the communities reported in this study is the sharp increase in the univariate metrics, especially the number of EPT families and genera collected. Scouring and dislodgement of free living taxa due to high shear stress is likely to be a leading reason for the depauperate EPT fauna in the spring 2009 samples, coupled with the very short time (8d) since flows receded and sampling commenced. It is proposed (for reason cited above) that the increase in EPT taxa is likely to be a function of the timing of our sampling program since the most recent disturbance.

Although seasonality is another likely factor accounting for the variation in taxa richness (Hynes, 1970), comparisons between the two autumn events indicates that there were considerable increases in the number of EPT taxa and their relative abundances in this study since autumn 2009. It is likely that these increases are due to the combined influence of several factors. For examples, the low taxonomic richness scores in autumn, coupled with low relative abundances were likely due to very low flows over an extended period leading up to the sampling run, resulting in some isolation from the main channel, increased fine sediment deposition and deteriorating water quality. In contrast, the two events that occurred 93days and 71days respectively, prior to this sampling run may have removed some of the fine sediment build up in both the riffle and edge habitats. The effects of this scouring may have increased the heterogeneity of the riverine habitat by “unblocking” the interstitial spaces amongst the benthic substrate, which is necessary for maintaining diverse macroinvertebrate communities – particularly EPT taxa which are sensitive to fine sediments and generally require a more diverse and complex habitat for survival (Hynes, 1970; Wood and Armitage, 1999; Kaller and Hartman, 2004).

The results from this sampling run and indeed previous sampling events have indicated that during periods of low base-flow along this section of the Murrumbidgee River, site specific influences tend to increase the dissimilarity of macroinvertebrate assemblages between monitoring sites. High flow events in contrast, have a homogenising effect, in which the assemblages become more similar to one another irrespective of their proximity to the MPS. This suggests that natural fluctuations in the hydrology of the Murrumbidgee River within the bounds of this monitoring program can have an overriding influence of local macroinvertebrate community assemblages which may mask or even remove any small-scale or subtle impacts related to the MPS project before they can be detected.

5 Conclusion

The results from the autumn 2010 sampling run are consistent with the previous two runs (spring 2009 and autumn 2009) in that no differences have been found between upstream and downstream locations in any of the parameters that have been monitored and all of the sites were assessed as "*significantly impaired"* – BAND-B by the AUSRIVAS model. In a similar manner to the spring results, all sites were dominated by Oligochaetes (worms), Simuliidae (black-fly larvae) and Chironomids (non-biting midges). These community assemblages are consistent with communities that have recently been impacted by a high flow event, as is the likely case in this study.

There has been an increase in the diversity of sensitive (EPT) taxa since spring. Although seasonal fluctuations can explain this to a certain degree, comparisons to our previous sampling run in autumn, where EPT taxa were comparable to spring, suggest that the increase in this sampling run is likely due to improved habitat and water quality parameters, resulting from the flushing flows of early February, followed in quick succession by a second high flow event in early March.

Most of the water quality parameters were within the ANZECC (Australian and New Zealand Conservation Council) guidelines. The exceptions to this were Total Nitrogen, which was over the recommended guidelines at all sites and Total Phosphorus, which was at the upper threshold level recommended for healthy ecosystems. Despite Total Nitrogen exceeding the trigger values, these concentrations are the lowest recorded since the inception of this program. The water quality results from autumn 2010 represent stable, low flow conditions, while the higher concentrations recorded in previous runs are likely a result of the timing of the sampling – which was conducted within 3 weeks of the last runoff event meaning that nutrient loads were still being conveyed through the system.

Based on the current MEMP assessment , we conclude that the MPS works are not impacting the water quality, periphyton or macroinvertebrate assemblages. The variation in the water quality parameters and biological data collected to date are a result of varying flow characteristics which, in the case of the high flow events have had a homogenising influence on these monitoring sites so that any small-scale or subtle impacts related to the MPS project are masked by the overriding influence of the flow regime.

6 Recommendations

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

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

1) One of the limitations of the current water quality data collection is that any event-related impacts are not accounted for under the current sampling regime. The continuous monitoring stations are positioned such that any point source impacts are likely to be missed. It is therefore recommended that event-based water quality sampling commence at suitable upstream and downstream locations (of the MPS).

2) 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 and Resh, 2001) if family level identification is perused. In light of this, it is advisable to continue monitoring to genus level as family level resolution may be too broad at this scale of assessment.

Literature Cited

ANZECC & ARMCANZ (2000) National water quality management strategy: Paper No. 4. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1. The Guidelines. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

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

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. & Kilroy, C. (2000) Stream Periphyton Monitoring Manual. NIWA, Christchurch. NIWA. Christchurch.

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

Cao, T., Larsen, D.P. & St-J. Thorne, R. (2001) Rare species in multivariate analysis for bioassessment: some considerations. *Journal of the North American Benthological Society,* **20,** 144-153.

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

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

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

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.

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.

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.

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

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

Hawking, J.H. (2000) Key to Keys. A guide to keys and zoological information to identify invertebrates from Australian inland waters. Identification Guide No.2 Cooperative Research Centre for Freshwater Ecology.

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. (1970) The Ecology of Running Waters, Liverpool University Press, Liverpool.

Kaller, M.D. & Hartman, K.J. (2004) Evidence of a threshold level of fine sediment accumulation for altering benthic macroinvertebrate communities. *Hydrobiologia,* **518,** 95-104.

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.

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.

R Development Core Team (2008). 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.

Rutherford, J.C. & Cuddy, S.M. (2005) Modelling periphyton biomass, photosynthesis and respiration in streams. Technical report No. 23/05, CSIRO Land and Water, Canberra.

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

Wood, P.J. & Armitage, P.D. (1999) Sediment deposition in a small lowland stream - management implications. *Regulated Rivers Research & Management,* **15,** 199-210.

APPENDIX A – SITE PHOTOGRAPHS

MUR 931

Looking upstream into the Tinderry nature reserve

Looking across-stream to the top of the riffle

MUR 28

Looking downstream

Sampling

Looking upstream

Looking across stream

Cotter Bridge

Looking upstream with the Cotter River confluence to the right of the photograph

A view looking downstream of the bridge with sediment control structure and MPS

Looking across stream from the MPS to the coffer dam and the site of the off-take weir development

MUR 935

Looking upstream, with Cotter road bridge in the background

Looking across stream to the true LHS bank

MUR 937

Main channel, looking upstream

Substrate at MUR 937

Looking downstream

Sampling

MUR 29

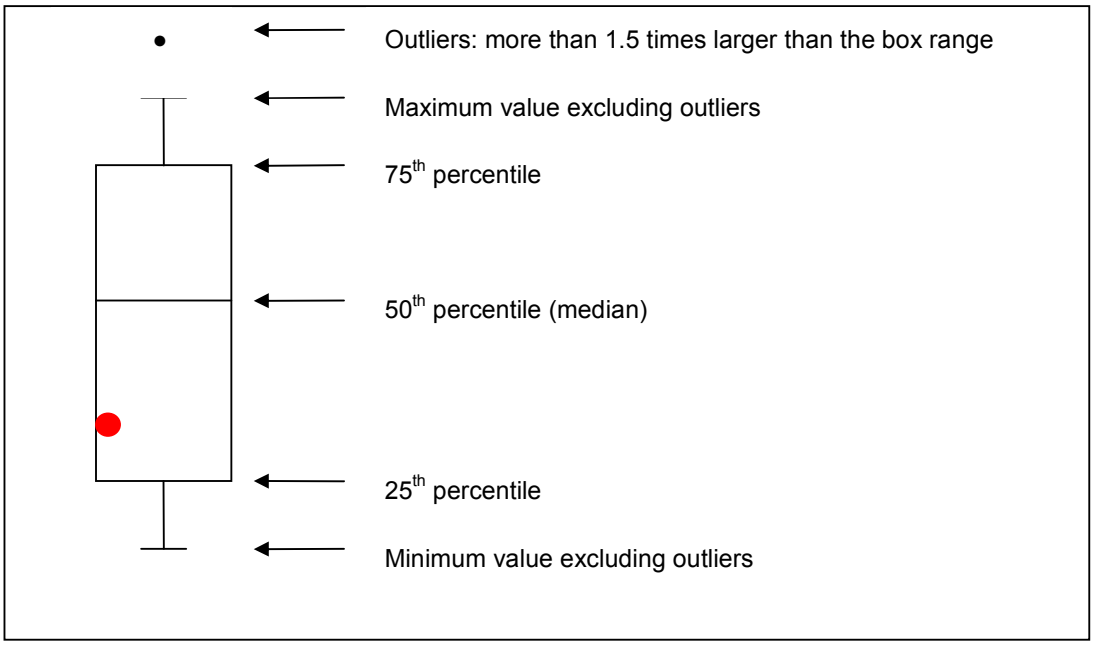
Looking upstream

Sampling riffle habitat

APPENDIX B - INTERPRETING BOX AND WHISKER PLOTS

Appendix B. Interpreting box and whisker plots.

Box and whisker plots are intended as an exploratory tool to help describe the distribution of the data. The strip chart (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 C – TAXA PREDICTED WITH >50% PROBABILITY, BUT WERE MISSING FROM THE AUTUMN 2010 SAMPLES

Appendix C. Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but absent from edge samples. Number in cells represents their given probability of occurrence at a given site. Blank cells indicate collection at a given site.

Edge

Site	Taxa	Planorbidae	Oligochaeta	Elmidae	Tanypodinae	Baetidae	Corixidae	Synlestidae	Gripopterygidae	Conoesucidae	Hydroptilidae	Ecnomidae	Total number of missing taxa
	SIGNAL	2	2	7	4	5	2	7	8	7	4	4	
MUR 931			*0.97*	*0.62*				*0.65*	*0.69*	*0.59*			5
MUR 931	Edge	*0.55*				*0.9*	*0.62*	*0.65*	*0.69*	*0.59*	*0.59*	*0.93*	8
MUR 931		*0.55*		*0.62*			*0.62*	*0.65*	*0.69*	*0.59*	*0.59*	*0.93*	8
MUR 28		*0.55*			*0.9*	*0.9*		*0.65*	*0.69*	*0.59*			6
MUR 28	Edge	*0.55*	*0.97*		*0.9*		*0.62*	*0.65*	*0.69*	*0.59*			7
MUR 28		*0.55*					*0.62*	*0.65*	*0.69*	*0.59*			5
MUR 935		*0.55*		*0.62*				*0.65*	*0.69*	*0.59*	*0.59*		6
MUR 935	Edge			*0.62*				*0.65*	*0.69*	*0.59*	*0.59*	*0.93*	6
MUR 935				*0.62*				*0.65*	*0.69*	*0.59*			4
MUR 937		*0.55*		*0.62*			*0.62*	*0.65*	*0.69*	*0.59*			6
MUR 937	Edge			*0.62*			*0.62*	*0.65*	*0.69*	*0.59*			5
MUR 937						*0.9*		*0.65*	*0.69*	*0.59*			4
MUR 29		*0.55*						*0.65*	*0.69*	*0.59*		*0.93*	5
MUR 29	Edge	*0.55*						*0.65*	*0.69*	*0.59*	*0.59*		5
MUR 29								*0.65*	*0.69*	*0.59*		*0.93*	4

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

Riffle

Site	Taxa	Oligochaeta	Elmidae	Tipulidae	Gripopterygidae	Total number of missing taxa
	SIGNAL	2	7	5	8	
MUR 931	Riffle			*0.8*	*0.6*	2
MUR 931			*1*	*0.8*	*0.6*	3
MUR 931			*1*	*0.8*	*0.6*	3
MUR 931			*1*	*0.8*	*0.6*	3
MUR 931			*1*	*0.8*	*0.6*	3
MUR 931			*1*		*0.6*	2
MUR 28	Riffle		*1*		*0.6*	2
MUR 28			*1*		*0.6*	2
MUR 28			*1*		*0.6*	2
MUR 28			*1*	*0.8*	*0.6*	3
MUR 28			*1*	*0.8*	*0.6*	3
MUR 28					*0.6*	1
MUR 935	Riffle		*1*	*0.8*	*0.6*	3
MUR 935			*1*		*0.6*	2
MUR 935			*1*	*0.8*	*0.6*	3
MUR 935			*1*		*0.6*	2
MUR 935				*0.8*	*0.6*	2
MUR 935					*0.6*	1
MUR 937	Riffle		*1*	*0.8*	*0.6*	3
MUR 937		*0.8*	*1*	*0.8*	*0.6*	4
MUR 937		*0.8*	*1*	*0.8*	*0.6*	4
MUR 937			*1*		*0.6*	2
MUR 937				*0.8*	*0.6*	2
MUR 937		*0.8*		*0.8*	*0.6*	3
MUR 29	Riffle			*0.8*	*0.6*	2
MUR 29				*0.8*	*0.6*	2
MUR 29		*0.8*		*0.8*	*0.6*	3
MUR 29			*1*	*0.8*	*0.6*	3
MUR 29				*0.8*	*0.6*	2
MUR 29					*0.6*	1