ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 1: Angle Crossing

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Cover Photograph: Looking southeast: Angle Crossing, March 2009

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Executive Summary

To improve the ACT water security for the future, ACTEW Corporation is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT).

The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to pump up to 100 ML/d, and is expected to be in operation in 2011. Abstraction will be dictated by the level of demand for water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G).

This program aims to determine the baseline river condition prior to the additional water abstraction and then continue monitoring after commencement to determine what changes are taking place that are attributable to abstraction from Angle Crossing.

The key aims of this sampling run were to:

1. Establish current macroinvertebrate community data, up- and downstream of Angle Crossing;

2. Provide ACTEW with river health assessments based on AUSRIVAS protocols at the key sites concerning the construction and operation and of pumping infrastructure at Angle Crossing;

3. Establish baseline periphyton data that will be used as a guide to monitor seasonal and temporal change;

4. Report on water quality up and downstream of Angle Crossing.

This report presents the results from biological sampling and monitoring of the Murrumbidgee River upstream and downstream of Angle Crossing in autumn 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 identified to genus level, with the purpose of a) establishing biological signatures at each site prior to the commencement of pumping and b) enabling the detection of any subtle changes to the invertebrate community corresponding to reduced flows.

The key results from the autumn 2009 sampling of Angle Crossing show that:

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

- *Several of the continuously monitored water quality analytes showed responses to low flow and seasonal conditions. Nutrient levels exceeded guideline targets at all sites except those immediately upstream and downstream of Angle Crossing. Overall however, water quality parameters were within the ANZECC guidelines.*

- *There were no differences in AFDM or Chlorophyll-a from the periphyton samples between the upstream and downstream sites. There were also no differences in the upstream and*

downstream macroinvertrate communities. However, Point Hut Crossing did show signs of potential nutrient enrichment – possibly because Point Hut Pond overtopped twice during low flow periods.

- *Low flows appear to be degrading the ecological health in this section of the river between Colinton and the Cotter River confluence, despite the potential localised effects noted at Point Hut Crossing possibly masking the broad scale effects of drought.*

- *High variation in sample replicates suggests that a single sample is not representative of the macroinvertebrate composition at a given site. We recommend maintaining the current regime to best describe macroinvertebrate communities at a given site.*

Improvements in macroinvertebrate communities and river health ratings are predicted with seasonal rainfall.

List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Fee Dry Mass (periphyton)
ANOVA – Analysis of Variance (statistics)
AUSRIVAS – Australian River Assessment System
DNR – Department of Natural Resources
EPA – Environmental Protection Authority
EPT taxa- Ephemeroptera; Plecoptera and Trichoptera
GL/a – Gigalitres per annum
GPS – Global Positioning System
ML/d – Megalitres per day
M2G – Murrumbidgee to Googong
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
SIMPER – Similarity Percentages
TN – Total Nitrogen
TP – Total Phosphorus

1 Introduction

The Murrumbidgee Ecological Monitoring Program (MEMP) 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 that commenced 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 1: Angle Crossing.

To improve ACT water security for the future, ACTEW Corporation is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT).

The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to pump up to 100 ML/d, and to be in operation in 2011. Abstraction will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G).

Due to the combined effects of climate change and increased demands from industry and households, the impacts of water abstraction on aquatic ecosystems, river health and water quality have been extensively researched (see Dewson *et al.*, 2007 for a recent review). It is expected there will be changes to the aquatic ecosystem within the Murrumbidgee River and Burra Creek as a result of M2G. Some of these effects include, but are not limited to: changes to water chemistry; and changes to channel morphology, velocity and depth. All of these changes have potential knock-on effects to the biota within the river's ecosystem (Appendix A). These impacts will be assessed by the relevant Government authorities through Environmental Impact Statements (EIS) or similar assessment. This current monitoring program will form the basis of an Ecological Monitoring Program to satisfy EIS requirements.

1.1 Background: The Upper Murrumbidgee River

The Murrumbidgee River flows for 1,600 km from its headwaters in the Snowy Mountains to its junction with the Murray River. The catchment area to Angle Crossing is 5096 km^2. As part of the Snowy Mountains Scheme, the headwaters of the Murrumbidgee River were constrained by the 252 GL Tantangara Dam, which was completed in 1961. The reservoir collects water and diverts it outside the Murrumbidgee catchment to Lake Eucumbene. This has reduced base flows and the frequency and duration of floods in the Murrumbidgee River downstream. The Murrumbidgee River is impounded again at Burrinjuck Dam, after the river passes through the ACT. This region above Burrinjuck Dam is generally known as the Upper Murrumbidgee.

Land-use varies from National Park in the high country to agriculture and farming in the valley regions. Annual rainfall varies from greater than 1400 mm in the mountains, to 620 mm at Canberra, and down to around 300mm in the west.

Drought has had the most significant impact on catchment quality within the upper Murrumbidgee catchments in recent times. More than 80% of catchments have been drought-affected since late 2002. Drought-induced land degradation in the upper Murrumbidgee catchments has been significant across all areas (ACT State of the Environment Report, 2004) and adverse effects include increased stress on surface and groundwater resources, increased soil erosion and a shift from mixed farming and cropping to grazing, and reduced stock numbers. Drought has also led to increased pressure on native vegetation in the catchments, a heightened risk of fire in native forests, and an increase in the abundance of several weed species.

1.2 Project objectives

There are two key phases to this project, which incorporates two sets of objectives, representing long and short term aims, i.e. before and after abstraction (Table 1). Phase 1 of this monitoring program involves the establishment of baseline macroinvertebrate community composition at selected sites up- and downstream of the proposed abstraction point. The focus of Phase 1 will be on the documentation of spatial and seasonal changes in macroinvertebrate and periphyton assemblages as well as monitoring water quality patterns. This will also include monitoring potential effects associated with (either directly or indirectly) the construction of the new pump station at Angle Crossing.

Phase 2, incorporates long term objectives, which aim to delineate potential ecological effects that are related specifically to the abstraction of water from the Murrumbidgee River at Angle Crossing, outside of what is considered natural, temporal and spatial variation.

The specific aims of this monitoring program are:

1. To determine seasonal and annual variation in the composition and abundance of periphyton at control and test sites before water abstractions commence, and to assist in the monitoring of river ecosystem health once the abstractions begin.

2. To determine baseline macroinvertebrate communities at test and control sites before the water abstractions commence, and to assist in the monitoring of riverine ecosystem health once the abstractions begin.

Table 1. Project objectives and estimated time frames

	Key objectives	Time frame	Outcomes
Phase 1	Obtain baseline information to include: hydrological, biological and physico-chemical water quality information. Establish spatial and temporal trends up and downstream of the existing low-level crossing that is Angle Crossing.	2-3 years	Help establish flow rules for the operation of the pump in the M2G project Establish biological signatures and inventories as references for changes over time
Phase 2	Monitor the ecological responses related specifically to water abstractions from Angle Crossing. The ability to do this depends on establishing a comprehensive data set of spatial and temporal variability at all concerned sites.	3+ years	Help minimise ecological impacts by better understanding biological responses to water abstraction.

1.3 Project scope

The current ecological health of the sites monitored as part of the Murrumbidgee to Googong (M2G) monitoring program was 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 autumn 2009 sampling runs. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009) this work includes:

- Sampling conducted in autumn 2009;
- Macroinvertebrate communities collected from riffle and edge habitats using AUSRIVAS protocols;
- Macroinvertebrate samples counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- *In-situ* water quality measurements collected and samples analysed for nutrients in Ecowise’s NATA accredited laboratory.

1.4 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most common biological indicators used in river bio-assessment. Macroinvertebrates provide a general characterisation of the health of a stream ecosystem because they represent a continuous record of preceding environmental, chemical and physical conditions at a given site; they are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to certain impacts such as: heavy metal contamination, sedimentation and other physical or chemical changes that might exist (Chessman, 2003).

Periphyton is the matted community that resides on the surfaces of 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 source of 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, and this 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; Biggs *et al.*, 1999; Whitton and Kelly, 1995). As changes in flow volume are expected with the proposed changes in the Murrumbidgee River flow regime, periphyton biomass and chlorophyll-a are included as biological indices.

2 Materials and Methods

2.1 Study sites

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from replicate sites on the Murrumbidgee River, up- and downstream of Angle Crossing (~2km west of Williamsdale) with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

The upper Murrumbidgee River is impacted by activities in its large catchment which includes a large array of land-use practices. As such, it was important to select a sufficiently large number of sites to enable the program to provide a reasonable snap-shot of the current macroinvertebrate community structure in both riffle and edge habitats. Sites were chosen based on several criteria, which included:

1. Safe access and approval from land owners;

2. Sites have representative habitats (i.e. riffle / pool sequences). If both habitats were not present then riffle zones took priority as the they are the most likely to be affected by abstractions;

3. Sites which have historical ecological data sets (e.g. Keen, 2001) took precedence over "new sites" –allowing comparisons through time to help assess natural variability through the system. This is especially important in this program because there is less emphasis on the reference condition, and more on comparisons between and among sites of similar characteristics in the ACT and surrounds over time.

Potential sites were identified initially from topographic maps, they were visited prior to sampling and their suitability was subsequently considered. Six sites suited the criteria mentioned above (Table 3; Figure 1). These sites include three sites upstream of Angle Crossing (in NSW) and three sites downstream (all in the ACT).

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ECOWISE gauging stations located at Lobb's Hole (downstream of Angle Crossing: 410761) and Mount MacDonald (410738: ~5.2 km downstream of the Cotter River Confluence). A new water quality site has been installed upstream of Angle Crossing.

Site locations and codes are given in Table 2. Stations are calibrated monthly and data is downloaded and verified before storage on the database where it is quality coded. Water level data is manually verified by comparing the logger value to staff gauge value. If there are differences between logger and staff, the logger is adjusted accordingly. Rain gauges are calibrated and adjusted as required. Records are stored on the HYDSTRA© database software and downloaded for each sampling period.

Table 2. Location and details of continuous water quality and flow stations

Site Code	Location/Notes	Parameters*	Latitude	Longitude
MUR W2	M'bidgee River U/S Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.3533	E 149.0705
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
410738	M'bidgee River @ Mt. MacDonald	WL, Q	S 35.2917	E 148.9553

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

2.3 Water quality

Baseline in-situ physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a multiprobe Hydrolab® minisonde 5a at sites indicated in Table 3. The Hydrolab® was calibrated following 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 Hydrolab verification and nutrient analysis. All samples were placed on ice, returned to the ECOWISE laboratory, and analysed for nitrogen oxides (total NOx), total nitrogen and phosphorus in accordance with the protocols outlined in A.P.H.A (2005). Collectively, this information on the water quality parameters will assist in the interpretation of biological data and provide basis to gauge changes that can potentially be linked to flow reductions at these key sites following water abstractions.

Table 3. Sampling site locations and details

Site Code	Location	Landuse	Habitat sampled
MUR 15	Near Colinton - Bumbalong Road	Grazing / Recreation	Riffle and Edge
MUR 16	The Willows - Near Michelago	Grazing	Riffle and Edge
MUR 18	U/S Angle Crossing	Grazing	Riffle and Edge
MUR 19	D/S Angle Crossing	Grazing / Recreation	Riffle and Edge
MUR 23	Point Hut Crossing	Recreation / Residential	Riffle and Edge
MUR 28	U/S Cotter River confluence	Grazing	Riffle and Edge

2.4 Macroinvertebrate sampling and processing

At each site, macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site (Coysh *et al.*, 2000a); and potentially allow 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 (Boulton, 2003; Dewson *et al.*, 2007; Smakhtin, 2001), whereas the effects of reduced flows on the macroinvertebrate assemblages might not occur at the magnitude and may be less immediate. On the other hand the loss of macrophyte beds, trailing bank vegetation and bank scouring are more likely to immediately affect the edge habitats. Therefore, separating flow effects with other environmental stressors can be achieved by monitoring both habitats before and after the proposed abstractions and comparing data after the abstractions with the natural variation that occurs before hand.

Riffle and edge habitats were sampled for macroinvertebrates and analysed in strict accordance with the ACT autumn riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000b) during autumn (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 directly upstream of the net opening was disturbed by vigorously kicking and agitating the stream bed, allowing any dislodged material to be carried into the net. The process continued, working upstream over 10 metres of riffle habitat. The samples were then preserved in the field using 70% ethanol, clearly labelled with site codes and date then stored on ice and refrigerated 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. 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.

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. The contents of randomly selected cells were removed and the macroinvertebrates within each 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, taxa were analysed at family level except for: Chironomidae (sub-family), Oligochaeta (class) and Acarina (order) until 200 animals were identified (identification followed taxonomic keys published by Hawking, (2000)). If 200 animals were identified before a cell had been completely analysed, identification continued until the animals in the entire cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

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 six sites, given in Table 2, were sampled for periphyton in autumn 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 1m wide transect was established across riffles at each site. Transects were marked using flagging tape and GPS coordinates were be taken. Along each transect, twelve samples were collected at regular intervals, using a syringe sampling device, based on two 60 ml syringes and a scrubbing surface of stiff nylon bristles, covering an area of ~637 mm^2. The samples were then divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM gm^{-2}), and chlorophyll-a. Samples for Ash Free Dry Mass (gm^{-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 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. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006). Univariate statistics were performed using R version 2.9.2 (R Development Core Team, 2009).

To test for differences in univariate metrics (SIGNAL-2 scores and AUSRIVAS OE50 ratios) upstream and downstream of Angle Crossing, mixed effect, nested ANOVA models were conducted (Quinn and Keough, 2002). Sites were considered random effects representing the river condition upstream and downstream of the proposed abstraction point; while location (up- and downstream) was considered a fixed, constant effect. Data transformations were not necessary because the model assumptions were met on all accounts.

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, (i.e. Oligochaeta and Chironomids) were examined at family and genus levels.

While in certain instances high numbers of taxa can indicate favourable ecological conditions, they can also indicate altered conditions. Where the disturbed conditions provide habitat that might not naturally occur; a new environment for previously absent taxa is provided. For the purposes of this program, taxa richness was quantified as baseline information from which further analyses, such as community stability, which assesses (as a percentage) temporal changes in community composition (turnover). For all analyses, alpha was set to 5%.

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 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 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 represent 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), with values near zero indicating that NMDS patterns are very representative of the multidimensional data, while stress values greater than 0.2 indicate a poor representation (Clarke and Warwick, 2001).

The analysis of similarities test (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different up and downstream of the MPS. Sites were nested within location for 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 (Clarke and Warwick, 2001), this was also used to describe groups (i.e. which taxa characterised each group of sites).

2.6.3 AUSRIVAS assessment

In addition to assessing the composition and calculating biometrics from the macroinvertebrate data, riffle and edge samples, river health assessments based the ACT AUSRIVAS autumn riffle and edge models were conducted. AUSRIVAS is a prediction system that uses macroinvertebrate communities 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 which can not be influenced due to human activities, 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 and 5).

The 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 an A assessment in the edge and a B Band in the riffle would be given an overall site assessment of B (Coysh *et al.*, 2000b). In cases where the bands deviate significant between habitat (e.g. D – A) then 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 be noted that the presence or absence of rare taxa does vary naturally 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 4. AUSRIVAS band-widths and interpretations for the ACT autumn riffle and edge models

	Riffle	Edge	
Band	**O/E bandwidth**	**O/E bandwidth**	**Explanation**
X -	>1.12	>1.17	*More diverse than expected. Potential enrichment or naturally biologically rich.*
A -	0.87-1.12	0.82-1.17	*Similar to reference. Water quality and / or habitat in good condition.*
B -	0.63-0.87	0.48-0.82	*Significantly impaired. Water quality and/or habitat potentially impacted resulting in loss of taxa.*
C -	0.39-0.63	14-0.48	*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.*

2.6.4 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 (AFDM) and live content (Chlorophyll-a) were different between sites upstream and downstream of the MPS, t-tests were performed on Log_e transformed data. Log transformation was necessary to meet the assumptions of normality. This did not correct for unequal variances, so the degrees of freedom are modified using Welch's extension of the t-test, to account for the unequal variances (R Development Core Team, 2009).

Data were pooled from sites upstream and downstream because the aim is to determine upstream (control) and downstream (impact) effects rather than site specific effects at this stage of the program. Data were back-transformed for the purposes of graphical visualization.

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. Attempts were made to obtain significantly more than 200 organisms, to overcome losses associated with damage to intact organisms during vial transfer.
- 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 maintains current ACT and NSW AUSRIVAS accreditation.

Mur 18. ~800m Upstream of Angle Crossing

Mur 18. Looking upstream

MUR 15. Near Colinton

MUR 16. “The Willows” near Michelago

Figure 1. Aerial and ground photographs of sampling sites (note: No aerial photographs available for MUR 15 and 16).

Mur 19. Downstream Angle Crossing

Mur 19. Looking downstream

Mur 23. Point Hut Crossing

Mur 23. Looking upstream to bridge

Mur 28. Upstream Cotter River confluence

Mur 28. Looking downstream

Figure 1 cntd. Aerial and ground photographs of sampling sites.

3 Results

3.1 Hydrology and rainfall

The average flow during the three months of autumn was 32.8 ML/d at Lobb's Hole. April had above average rainfall with a total (at Lobb's Hole) of 71.8 mm; compared to March (6mm) and May (4.6mm). The autumn average of 27.4mm/mth could be misleading due to the majority of rainfall recorded in April alone.

Samples were collected during early May and approximately 3 weeks after the two largest events that occurred in April (Figure 1). In late April 15 mm fell at Lobb's Hole, causing a small peak (90ML/d) in the hydrograph, which subsided to < 60ML/d by the time sampling was under way. At the time of sampling, the new gauging site upstream of Angle Crossing (MUR W2) was not yet operational. The installation and commencement of data collection is likely to be complete during spring sampling, pending landowner approvals.

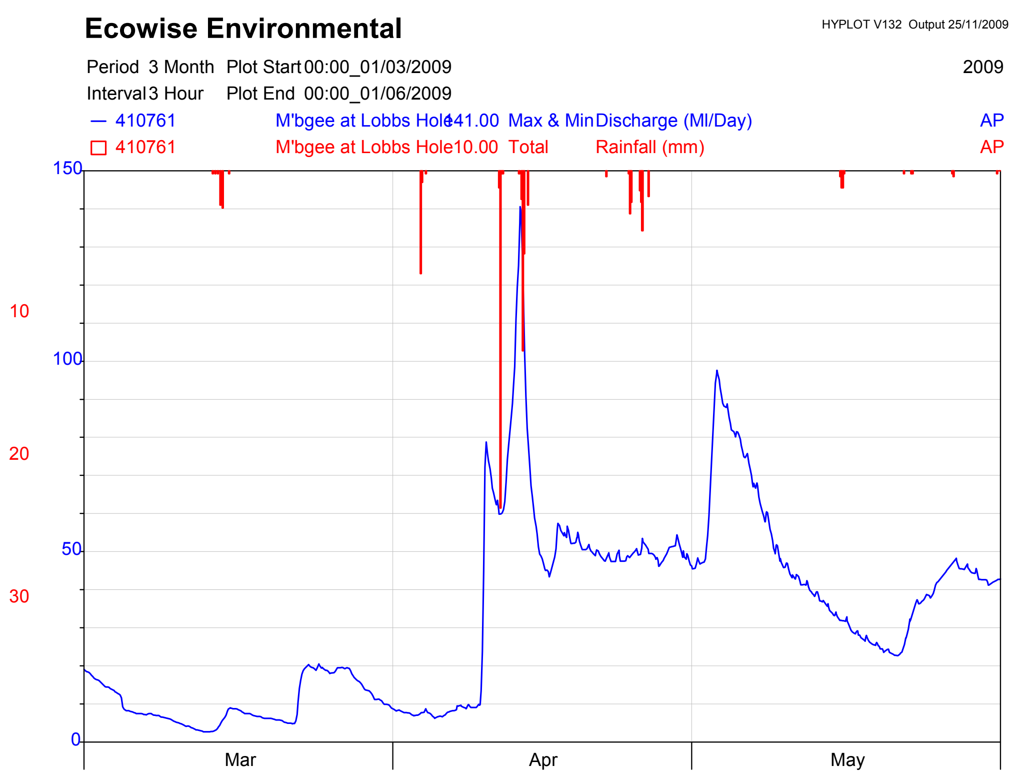

Figure 2. Autumn hydrograph of the Murrumbidgee River at Lobb's Hole. Total rainfall (mm) is shown in red**.**

Table 5. Autumn rainfall and flow summary for Lobb's Hole (410761).

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

Site	Lobb's Hole (410761)	
	Rainfall (total)	Flow (ML/d)
March	6	10.3
April	71.8	42.7
May	4.6	45.6
Autumn mean	27.4	32.8

3.2 Water quality

The continuous water quality data obtained from Lobb's Hole for the period 1/3/09-31/5/09 (Figure 3) show declines in all measured parameters of the course of three months from March 2009. The average water temperature declined from 20.8°C in March to 11.3°C in May. Electrical conductivity was 48% lower in May (mean: 175.9 µs/cm) than it was in March (mean: 93.8 µs/cm). Turbidity readings were consistent over autumn, with monthly means only fluctuating by 2-3 NTU. NTU maximums were highest in May, which corresponded to rainfall events, but even these maximums (i.e. 18.8 NTU) were below the ANZECC water quality guidelines for healthy upland rivers.

The grab sample results are presented in Table 6. Total Nitrogen (TN) and Total Phosphorus exceeded the ANZECC (2000) guidelines at all the sites sampled. The highest TP levels were recorded at MUR 16 (0.04 mg/L), while all other sites recorded between 0.02 and 0.035 mg/L. TN ranged from 0.33 at site MUR 15 to 0.51 at site MUR 28. These results are very similar to those recorded in the spring 2008 sampling period, although there has been more than a 50% reduction in the TN levels recorded at MUR 19 (downstream of Angle Crossing) since spring.

All other parameters were within the guideline limits. Electrical conductivity increased steadily downstream and the variation in water temperature and dissolved oxygen were correlated to the time of day the measurements were made.

3.3 Periphyton

On average Ash Free Dry Mass (AFDM) was slightly higher downstream of Angle Crossing (mean: 1189 mg/m^{-2}) compared to the upstream sites (mean: 1002 mg/m^{-2}), but these differences were not statistically significant (t_{34}= 1.77, P=0.085; Figure 4). These results are supported by the qualitative on-site estimates. All the sites were assessed as having Category 4 (65-90%) or Category 5(>90%) levels of periphyton growth, with no obvious differences being noted between locations.

Chlorophyll-a measurements indicated a higher mean downstream of Angle Crossing (5733 µg/m^2) compared to upstream (2496 µg/m^{-2}), however, these differences were not statistically different (t_{28}= 1.144, P=0.26). This is evidenced by the large variation around the means at both locations. AFDM tended to be more evenly distributed than the chlorophyll-a estimates from the periphyton, suggesting a patchy distribution across the transects. Observations in the field suggest that the larger patches of filamentous algae mainly occurred along the margins, however there were exceptions, namely Mur 18 and Mur 23, where there were no discernable differences along the transects.

There were no strong correlations between water quality variables (specifically nutrient data and temperature) and AFDM or Chlorophyll-a, but this is not surprising since there are no clear differences in the water quality parameters between sites. Habitat parameters including the substratum coverage revealed no clear relationship between chlorophyll-a concentrations or AFDM. However, mean AFDM estimates showed a moderate negative correlation with increasing stream velocity (R^2=0.56). There was no such relationship for the chlorophyll-a samples. Furthermore, the correlation between Chlorophyll-a and AFDM was weak (R^2=0.02, P=0.63) suggesting that the detrital content of the periphyton was not algal derived.

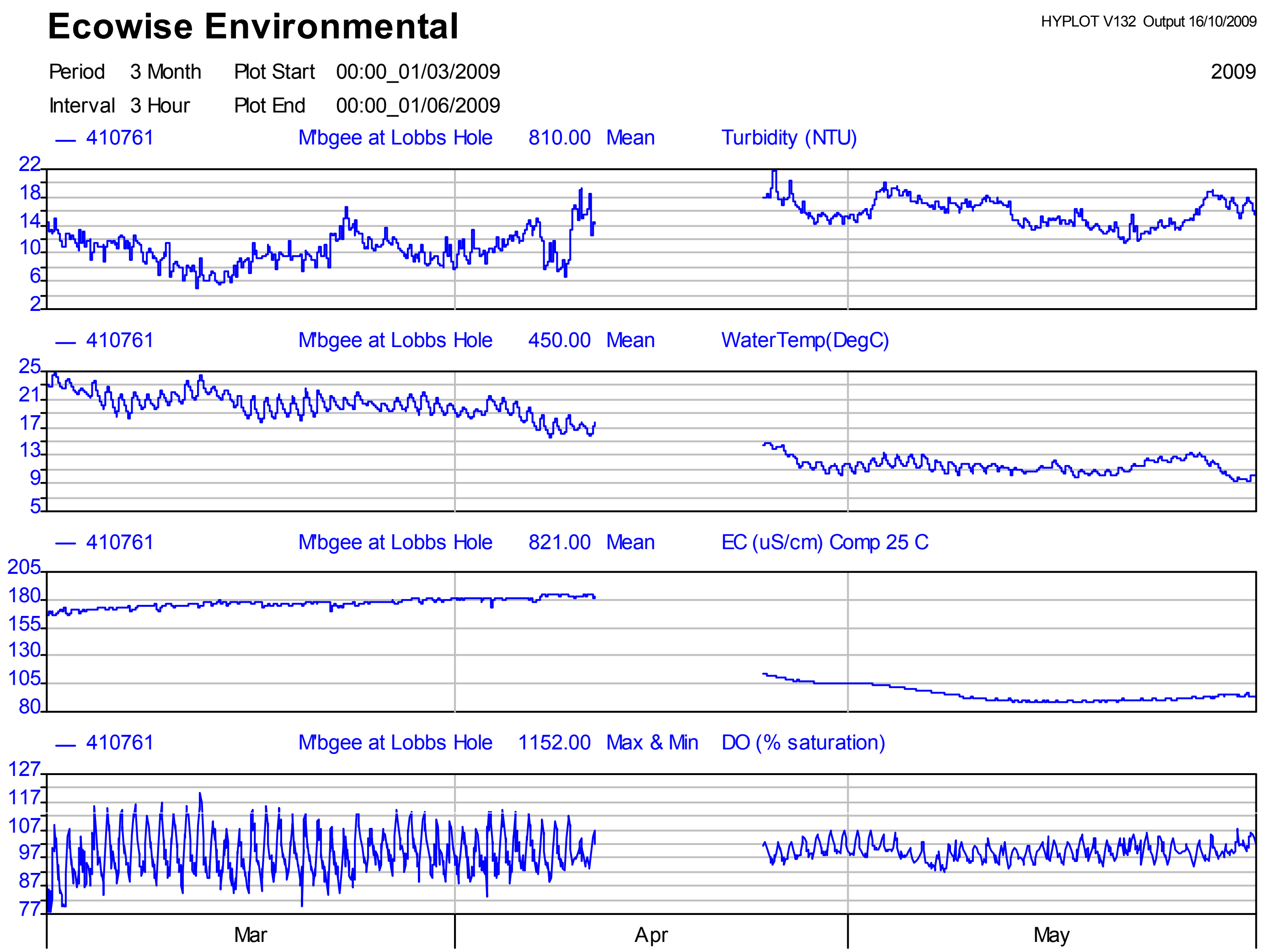

Figure 3. Water quality records from Lobb's Hole during autumn 2008

The break in the series, occurring from the12th to the 23rd of April was due to the cessation of flows recorded at Lobb's Hole.

Table 6. In-situ water quality and nutrient results from autumn 2009. (ANZECC guideline values are in parentheses). 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)	TP* (mg/L) **(0.02)**	TN† (mg/L) **(0.25)**
Bumbalong Road	MUR 15	09.50	10.6	66	11.4	7.6	100.7	10.3	30	<0.01	<0.01	<0.01	<0.01	0.030	0.33
The Willows	MUR 16	13.35	11.5	84	12.4	7.7	102.7	10.1	38	<0.01	<0.01	<0.01	<0.01	0.042	0.4
U/S Angle Crossing	MUR 18	09.15	10.7	90	13.5	7.7	99.8	9.5	41	<0.01	<0.01	<0.01	<0.01	0.026	0.35
D/S Angle Crossing	MUR 19	12.20	11.5	91	14	7.7	101.6	9.9	41	<0.01	<0.01	<0.01	<0.01	0.026	0.35
Point hut Crossing	MUR 23	11.45	13.3	110	17.3	7.9	96.3	8.4	51	<0.01	<0.01	<0.01	<0.01	0.033	0.4
U/S Cotter Confluence	MUR 28	14.15	12.8	120	13.5	7.9	103.3	9.8	63	<0.01	<0.01	<0.01	<0.01	0.035	0.51

^ Dissolved Oxygen
* Total Phosphorus
† Total Nitrogen

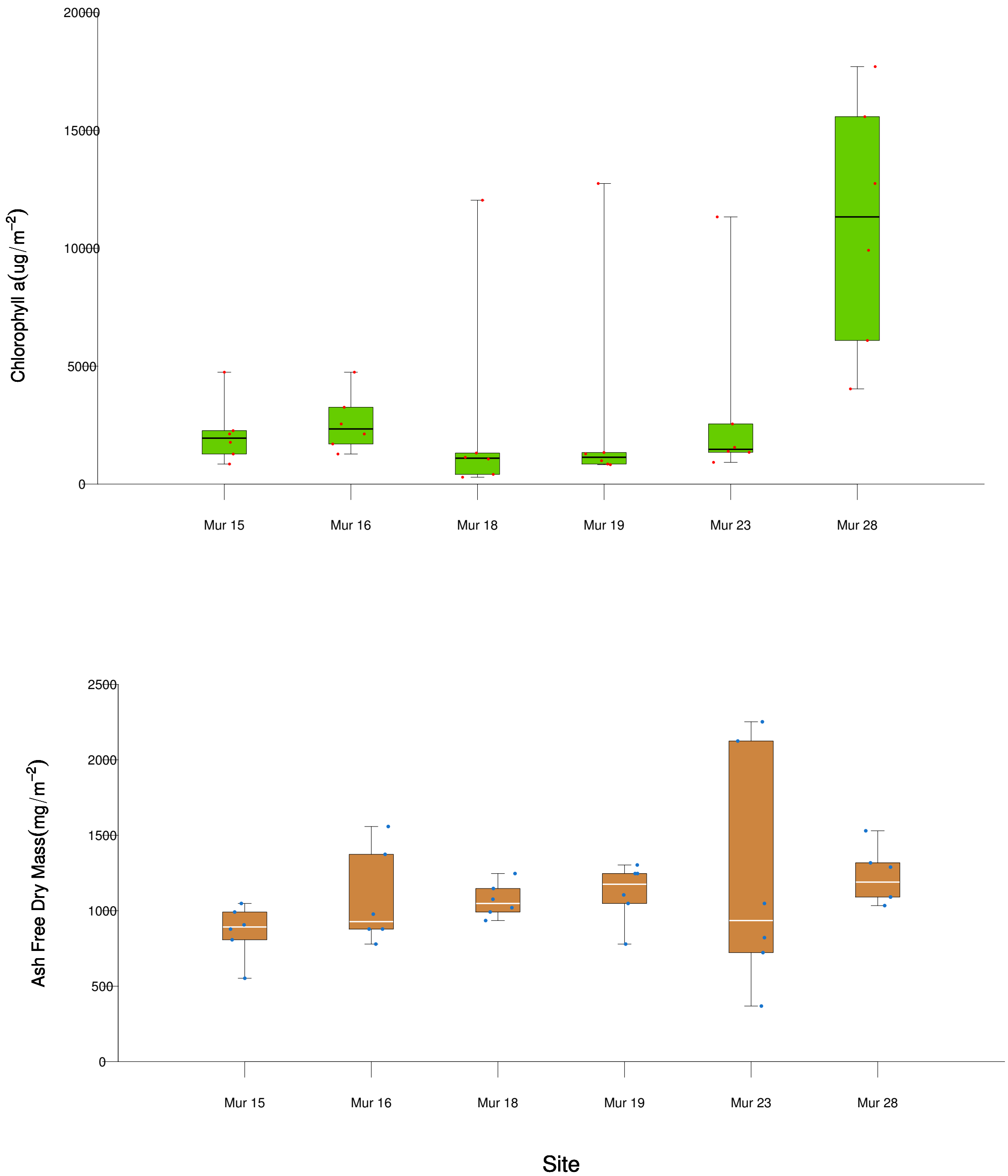

Figure 4. The distribution of a) Chlorophyll-a; and b) Ash Free Dry Mass (AFDM) up - and downstream of Angle Crossing.

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

3.4 Macroinvertebrate communities

ANOSIM analysis (see APPENDIX C) did not detect significant differences in the macroinvertebrate communities collected form the riffle zones between sites upstream and downstream of the proposed abstraction point at Angle Crossing the (R=-0.074; P=0.70: Figures 5 and 6). Similarly, there were no significant differences in edge community structure at sites upstream and downstream of Angle Crossing (R=0.5; P=0.10: Figure 7 and 8). Pairwise comparisons between sites were not carried out because of the non-significant global R-values for both habitats.

The stress illustrated in the NMDS plots is relatively high (>0.2), indicating that the depiction of the relationship between the sampling sites should be treated with some caution (Clarke and Warwick, 2001); however, the observed relationships are still evident when viewed in conjunction with the cluster analysis (Figures 6 and 8).

The negative R-statistic calculated in the riffle analysis suggests that in some cases (i.e. Mur 19 and 28; Figure 6) similarities between sites are higher than those within sites (Clarke and Warwick, 2001). The probable cause of the negative R-value can be seen in Figure 6 with the identification of two outlying samples taken from Mur 19 and the position of the samples taken from Mur 28 (i.e. three samples appear to be more similar to Mur 16 than they do to samples taken from within the same site). In the case of Mur 28, the community structure in these samples, and hence their dissimilarities to the other samples from that site are a result of sharp declines in the abundance of three Mayfly (Ephemeroptera) families, namely Leptophlebiidae, Baetidae and Caenidae and the Caddisfly, Hydropsychidae.

The most obvious outlying samples are replicates 1 and 3 from Mur 19. Theses two samples were dominated by high numbers of Ecnomidae and Hydrobiosidae, which made up 54% of and 52% of the total number of macroinvertebrates from replicate 1 and 3 respectively. Hydrobiosidae was absent from the remaining replicates at Mur 19 indicating a patchy distribution with very high densities in the isolated patches.

The moderate R-statistic (R=0.5) from the edge dataset suggests there is no clear indication of complete separation of the sites, nor is there a strong indication that within site variation is greater than between site variation. The high dispersion (multivariate variance) (Anderson *et al.*, 2008) of each edge site is evident when compared to the more tight clustering (generally) of samples in the riffle data (Figure 5).

3.4.1 Riffles

The total number of taxa collected in the riffle habitats ranged from 16 families and 36 genera at site Mur 15 to 26 families and 51 genera at site Mur 23 (Point Hut Crossing) (Figure 9). The number of genera at each site was almost double the number of families (Mur 16, 18, 23) present and in some cases (e.g. Mur 15, 19 and 28) more than double the number of families indicating high genus level diversity at these sites, particularly Chironomids and Orthocladiinae.

Sites upstream of Angle Crossing were characterised by (in order of numerical dominance):
Cheumatopsyche sp. (Hydropsychidae); *Simulium* sp. and *Austrosimulium* sp. - both in the black fly family (Simuliidae; SIGNAL =5); *Cricoptus sp.* (Chironomidae: *sf*. Orthocladiinae); *Ecnomus* sp. (Ecnomidae: SIGNAL = 4) and *Tasmanocoenis* sp. (Caenidae: SIGNAL=6). The caddis, *Cheumatopsyche* sp. (Hydropsychidae: SIGNAL =6) contributed up to 51% of the total number of invertebrates in a given sample in the upstream sites; and combined these taxa contributed to ~80% of the relative abundance of the sample.

The average relative abundance of sensitive taxa (EPT) and tolerant taxa (Oligochaeta Chironomids and other Dipterans) were not statistically different between upstream locations (mean =0.49%) and downstream locations (mean= 0.48%) [$F_{(4,30)}$ = 0.02, P=0.98]. It should be noted however, that Mur 23 and Mur 28 had very low relative abundance of EPT, while Mur 19 recorded the highest of 78% (Figure 10). The high value at Mur 19 therefore, should be recognised as highly influential in the calculation of the "location" average.

The macroinvertebrate assemblages collected downstream of Angle Crossing were "patchier" in there distribution of specific taxa than the sites sampled upstream. This is apparent in the NMDS plot (Figure 6) where each of the three sites (Mur19, 23 and 28) had samples that were more similar to other sites than to samples taken from the same site. The dissimilarity with samples taken from Mur 23 for example, are explained by a 5-fold increase in Simulids in three of the samples, while the two outlying samples from Mur 19 (Figure 6) are due to very high numbers of *Ecnomus* sp. (an order of magnitude higher than any other sample) and *Psyllobetina* sp. (Hydrobiosidae: SIGNAL = 8). In the later, these taxa were absent upstream of Angle Crossing and were only present in 26% of samples downstream of Angle Crossing. Hydrobiosidae and Hydropsychidae had a combined relative abundance of 73%, which explains the high proportion of EPT taxa at Mur 19 (Figure 10).

3.4.2 Edges

Genus and family level macroinvertebrate richness was highest at site Mur 23 (Point Hut Crossing) with 67 and 39 taxa recorded respectively; and lowest at site Mur 16 ("The Willows") recording 19 genera and 14 families (Figure 9). The number of invertebrate taxa in the edge habitat is less uniform than the riffle habitats; and this can be related to differences in the depth, overhanging (trailing) vegetation, woody debris and diversity of substrate recorded on the AUSRIVAS habitat sheets during sampling and the number of replicates and subsamples processed, between the less diverse and more diverse sites (Figure 9). The number of subsamples per site ranged from 1-6 and it should be noted that the number of genera tended to increase with the number of subsamples (R^2 =0.46) as did the number of families recovered from each sample (R^2 =0.58).

Edge samples were dominated by the genus *Micronecta* (Signal scores in parentheses) (Corixidae: (2) at sites Mur 23 and 28. While Simulids (5), Atyidae (Freshwater shrimps) (3), Caenidae (6), *Cricoptus* sp. (Orthocladiinae: SIGNAL = 4) and genera in the Chironominae (3) were ubiquitous across all sites. All of these taxa have intermediate SIGNAL scores, thus being relatively tolerant to poor water quality. All sites have the same suite of taxa, but there relative abundances differed considerably between sites. Most notably, in the deeper pool/edges of Mur 23 and site Mur 28, *Micronecta* spp. was the most abundant, but numbers were surprisingly low at Mur 18 and 19 considering the apparent quality of the edge habitat.

The relative abundance of several taxa was highest at Mur 23 (Point Hut Crossing); including: *Triplectides* sp. (Leptoceridae: SIGNAL =6); *Tasmanocoenis* sp. (Caenidae); *Simulium* sp. (Simuliidae); *Ablabesmyia* sp. (Chironomidae: *sf.* Tanypodinae) and the introduced freshwater snail: *Physa acuta*. The abundance of these taxa were approximately 50% lower at all other sites sampled.

3.5 AUSRIVAS assessment

The AUSRIVAS assessment of river health indicates that all sites appear to be under environmental stress (Table 6; Figures 11 and 12), with all sites having a combined habitat assessment of Band B or *"significantly impaired"* (Table 3); with the exception of Mur 23 (Point Hut Crossing). AUSRIVAS assessment protocols require that when both habitats are under assessment, that the overall assessment should be based on the lowest value of the two The edge samples at point hut crossing provided an unreliable final assessment because the range of bands was irregular (A-C). The final is assessment is given as Band C for the edge, but given that three subsamples recorded Band B assessments and two recorded Band A assessments, this should be treated with some caution even though the 95% confidence limits do contain these lower values (Figure 12).

The three upstream sites (Mur 15,16 and 18) were not assessed using AUSRIVAS in spring so there is no comparable data for these sites at this stage. The three downstream sites (all within the ACT): Mur 19, 23 and 28 declined in ecological condition in both habitats since spring 2008 (Ecowise, 2008), with the exception of Mur 28 which remained the same (Band B) for the edge habitat.

Taxa predicted to occur with ≥50% probability, but were absent from each habitat and site are presented in Appendix D.

Mur 28 recorded five missing taxa in the riffle zone. This was the most among all sites and included the usually ubiquitous Oligochaeta and Hydropsychidae, which were present in all of the remaining subsamples. The Band C assessment recorded at Mur 23 was a result of 10 taxa predicted to occur but missing from one of the samples. These included again the otherwise ubiquitous Oligochaeta, Leptoceridae and Hydroptilidae.

Gripopterygidae were absent from all sites sampled, except Mur 16, where it was recorded in three samples in very low numbers (3 or 4 individuals per subsample). This is a highly sensitive family of stonefly (Plecoptera; SIGNAL = 8), which requires cool, fast flowing water. This family has previously only been recorded in spring 2008 upstream of Cooma in the Murrumbidgee River (Ecowise, 2008).

Elmidae (SIGNAL =7) were absent from ~60% of the samples including the complete absence form sites Mur 18, 19 and 23. Other missing taxa included crane flies Tipulidae (SIGNAL =5); Baetidae was only missing from one sample and Caenidae, missing from two samples. The sensitive Caddisfly, Conoesucidae (SIGNAL =7) was missing from all but one edge sample. Leptophlebiidae (SIGNAL = 8) was absent from Mur 19 and 28 and had a limited occurrence at the remaining sites.

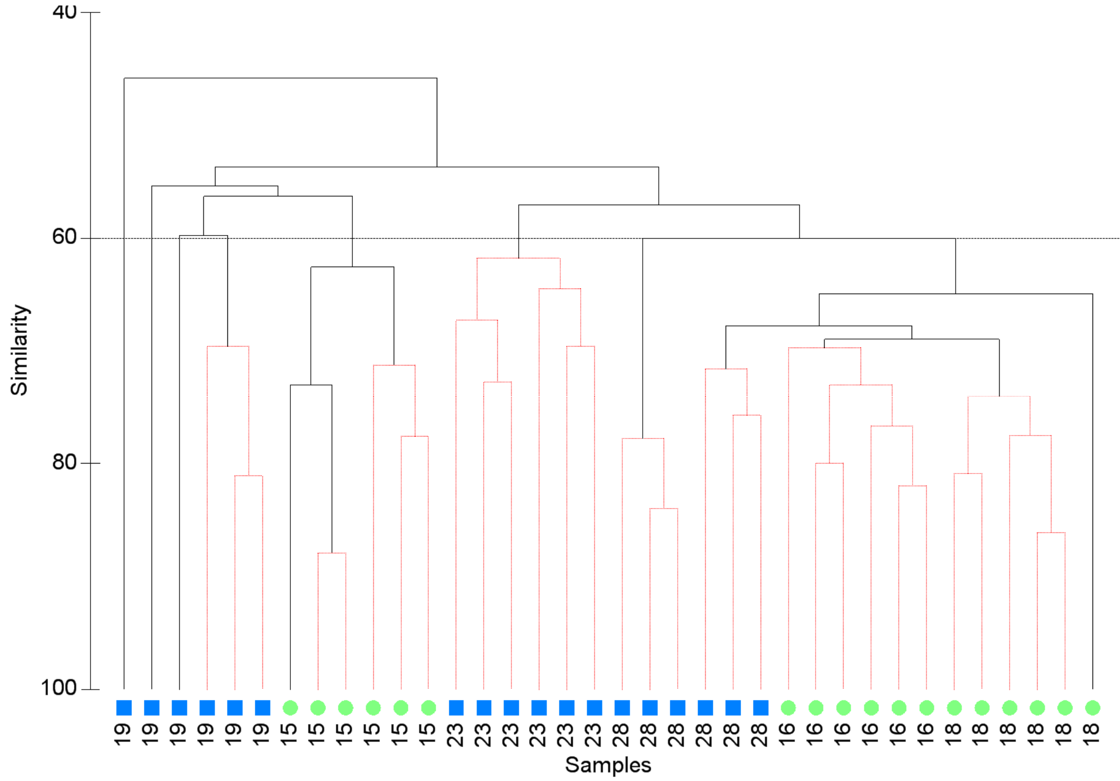

Figure 5. Cluster analysis based on genus level data for autumn riffle samples.

Blue squares indicate sites downstream of Angle Crossing; green circles are upstream of Angle Crossing.

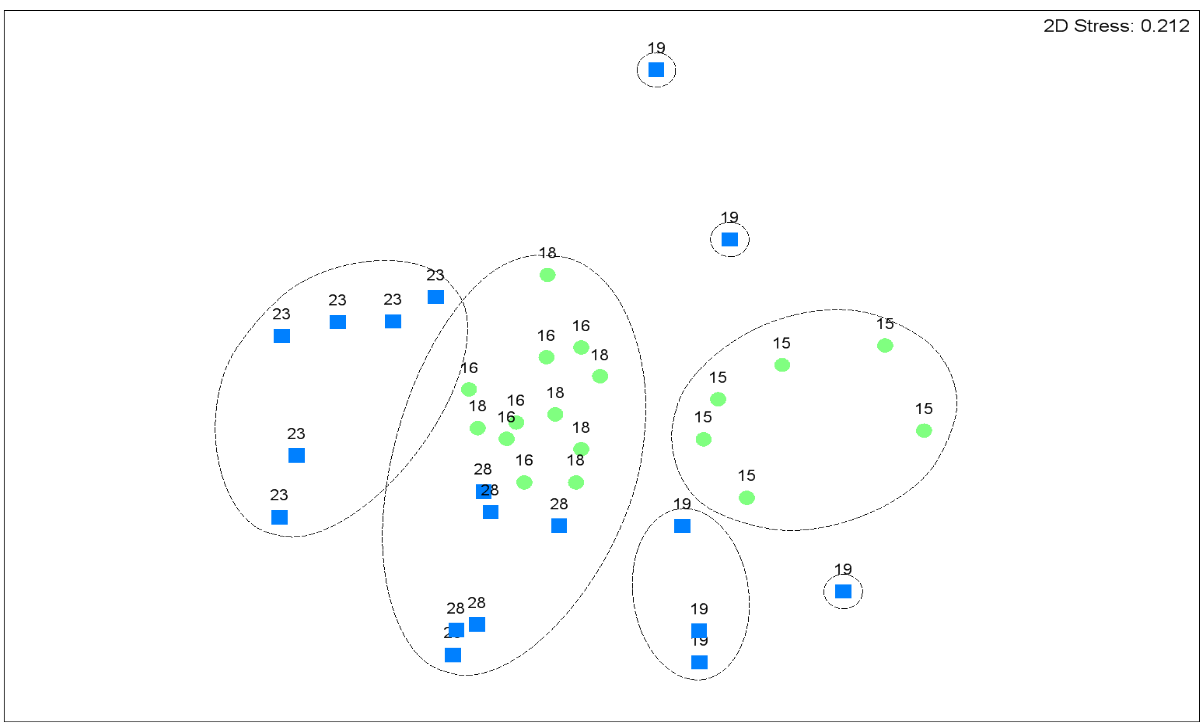

Figure 6. Non-metric multidimensional scaling of genus data from autumn riffle samples.

Ellipses represent the 60% similarity groups superimposed from the cluster analysis (above).

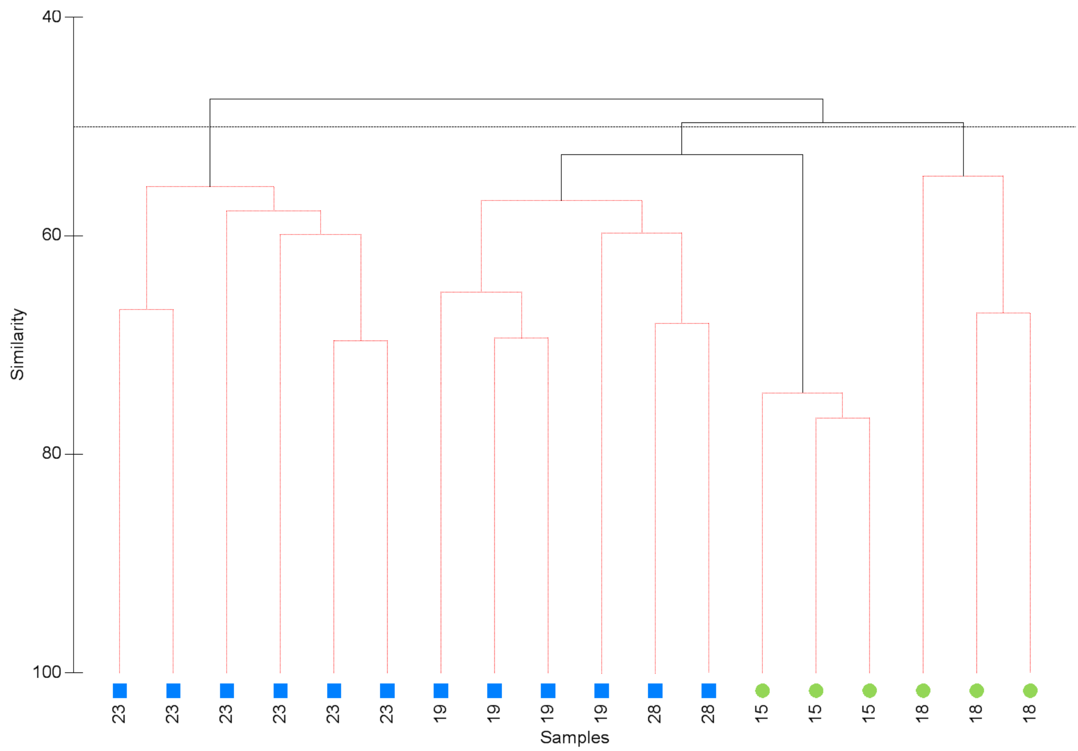

Figure 7. Cluster analysis based on genus level data for autumn edge samples.

Blue squares indicate sites downstream of Angle Crossing; green circles are upstream of Angle Crossing.

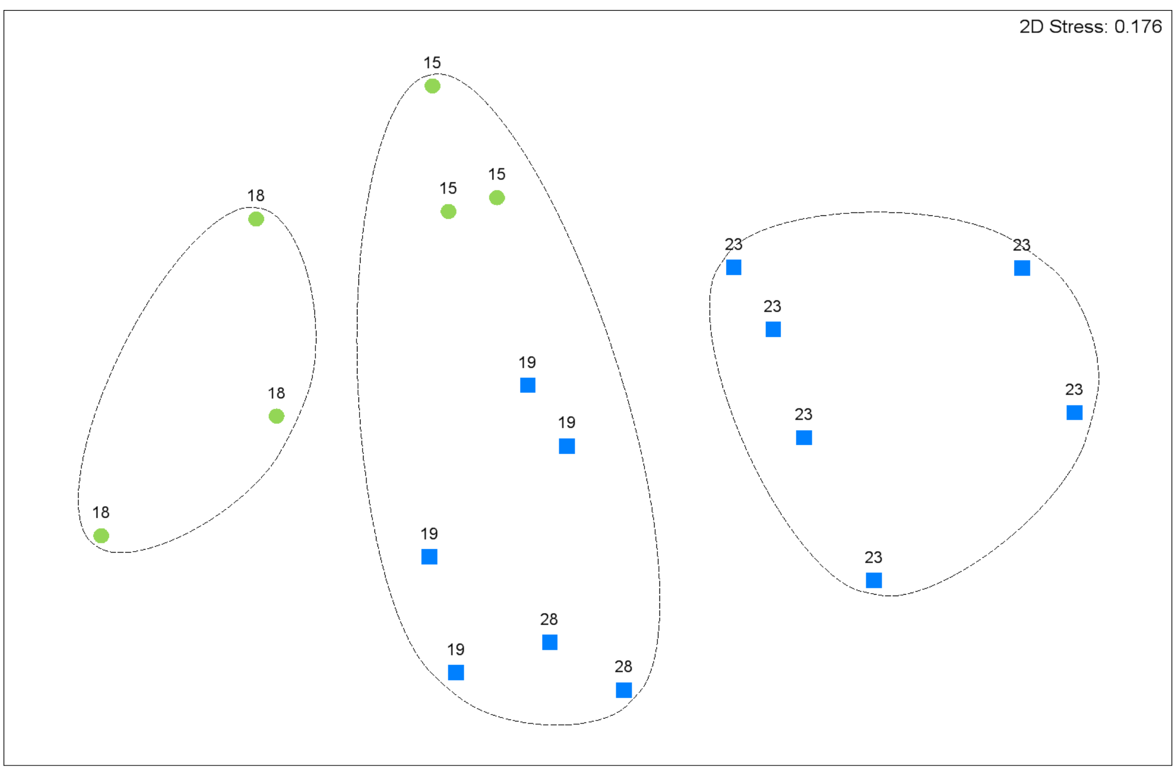

Figure 8. Non-metric multidimensional scaling of genus level data from autumn edge samples.

Ellipses represent the 50% similarity groups superimposed from the cluster analysis (above).

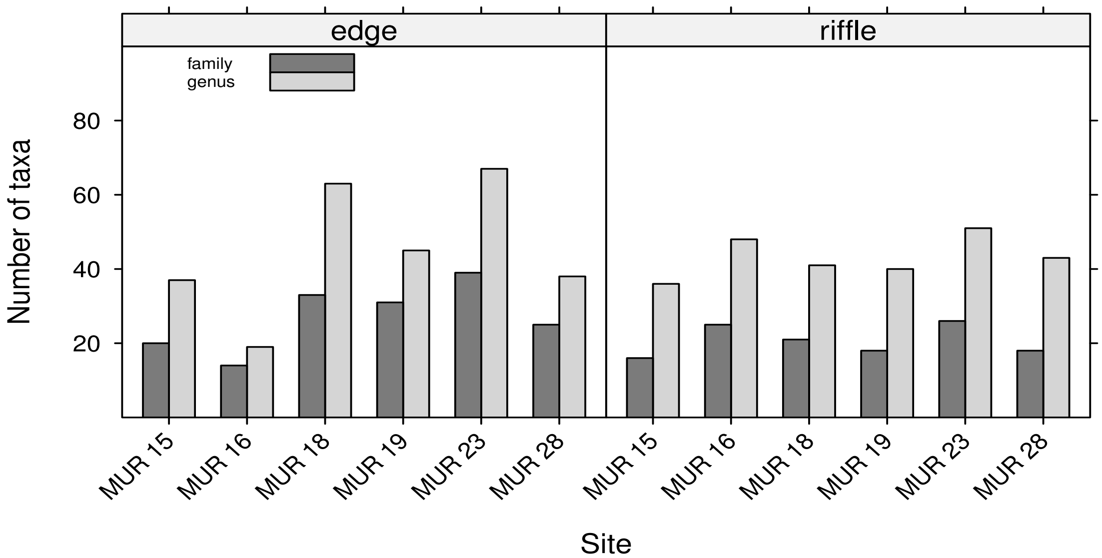

Figure 9. Total number of taxa at genus and family levels in the riffle and edge habitats.

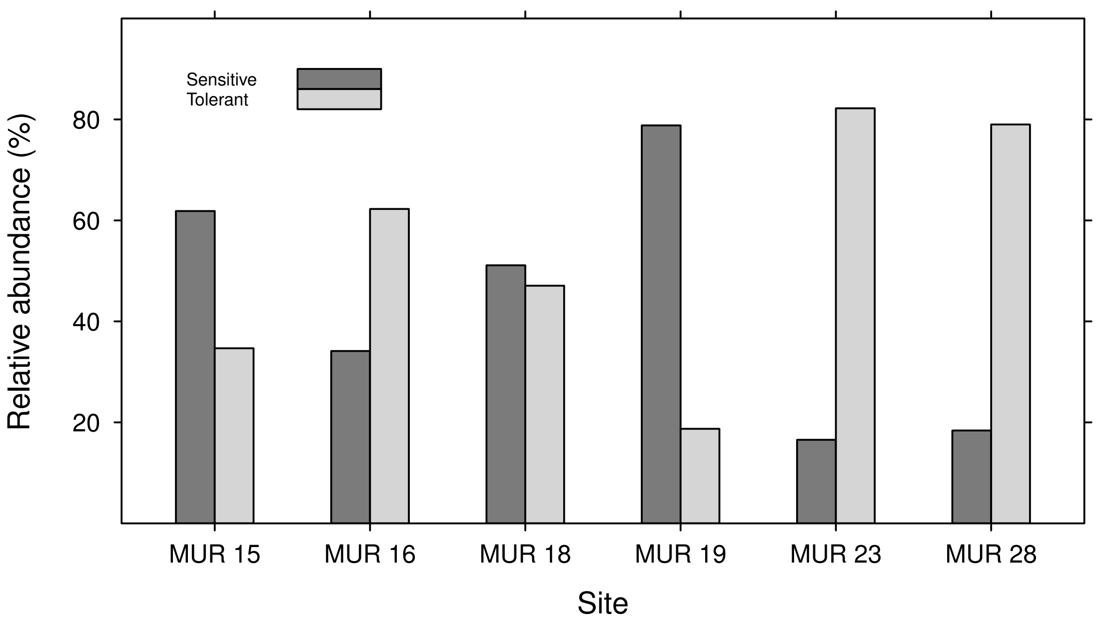

Figure 10. Average relative abundances of sensitive and tolerant taxa from sites upstream and downstream of Angle Crossing.

Table 6. AUSRIVAS and SIGNAL scores for autumn 2009. *No Reliable Assessment.

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 15	1	*4.14*	*3.78*	*0.78*	*0.70*	B	B	**B**	**B**	**B**
Mur 15	2	*4.17*	*3.78*	*0.67*	*0.70*	B	B			
Mur 15	3	*4.17*	*3.75*	*0.67*	*0.62*	B	B			
Mur 15	4	*4.14*		*0.78*		B				
Mur 15	5	*4.14*		*0.78*		B				
Mur 15	6	*4.20*		*0.78*		B				
Mur 16	1	*4.14*	*3.75*	*0.78*	*0.62*	B	B	**B**	**B**	**B**
Mur 16	2	*4.56*		*1.00*		A				
Mur 16	3	*4.63*		*0.89*		A				
Mur 16	4	*4.67*		*1.00*		A				
Mur 16	5	*4.67*		*1.00*		A				
Mur 16	6	*4.25*		*0.89*		A				
Mur 18	1	*4.86*	*3.67*	*0.78*	*0.70*	B	B	**B**	**B**	**B**
Mur 18	2	*4.67*	*4.67*	*1.00*	*0.70*	A	B			
Mur 18	3	*4.14*	*3.86*	*0.78*	*0.62*	B	B			
Mur 18	4	*4.50*		*0.89*		A				
Mur 18	5	*4.56*		*1.00*		A				
Mur 18	6	*4.14*		*0.78*		B				
Mur 19	1	*4.50*	*0.93*	*0.89*	*0.93*	A	A	**B**	**B**	**B**
Mur 19	2	*4.50*	*0.78*	*0.89*	*0.78*	A	B			
Mur 19	3	*4.50*	*0.78*	*0.89*	*0.78*	A	B			
Mur 19	4	*4.50*	*0.54*	*0.89*	*0.54*	A	B			
Mur 19	5	*4.86*		*0.78*		B				
Mur 19	6	*4.86*		*0.78*		B				
Mur 23	1	*4.38*	*3.57*	*0.89*	*0.54*	A	B	**B**	**C**	**NRA***
Mur 23	2	*4.56*	*4.00*	*1.00*	*0.93*	A	A			
Mur 23	3	*4.86*	*4.18*	*0.78*	*0.85*	B	A			
Mur 23	4	*4.25*	*3.78*	*0.89*	*0.70*	A	B			
Mur 23	5	*4.50*	*4.60*	*0.89*	*0.39*	A	C			
Mur 23	6	*4.50*	*4.25*	*0.89*	*0.62*	A	B			
Mur 28	1	*4.14*	*4.25*	*0.78*	*0.93*	B	A	**B**	**B**	**B**
Mur 28	2	*4.14*	*4.56*	*0.78*	*0.70*	B	B			
Mur 28	3	*4.50*		*0.67*		B				
Mur 28	4	*4.14*		*0.78*		B				
Mur 28	5	*4.14*		*0.78*		B				
Mur 28	6	*4.86*		*0.78*		B				

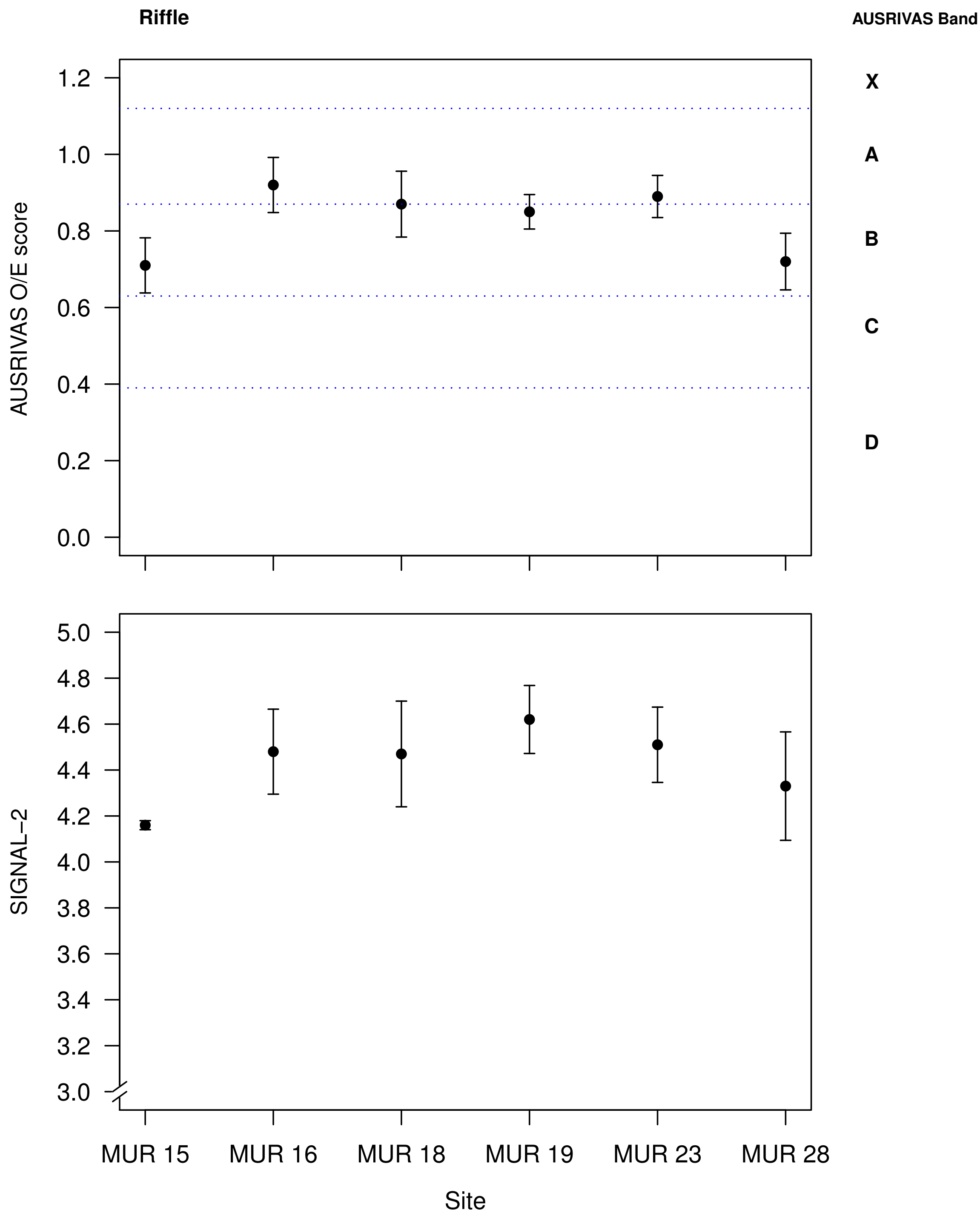

Figure 11. Average AUSRIVAS OE50 scores (top) and average SIGNAL-2 scores for riffle samples upstream and downstream of Angle Crossing. Error bars are 95% confidence intervals.

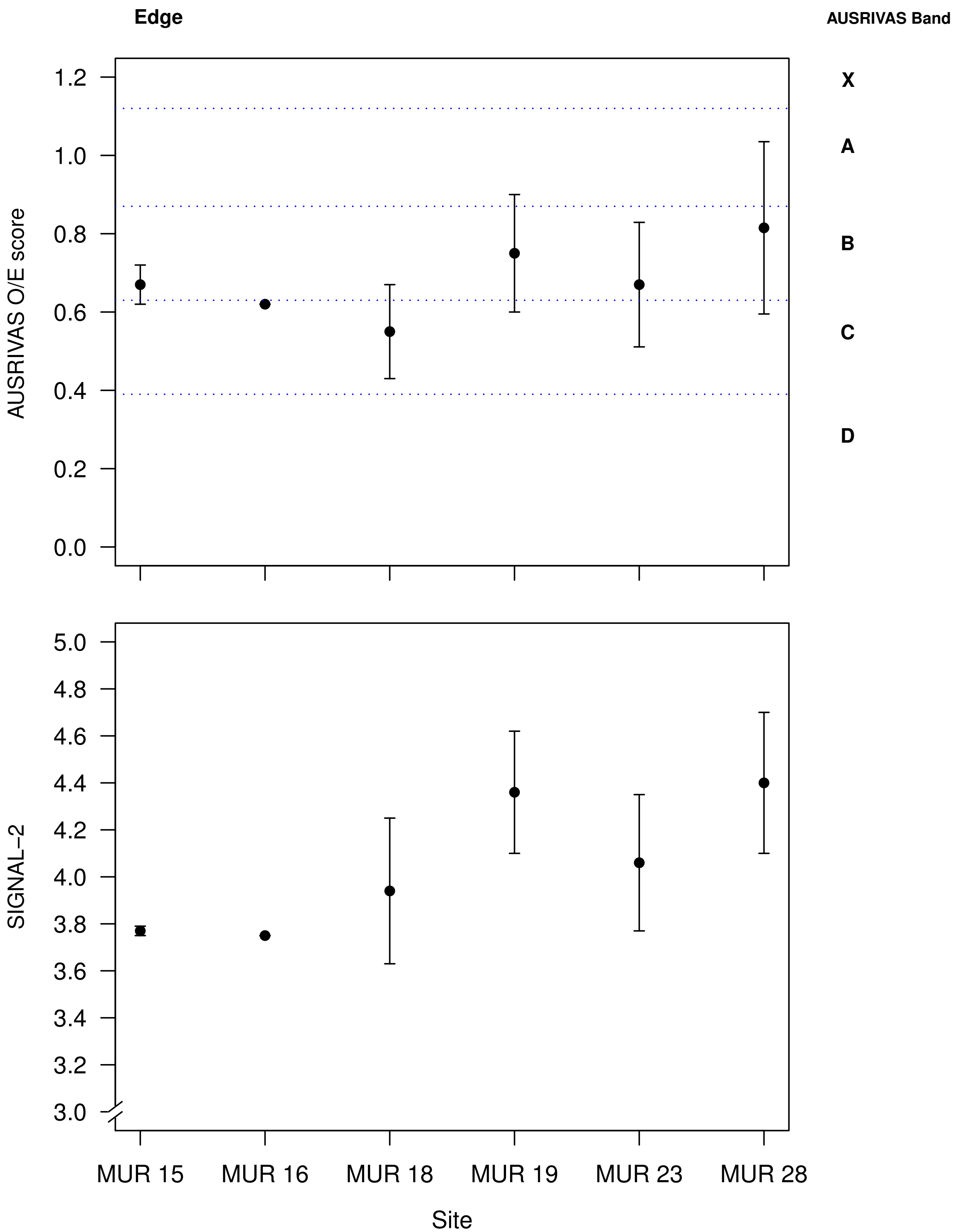

Figure 12. Average AUSRIVAS OE50scores (top) and SIGNAL-2 scores for edge samples upstream and downstream of Angle Crossing. Error bars are 95% confidence intervals.

4 Discussion

4.1 Water quality

The water quality parameters from the continuous gauging at Lobb's Hole are indicative of responses to reduced flow and seasonal changes (Figure 3). For example, low water temperatures at Lobb's correspond to declining ambient temperatures, but also to increased flows during sampling. It is likely that the slight increases in turbidity are related to re-suspended fines following rainfall runoff, and inflow from tributaries, though these increases in turbidity are minor and remain inside the ANZECC (2000) water quality guidelines for ecosystem health (Table 5).

There was almost a two-fold increase in electrical Conductivity (EC) values recorded at all sites compared to the previous sampling period of spring 2008 (Ecowise, 2008). These high EC prior to flow levels falling below the threshold for reliable readings in mid-April implies a high groundwater contribution.

The results from the grab samples show that almost all the analytes were within the ANZECC (2000) water quality guidelines, the exceptions being total nitrogen (TN) and total phosphorus (TP) concentrations. There were minor changes in the nutrient concentrations at all sites since spring 2008; but the most notable changes occurred at Mur 19 (downstream of Angle Crossing) where there was a 55% reduction in TP and a 50% decrease in TN. This suggests that less sediment and runoff entering the river downstream of the level crossing due to low seasonal rainfall throughout the catchment (Verhoff *et al.*, 1982). Despite these reductions, nutrient values remain more than double the guideline values at some sites (Table 6) which could be problematic if they remain high, during periods of low flows; as this will encourage algal growth.

4.2 River health

The results from this sampling period indicate that all sites upstream and downstream of Angle Crossing are under environmental stress, based on the banding scheme of the AUSRIVAS river health assessment (Table 6), although it should be recognised that many of the sites in this round of sampling contained subsamples registering a Band A assessment (i.e. Mur 16, 18, 19 and 23).

There was no statistical difference found between upstream and downstream locations in either habitat based on the ANOVA results for AUSRIVAS OE50, or SIGNAL -2 scores (Figure 11 and 12). All of the sites sampled, except Mur 23 had an <u>overall site assessment</u> of "significantly impaired" (Band B) based on <u>both</u> habitat types. Due to a discrepancy in one of the subsamples, site Mur 23 (Point Hut crossing) had no reliable assessment available for the site assessment based on both the riffle and edge samples (Table 6). At this site, subsample five resulted in an assessment of Band C (Table 6) which was two band widths below the highest for the site. This assessment resulted from nine missing taxa in the edge habitat that were predicted to occur by the AUSRIVAS model (Appendix D). Some of these taxa were otherwise common albeit in relatively low numbers, in the other subsamples which could be an indication that the additional subsamples were reducing total numbers thus resulting in fewer taxa being recovered.

The number of taxa missing but predicted by the AUSRIVAS model (Appendix D) highlights the similarities in macroinvertebrate assemblages between sites, particularly in the riffle habitat, with all of the sites sharing a similar suite of missing taxa. The absence of Gripopterygidae (SIGNAL =8), a stonefly, from all sites except Mur 16 indicates some degree of water quality impact. However, this seems anomalous given that Mur 16 is downstream of intensive grazing and agricultural practices. One possible explanation is that the physical location of the site, lying in a steep valley on the opposite side of the ridge to the grazing and agriculture practices, misses any immediate effects of agricultural runoff. Any upstream effects may be small or dissipate before reaching this site (~15km downstream).

The other pattern in the distribution of missing taxa, is the absence of (Elmidae: SIGNAL =7) from Mur 15, 16 and 28. Elmidae, also known as the riffle beetle because of their affinity to clean, fast flowing water (Gooderham and Tsyrlin, 2005), are also considered to be a useful bioindicators because of their intolerance to even low levels of pollution (Young, 1961). Their absence at these sites therefore seems anomalous give that: a) velocity readings (range: 0.56 – 0.71 m/s^{-1}) from these sites did not differ and b) the water quality variables between sites did not differ enough to suggest that water quality alone was impacting the Elmidae distributions at these sites; although water quality is a less likely cause, given that Elmidae were present in most of the edge samples.

Slight differences in the percentage cover of silt, sand, and detritus noted in riffle habitats at these sites could be interacting with other localised effects (e.g. point source impacts), but this remains unclear. Another possibility, as suggested by Brookes *et al*. (2005) include small-scale hydraulic variations causing these patterns; and finally, their presence at all sites in the edge samples could indicate localised impacts on flow forcing the Elmid's to seek refuge in the edge habitat. Therefore, the period that samples were taken at these sites, could have been during the early stages of recovery when the Elmidae had not yet recolonised the riffle zones (e.g. Boulton, 2003).

4.3 Patterns in macroinvertebrate assemblages

Comparisons of macroinvertebrate and community assemblages between all sites upstream and downstream of Angle Crossing revealed no significant location effect, despite some apparent differences within sites (Figures 6 and 8), which is consistent with the AUSRIVAS output. The high, within-site variation, most evident at Mur 19 and 28, and to a lesser extent Mur 23 (Figure 6) could be limiting the ability to detect differences between locations.

The variation within these sites is a result of changes in the abundances of taxa rather than the absence of taxa (Figure 9) suggesting perhaps that small scale differences in depth, velocity or substrate (Brooks *et al.*, 2005) may be more pronounced at these sites. For example, riffle depth varied by more than 30% at Mur 19 between the points where the samples were collected, while Mur 28 varied considerably in velocity and substrate. In the case of Mur 28, the 6 subsamples are split into two groups of three; the two groups coming from the two physically different riffle habitats. Previous work has shown that similar habitats are more likely to contain taxa similar to like habitats (Canton and Chadwick, 1988, Parsons *et al.*, 2003) stressing the importance of finding sites having as similar habitat as possible in biological assessments.

Drought effects including loss of sensitive taxa and loss of habitat were less pronounced (except at Mur 19) than in other sections of the Murrumbidgee (Ecowise, 2009). However, there were obvious changes in the relative abundances of genera in the family Hydrobiosidae (caddis: Trichoptera) and a corresponding negative decline of Simuliidae numbers recorded at Mur 19 which can be indicative of competitive responses to low flow conditions (Dean and Bunn, 1989, Lake, 2003, Zhang *et al.*, 1998) for available habitat and resources.

In this study, edge zones tended to be deeper than further downstream so probably function as a refuge during these low flow periods (Stanley *et al.*, 1997). The different landuse practices associated with these sites also complicates their interpretation. Similar landuse practices at sites monitored for Part 3 of the MEMP (i.e. Murrumbidgee Pump Station) facilitated Ecowise in determining that because of the apparent broad-scale nature of the impact coupled with the evidence from missing taxa and community assemblages that the likely cause of this was the current drought situation.

In this assessment, however, landuse changes downstream of Angle Crossing from predominantly grazing and agricultural land, to a mixture of urban, recreational and grazing; make it difficult to separate the impacts of the different land uses from the impacts of drought. However, the potential impacts of urban stormwater was a likely cause of the condition of the macroinvertebrate assemblages at Mur 23 because the community structure at this site (Point Hut Crossing) was distinctly different from all the other sites, being comprised of a highly diverse Chironomid population, dominated by Simuliidae and having a low relative abundance (16.5%) of sensitive taxa. This combined with elevated concentrations of AFDM and Chlorophyll – a (Figure 4) and Point Hut pond over-topping twice in autumn (Appendix E) may indicate slight organic pollution at this site (Paul and Meyer, 2001), although our grab samples did not indicate this. More detailed screening of samples will be needed to isolate this as a possible impact.

At this stage we believe, despite the confounding effects of differing landuse, that the current ecological condition (as determined by AUSRIVAS) of this section of the Murrumbidgee River is due to the continuing drought. Lack of rainfall and associated low flows are known to drive patterns of macroinvertebrate communities (Bunn and Arthington, 2002), and the fact that nutrient enrichment through agricultural and urban runoff is most pronounced following surface runoff (Delong and Brusven, 1992) it is unlikely that this is the main cause of this broad-scale decline in river health.

5 Conclusions

The results from the Angle Crossing assessment in autumn 2009 indicate a decline in ecological health in the riffle habitats at three of the previously sampled sites downstream of Angle Crossing. The three upstream sites, not previously assessed under AUSRIVAS protocols, had the same ecological health assessment of (Band B) “significantly impaired” as the downstream sites.

Water quality was within ANZECC & ARMCANZ (2000) water quality guidelines, with the exception of Total Phosphorus and Total Nitrogen. Despite these parameters exceeding the upper acceptable limits, they were up to 50% lower than they were for spring 2008. The water quality trends for autumn are consistent with temporal changes induced by changes in ambient temperatures and low river flows for the period.

The current assessment and general decline in the AUSRIVAS ecological health bands is likely a result of reach-wide influences, such as low flows during this prolonged drought period. The relationship between the AUSRIVAS assessments and drought conditions is less clear than in previous assessments. It is likely that the effects of drought are being confounded by possible nutrient enrichment and other landuse impacts downstream of Angle Crossing, but further and more detailed analysis of water quality samples is required. The deeper edges may be acting as refuges for taxa sensitive to low flows at some of the sampled sites

Determining the relationship between drought affects related to flow regime and water quality and their effects on river health will be facilitated with the installation of continuous gauges upstream of Angle Crossing.

The condition of these sites is likely to improve with increased flow associated with winter and spring rainfall events.

6 Recommendations

A condition stated in the Angle Crossing monitoring proposal (section 5.1.5) 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.

As this is the first round of sampling, any limitations of the methods are not yet evident.

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 and 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) Continuous water quality monitoring is restricted to Lobb's Hole (410761) which misses the potential impacts of water entering the Murrumbidgee River at Point Hut Crossing from Point Hut Pond and potential impacts upstream during storm events. Grab samples taken during storm events should help explain the distinctly different composition of macroinvertebrates at this site.
3) The high within-site variation found in this round of sampling suggests that a single replicate might not be adequate to describe the sites in this assessment. This is consistent with the findings of (Nichols *et al.*, 2006) who recommended taking replicate samples at impaired sites for biological assessments. Taxonomic diversity and abundances differed considerably between replicates and subsamples, which resulted in considerable variability in the AUSRIVAS bioassessment of a given site. It is recommended that this level of replication be maintained.

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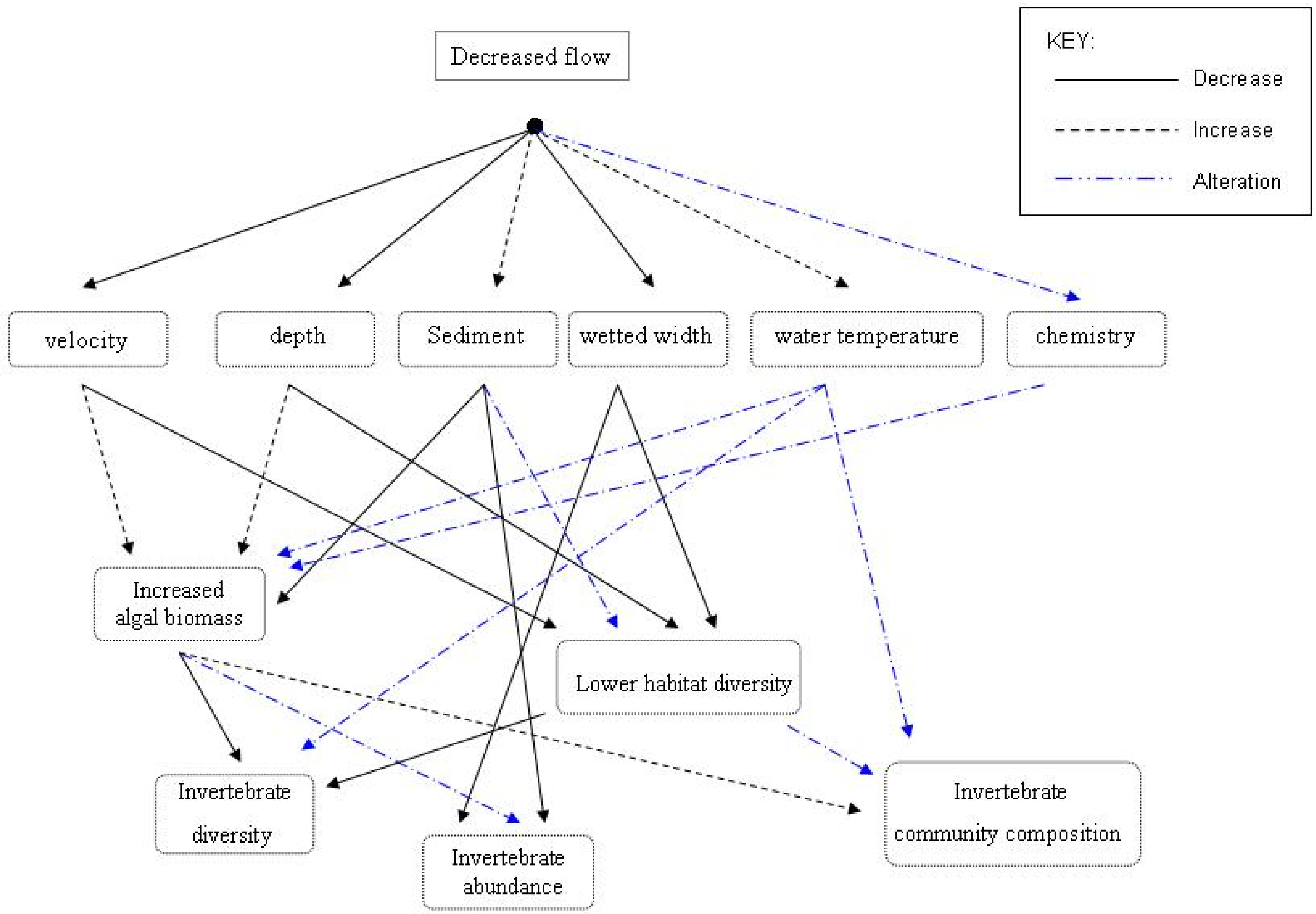
Appendix A –

Potential effects of reduced flow and their knock-on effects on habitat conditions and macroinvertebrate communities



Summary of the effects of reduced flows on various habitat conditions and macroinvertebrate communities from recent literature (Dewson et al. 2007)*.

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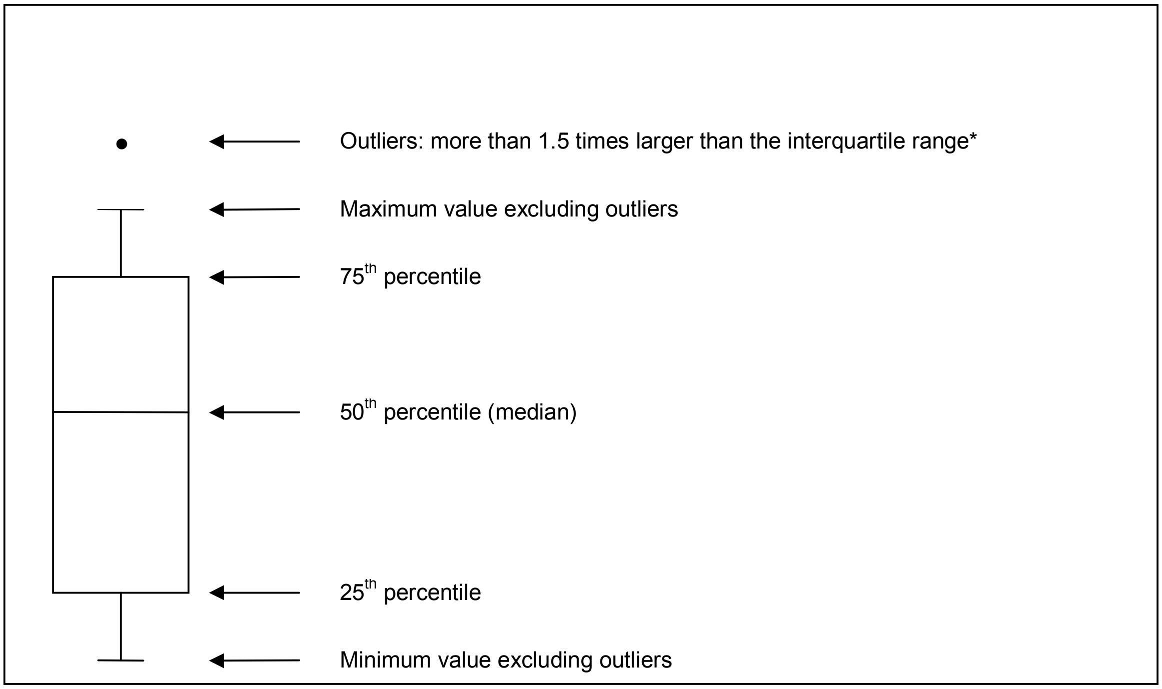
Appendix B –

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 C – ANOSIM output for riffle and edge samples

ANOSIM
Analysis of Similarities

Two-Way Nested Analysis

RIFFLE

```
TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): -0.074
Significance level of sample statistic: 70%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 7
```

EDGE

```
TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): 0.5
Significance level of sample statistic: 10%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 1
```

Appendix D –

Taxa predicted to occur with >50% probability but were not collected in the autumn samples

APPENDIX D. Taxa expected, but not collected in the riffle habitat. Highest number missing is in red.

Site	Taxa	Oligochaeta	Elmidae	Tipulidae	Baetidae	Caenidae	Gripopterygidae	Hydropsychidae	Total number of missing taxa
	SIGNAL	2	7	5	5	4	8	6	
Mur 15	Riffle		●	●			●		**3**
Mur 15			●	●		●	●		**4**
Mur 15			●	●		●	●		**4**
Mur 15	Riffle		●	●			●		**3**
Mur 15			●	●			●		**3**
Mur 15			●	●			●		**3**
Mur 16	Riffle		●	●			●		**3**
Mur 16							●		**1**
Mur 16			●	●					**2**
Mur 16	Riffle		●						**1**
Mur 16			●						**1**
Mur 16			●				●		**2**
Mur 18	Riffle	●		●			●		**3**
Mur 18				●			●		**2**
Mur 18				●			●		**2**
Mur 18	Riffle			●			●		**2**
Mur 18				●					**1**
Mur 18				●			●		**2**
Mur 19	Riffle			●			●		**2**
Mur 19				●			●		**2**
Mur 19				●			●		**2**
Mur 19	Riffle			●			●		**2**
Mur 19		●		●			●		**3**
Mur 19		●		●			●		**3**
Mur 23	Riffle						●	●	**2**
Mur 23							●		**1**
Mur 23					●		●		**2**
Mur 23	Riffle						●		**1**
Mur 23				●			●		**2**
Mur 23				●			●		**2**
Mur 28	Riffle		●	●			●		**3**
Mur 28		●	●	●			●	●	**5**
Mur 28		●	●	●			●		**4**
Mur 28	Riffle		●	●			●		**3**
Mur 28			●	●			●		**3**
Mur 28		●		●			●		**3**

APPENDIX D (cntd.). Taxa expected, but not collected in the edge habitat autumn 2009. Highest number missing is in red.

Site	Taxa	Oligochaeta	Elmidae	Gripopterygidae	Planorbidae	Synlestidae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Hydroptilidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	7	8	2	7	4	5	8	4	4	4	7	6	
Mur 15	Edge			●					●	●			●		4
Mur 15				●					●		●		●		4
Mur 15				●			●		●	●			●		5
Mur 16	Edge			●			●		●			●	●		5
Mur 18	Edge			●								●	●		3
Mur 18				●				●	●				●		4
Mur 18		●	●	●				●	●	●			●		7
Mur 19	Edge		●									●			2
Mur 19				●									●		2
Mur 19				●									●		2
Mur 19	Edge			●			●						●		3
Mur 19				●			●						●		3
Mur 19		●		●			●					●	●	●	6
Mur 23	Edge			●			●	●	●			●	●		6
Mur 23				●	●								●		3
Mur 23				●									●		2
Mur 23	Edge			●					●				●		3
Mur 23		●		●			●		●	●	●	●	●	●	9
Mur 23				●			●			●		●	●		5
Mur 28	Edge			●									●		2
Mur 28				●									●		2

Appendix E –

Point Hut Pond Hydrograph: autumn 2009

Appendix E. Hydrograph of point hut pond and Lobb's Hole for autumn 2009.