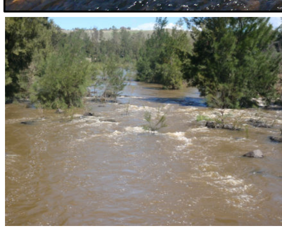
Ecowise Environmental

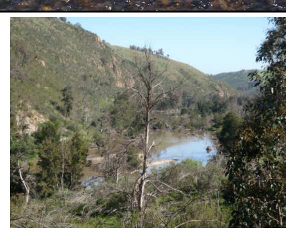
ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 4: Tantangara to Burrinjuck

Spring 2009





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	Position	**Name**	**Signature**	**Date**
Prepared by:	Environmental Project Officer	Phil Taylor		29/6/10
Internal Review by:	Manager-Water Sciences	Norm Mueller		27/6/10
Peer Review by:	Principal Scientist	Jamie Corfield		24/6/10
Approved by:				

For further information on this report, contact:

Name: Phil Taylor
Title: Environmental Project Officer
Address: 16a Lithgow Street, Fyshwick, ACT 2609

Phone: 02 6270 7926

Mobile: 040 6375 290

E-mail: p.taylor@ecowise.com.au

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Ecowise Australia Pty Ltd ABN 94 105 060 320

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List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
ANZECC – Australian and New Zealand Environment and conservation Council
ANOSIM – Analysis of Similarities (statistics)
ANOVA – Analysis of Variance (statistics)
ARI – Annual Recurrence Interval
ARMCANZ - Agriculture and Resource Management Council Of Australia and New Zealand
AUSRIVAS – Australian River Assessment System
CPOM – Coarse Particulate Organic Matter
CRCFE – Cooperative Research Centre for Freshwater Ecology
EC – Electrical Conductivity
ECD – Enlarged Cotter Dam
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
EPT – Ephemeroptera, Plecoptera, Trichoptera
D.O. – Dissolved Oxygen
GL/a – Gigalitres per annum
GPS – Global Positioning System
LMWQCC – Lower Molonglo Water Quality Control Centre
LWD – Large Woody Debris
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)
O/E Family – Observed to Expected ratio of macroinvertebrate families
PCA – Principal Components Analysis
Q – Daily flow (ML/d)
QA – Quality Assurance
QC – Quality Control
RBA – Rapid BioAssessment
SIGNAL – Stream Invertebrate Grade Number – Average Level
SIMPER – Similarity Percentage (statistics)
TN – Total Nitrogen
TP – Total Phosphorus
Temp. Water temperature (°C)
WAE – Water Allocation Entitlement
WL – Water Level

Executive summary

The major water security program introduced by ACTEW Corporation in 2007 is in the process of upgrading existing, and developing new infrastructure in order to secure water for the Australian Capital Territory in light of continuing drought in the region. Included in the new water security projects is the proposed "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow with the aim of providing a source of water that is less dependent on rainfall within the ACT.

The Murrumbidgee (River) Ecological Monitoring Programme (MEMP) is designed to address any concerns brought up by both Government and non-Government stakeholders and provides ACTEW with relevant information and data regarding beneficial and/or detrimental ecological effects of this project. The aims of 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, before and after the proposed abstractions are implemented.

The key aims of this sampling run were to:

1. Establish baseline macroinvertebrate data for key sites along the Murrumbidgee River, and in doing so establish a data base of the existing condition prior to any releases from Tantangara reservoir;

2. Commence in-situ water quality sampling – including nutrient analysis as a baseline for future condition assessments;

3. Provide ACTEW with AUSRIVAS assessments of riffle and edge habitats between Tantangara Reservoir and Burrinjuck reservoir on the Murrumbidgee River

This report presents the results from the macroinvertebrate sampling run carried out in spring 2009. During spring 2009 Ecowise conducted biological sampling from downstream of Tantangara Dam to approximately 2km upstream of the Burrinjuck Dam delta. Samples were taken in accordance with the ACT AUSRIVAS protocols to provide an overall assessment of river health in the upper Murrumbidgee Catchment.

The key outcomes of the spring 2009 MEMP include:

- *A high flow event (1600 ML/d) occurring in early November interrupted the spring sampling run. This event originated in the Numeralla River and affected all reaches in the Murrumbidgee River downstream of the Numeralla River – Murrumbidgee River confluence.*
- *Water quality results show a dilution effect of both the nutrient data and EC results.*
- *In areas upstream of the Numeralla confluence, nutrient levels were higher than for the previous sampling period, probably resulting from increasing agricultural runoff, particularly in areas close to the Numeralla River – Murrumbidgee River confluence, where the riparian buffer zone is lacking. Downstream of the (Numeralla) confluence, there was a homogenising effect of the spring high flow event on these parameters, effectively reducing the strength of the longitudinal gradient in nutrient concentrations seen in previous sampling events.*

- *Despite the dilution effect on the nutrient concentrations,, only four sites were inside the upper ANZECC and ARMACANZ (2000) guideline limits for TP and only two sites for TN. EC and turbidity also seem to have been affected by the high flows. Turbidity was higher than the recommended upper limits downstream of the Bredbo confluence, while EC levels were below the ANZECC and ARMACANZ (2000) guideline lower limit.*

- *The AUSRIVAS assessment indicates little change since autumn in terms of the assigned BANDS. There were some improvements seen at sites upstream of the Bredbo confluence. These slight improvements are likely to have been attributed to reduced nutrient and EC levels as a result of elevated flow conditions. However, the much higher flows in the mid-reaches resulted in the dislodgment and removal of some usually common and tolerant taxa, resulting in some particularly poor assessments.*

- *The main change to macroinvertebrate communities was a large reduction in: a) the number of taxa collected (family richness) and b): the abundance and proportion of EPT taxa (a grou of taxa considered to be sensitive to water pollution). Seasonality can explain some of these changes, but the degree of change increased in magnitude downstream of the Numeralla confluence – particularly in terms of the reduction of EPT taxa – suggesting that high flows increased dislodgement and removal of these taxa*

- *Care should be taken when interpreting the findings of this study in relation to the macroinvertebrate community data because data were collected within the usual four week waiting period following high flow events. The reason this occurred was that a further delay in sampling would have meant that sampling would have had to be carried out in summer. In turn, this would have precluded the use of the AUSRIVAS model bandings to determine current condition as the ASURIVAS model only applies to sample data collected in autumn and spring.*

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 4: Tantangara to Burrinjuck.

The major water security program introduced by ACTEW Cooperation in 2007 is in the process of upgrading existing, and developing new infrastructure in order to secure water for the Australian Capital Territory in light of continuing drought in the region. Included in the new water security projects is the "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via the snowy mountains scheme with the aim of providing a source of water that is less dependent on rainfall within the ACT.

In order to use water from the Tantangara Reservoir, ACTEW is committed to the construction of a River offtake, pumping structure and pipeline from a location 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 enable pumping of up to 100 ML/d, and to be in operation by around 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). A schematic overview of the proposed operations is given in **APPENDIX A**.

Water abstractions will be regulated through the *2006 Environmental Flows Guidelines.* ACT and NSW Government agencies, and recreational and rural users in the regional Murrumbidgee River reach (both upstream and downstream of Angle Crossing), are key stakeholders in the M2G project.

The Murrumbidgee River Ecological Monitoring Program (MEMP) is designed to address concerns raised by both Government and non-Government stakeholders; and provide ACTEW with relevant information and data regarding any beneficial and/or detrimental ecological effects of the project. The project is to be implemented prior to the commencement of the M2G project, allowing ACTEW to collect pre and post abstraction data.

1.1 Objectives

The overall objectives of the MEMP are to monitor physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs (details are given in Ecowise, 2009). The intention of the first season of sampling was to establish baseline macroinvertebrate data for key sites along the Murrumbidgee River and in doing so, establish a data base of the existing condition prior to any releases from Tantangara Reservoir. The baseline monitoring incorporates water quality monitoring (including nutrient analysis) macroinvertebrate monitoring based on the AUSRIVAS sampling and assessment framework

With these procedures in place, Ecowise will be able to provide ACTEW and the EPA with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this program will also support ACTEW's and the ACT Environmental Protection Authority's adaptive management approach to water abstraction and environmental flow provision in the ACT. Frequent assessments of the program will ensure that the monitoring program put in place has the capacity to adapt to changing environmental, social and economic conditions, with regard to ACTEW's operations and requirements.

1.2 Scope of works

The scope of this report is to convey the results from autumn 2009.

The works outlined in the original proposal to ACTEW Corporation (Ecowise, 2009) included the following:

- *Sampling to commence in spring 2008*
- *Macroinvertebrate sampling in triplicate in both, the riffle and edge habitats;*
- *Riffle and Edge samples to be collected as per the AUSRIVAS protocols;*
- *Macroinvertebrates to be enumerated to the taxonomic level of family*
- *Edge samples to be assessed through the appropriate AUSRIVAS model;*
- *In-situ water quality measurements to be collected and analysed;*
- *Nutrient analysis to be conducted in Ecowise's NATA accredited laboratory.*

Following further consultation between Ecowise and ACTEW Corporation, it was agreed that the Tantangara to Burrinjuck component was to be adjusted to include AUSRIVAS assessments in both the riffle and edge habitats, not just the edge as in the previous sampling run (Ecowise, 2008). The inclusion of the riffle habit in the RBA has meant the discontinuation of triplicate HESS sampling and coarser taxonomic resolution (family instead of genus). One of the recommendations made by Ecowise (2008) was to use the ACT AUSRIVAS model to in place of the NSW model used in he previous sampling run.

The amended scope of the MEMP for the Tantangara to Burrinjuck component includes the following:

- Sampling to continue in autumn 2009
- Macroinvertebrate sampling both the riffle and edge habitats;
- Macroinvertebrate samples to include one sample only;
- Riffle and Edge samples to be collected as per the ACT AUSRIVAS protocols;
- Macroinvertebrates to be identified to the taxonomic level of family;
- In-situ water quality measurements to be collected and analysed;
- Nutrient analysis to be conducted in Ecowise's NATA accredited laboratory.

2 Materials and method

2.1 Study sites

As stated in the objectives of this program, macroinvertebrate community composition and water quality is to be monitored from Tantangara reservoir to upstream of Burrinjuck reservoir along the Murrumbidgee River, with the aim of obtaining baseline ecological condition information following the ANZECC and ARMCANZ guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

The upper Murrumbidgee River is impacted by a range of land-use practices in its catchment. Consequently, it was important to sample 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 that captures any existing landuse impacts. Sites were chosen based on several criteria which included:

1. Accessibility –safe and with approvals from land owners;

2. Sites which 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 water abstractions;

3. Sites which have historical ecological data sets (Keen, 2001) took precedence over "new sites" – thus allowing comparisons through time to help assess natural variability through the system.

Potential sites were identified initially from topographic maps and then visited prior to sampling to assess suitability.

In total, 23 sites fulfilled the above criteria. These sites include ten sites upstream of Angle Crossing (NSW) and thirteen sites downstream. The sites include locations up and downstream of the major abstraction site at Angle Crossing and locations up and downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC) and several of the Murrumbidgee Rivers Major tributaries (Figure 1; Table 1). The sites were divided up into four macro-reaches (zones) which represent geographic or hydrological changes (Allan & Castillo, 2008) throughout the system; and obvious changes terms of in landuse, erosional processes and/or other potential anthropogenic impacts. These classifications are to some extent subjective, but are based on previous frameworks which have suggested methods for such classifications (e.g. Allan and Castillo, 2008; Frissell et al., 1986). Details are listed in Table 2.

Sites MUR 35 and MUR 36 have been discontinued since the spring 2008 sampling run. Poor access and insufficient habitat for macroinvertebrate sampling were the reasons for their removal from the program. Site MUR 37 was chosen to replace these sites. MUR 37 has good riffle and edge habitats and is situated approximately 5km upstream of Taemas Bridge and half way between the two original sites.

2.2 Sampling details

Sampling occurred in late October and early November, 2009. All sampling was carried out by AUSRIVAS accredited staff. The conditions during the period were predominantly fine with ambient temperatures ranging from 19-32°C.

Table 1. Sampling site location and details

Site Code	Location	Alt. (m)	Landuse	Habitat sampled
Mur 1	D/S Tantangara Reservoir	1200	Native	Edge
Mur 2	Yaouk Bridge	1070	Grazing	Riffle and Edge
Mur 3	Camp ground of Bobyon Road	968	Recreation / Grazing	Riffle and Edge
Mur 4	Bobeyan Road Bridge	968	Grazing	Riffle and Edge
Mur 6	D/S STP Pilot Creek Road	743	Native / Residential	Riffle and Edge
Mur 9	Murrells Crossing	723	Grazing	Riffle and Edge
Mur 12	Through Bredbo township	698	Grazing / Residential / Recreation	Riffle and Edge
Mur 15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	Riffle and Edge
Mur 16	The Willows - Near Michelago	646	Grazing / Recreation	Riffle and Edge
Mur 18	U/S Angle Crossing	608	Grazing	Riffle and Edge
Mur 19	D/S Angle Crossing	608	Grazing / Recreation	Riffle and Edge
Mur 22	Tharwa Bridge	572	Recreation / Grazing / Residential	Riffle and Edge
Mur 23	Point Hut Crossing	561	Recreation / Residential	Riffle and Edge
Mur 27	Kambah Pool	519	Recreation / Residential	Riffle and Edge
Mur 931	“Fairvale” ~4km U/S of the Cotter Confluence	480	Grazing	Riffle and Edge
Mur 28	U/S Cotter River confluence	468	Grazing	Riffle and Edge
Mur 935	Casuarina sands	471	Grazing	Riffle and Edge
Mur 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	460	Grazing / ex-forestry/ Recreation	Riffle and Edge
Mur 29	Uriarra Crossing	445	Grazing	Riffle and Edge
Mur 30	U/S Molonglo Confluence	445	Grazing	Riffle and Edge
Mur 31	D/S Molonglo Confluence	443	Grazing	Riffle and Edge
Mur 34	Halls Crossing	393	Grazing	Riffle and Edge
Mur 37	Boambolo Road	370	Grazing	Riffle and Edge

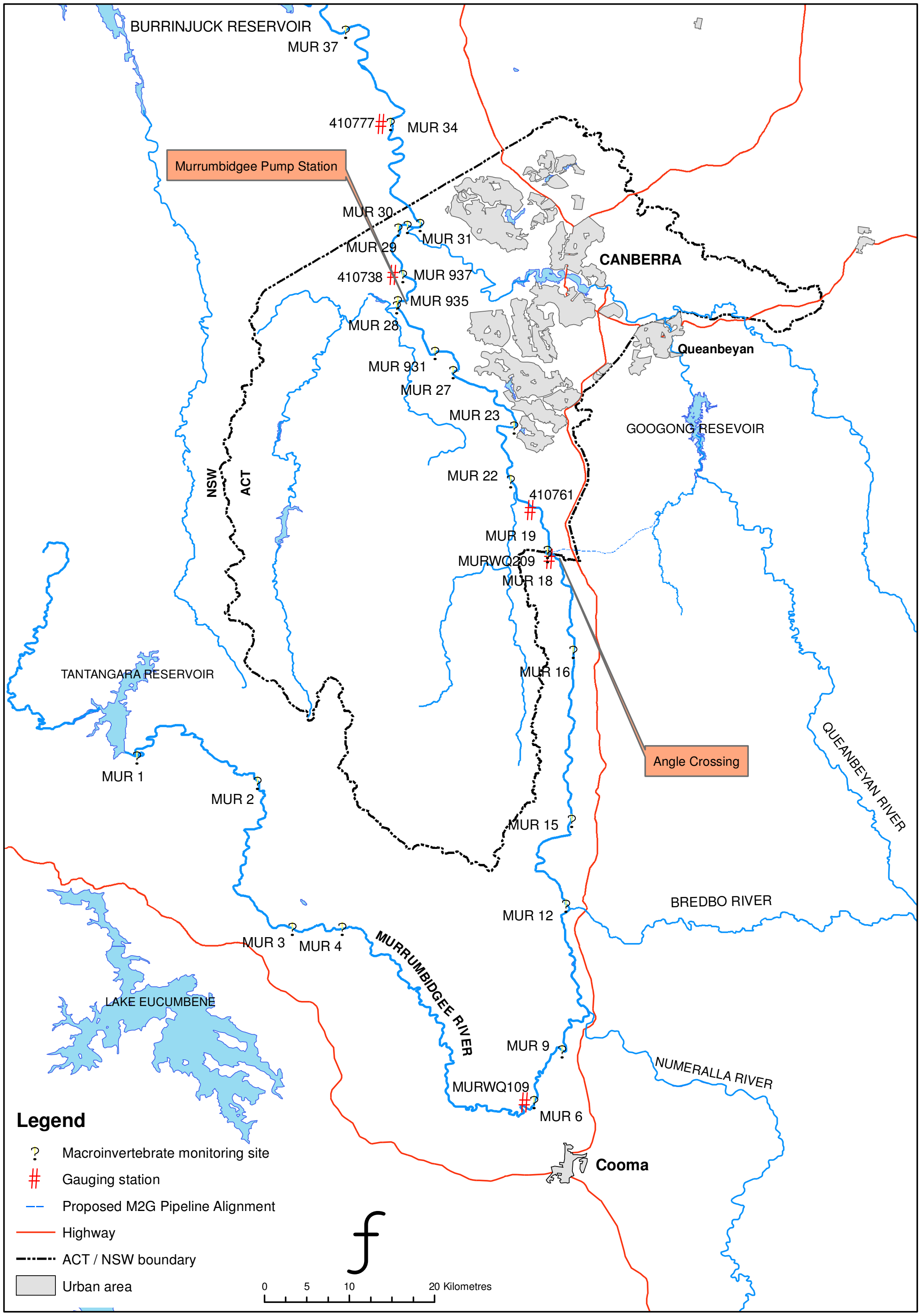


Figure 1. Location map of macroinvertebrate monitoring sites on the Murrumbidgee River

Table 2. Zone structure of sites along the Murrumbidgee River

Macro-reach	Zone	Sites included	Land use
Tantangara - Cooma	1	MUR 1 - 4	Native. Reservoir within national park. Recreation. Agricultural land downstream of Yaouk
Cooma – Angle Crossing	2	MUR 6 - 18	Agriculture dominant. Some urbanization. STP present upstream of MUR 6.
Angle Crossing - LMWQCC	3	MUR 19 - 30	Residential and residential / urban development increases. Less grazing than in the Tantangara – Cooma and LMWQCC – Taemas Bridge macro-reaches
LMWQCC – Taemas bridge	4	MUR 31 - 37	Intensive agricultural landuse. Downstream of LMWQCC. Previous work has shown a marked change in water quality downstream of the treatment plant

2.2.1 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at gauging stations operated and maintained by ECOWISE located at Lobb's Hole (downstream of Angle Crossing: 410761); Mount McDonald (downstream of the Cotter River Confluence: 410738) and Halls Crossing (located at MUR 34: 410777). Site locations and codes are given in table 3.

Stations are calibrated monthly and data is downloaded and verified before quality coding and storage in the database. Water level data is manually verified by comparing the logger value to staff gauge value and 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 3. River flow monitoring locations and parameters

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	410738	M'bidgee River @ Mt. McDonald	WL, Q	S 35.2917	E 148.9565
2	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
3	410777	M'bidgee River @ Hall's Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.13277	E 148.9425

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

2.2.2 Water quality

In-situ physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a multiprobe HYDROLAB® Minisonde 5 and Surveyor meter. The Minisonde and Surveyor unit were calibrated in accordance to QA procedures and the manufactures requirements prior to sampling.

From each site, grab samples were taken in accordance with the AUSRIVAS protocols (Coysh et al., 2000) 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.

2.2.3 Macroinvertebrate sampling

Each habitat was sampled and analysed in strict accordance with the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al*., 2000) during autumn 2009. At each site, one sample was taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm; (Coysh *et al.,* 2000) 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.. Sampling protocols for the edge follow those described above, except that samples were collected by sweeping the collection net along the edge habitat at the sampling site with the operator working systematically over a ten metre section and sampling where there was overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. The samples were then preserved in the field using 70% ethanol in clearly labelled vials showing site codes, habitat and date information. Samples were then stored on ice and then placed in a refrigeration unit until laboratory sorting commenced.

The purpose of this seasonal report is to convey the results from the macroinvertebrate and water quality sampling from Tantangara Reservoir to Burrinjuck Reservoir. Several sites within this report are key components of the three main sub-sections of the Murrumbidgee Ecological Monitoring Program (MEMP), including monitoring for the Murrumbidgee Pump Station (MPS) upgrade; and the impact assessment of the construction and operation of the Angle Crossing pump station and pipeline, which includes the eventual discharge into Burra Creek. The sampling regime for these sub-sections differs slightly to those report here, mainly because multiple replicates were taken. This means that a more comprehensive list of macroinvertebrate taxa is likely for thos sub-sections. For the purposes of keeping consistency in results for this component of the project, only the first sub-sample from the first replicate was analysed since only one sample was taken from the remaining sites outside of parts 1-3 of the MEMP. As such, it should be recognised that there are small discrepancies between the taxonomic inventories, taxonomic richness measurements and presence / absence of taxa reported here due to only a single sample per site being considered as part of the data analysis.

2.3 Sample processing

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 family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order) until 200 animals were identified (identification followed taxonomic keys published by Hawking (2000)). If 200 were identified before a cell had been completely analysed, identification continued until the animals within the entire cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer. QA/QC procedures for macroinvertebrate sample processing are described in Section 2.5.

Upon the completion of macroinvertebrate identification, the samples were transferred to a solution of 75% methanol and 5% glycerol for long-term achieving. This process allows samples to be re-examined at a later date if required (e.g. if the taxonomy changes significantly during the course of a long term monitoring program).

2.4 Data analysis

2.4.1 Water quality

Principal components analysis (PCA) - based on Euclidean distances - was used in to determine which physico –chemical variables were most associated with differences among sites. PCA is a multivariate analysis technique that is commonly used on environmental data as an exploratory technique. It compresses a set of variables – in this case water quality- into a smaller number of derived variables, called components. These components are linear combinations of the original variables that help explain as much of the variation in the data matrix as possible (Quinn & Keough, 2002); PCA summaries the data in a way which best explains the variance within the data set, so is similar to a multivariate extension of linear regression.

The output from the PCA includes a two or three dimensional plot similar to those produced by non-metric multidimensional scaling and a list of eigenvalues and eigenvectors. The eigenvalues represent the amount of the original variance explained by each new component and the eigenvectors are coefficients or weights that show how much each original variable contributes to each new, derived variable, or component.

Principal Component Analysis was performed in PRIMER version 6 (Clarke & Gorley, 2006) using normalized and log transformed (except pH) water quality variables collected in spring 2009. The analysis began with 14 variables; following initial inspections of the data, dissolved oxygen (mg/L), was removed from the analysis because they highly correlated with dissolved oxygen (% saturation). Total Nox, Nitrate, nitrite and ammonia records were removed from the analysis because most values were censored (their values were below detectable limits) and could not be reliably analysed in PRIMER.

Water quality parameters were also examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000).

2.4.2 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 which can not be influenced by 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).

The site assessments are based on the results from both the riffle and edge samples. The overall site assessment is 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.*, 2000).

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 expected less 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 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.

2.4.3 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.

2.4.4 Macroinvertebrate communities

The Macroinvertebrate data were examined separately for riffle and edge habitats. All multivariate analyses were performed using PRIMER version 6 (Clarke & Gorley, 2006). Univariate statistics were performed using R version 2.10.1 (R Development Core Team, 2009).

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 and facilitates its interpretation. It reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke & Warwick, 2001). The number of dimensions (axes) used in the NMDS procedure was based on the resultant stress levels. The stress level is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions and will increase as the number of dimensions is reduced and can be consider a measure of "goodness of fit" to the original data matrix (Kruskal, 1964).

The Similarity percentages (SIMPER) routine was carried out on the datasets following a significant ANOSIM test to examine which taxa were responsible for, and explained the most variation among statistically significant groupings (Clarke & Warwick, 2001). This analysis proceedure was also used to describe which taxa characterised each group of sites.

Several additional metrics to the AUSRIVAS and SIGNAL-2 were utilized. The number of taxa (taxa richness) was counted for each site and other descriptive metrics such as the relative abundances of sensitive taxa (e.g. Ephemeroptera, Plecoptera and Trichoptera or EPT) and, tolerant taxa, i.e. Oligochaeta and Chironomids were examined at the class and sub-family levels respectively. Differences in SIGNAL-2 scores and O/E 50 ratios were determined between Zones using separate one-way ANOVAs coding "Zone" and "Habitat" as fixed factors. Differences between groups were assessed using a modified version of Tukey's HSD (honestly significant differenced) test for factors with $k \geq 3$ levels with uneven sample sizes.

High taxonomic richness does not necessarily indicate better ecological condition at a given site. While in certain instances high scores can indicate favourable conditions, they can also indicate altered conditions, indicative of an ecologically impacted site. 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). Community turnover is a useful metric for assessing small scale changes in macroinvertebrate communities and can provide complimentary information to the AUSRIVAS output. For all analyses, alpha was set to 5%.

2.5 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 who had 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.
- Characteristics of geological and instream attributes were documented according to AUSRIVAS methods. These characteristics were cross-checked between sites with similar characteristics to ensure that habitat descriptions were consistent (some of the attributes involve percentage estimates, and are subjective by definition).

All procedures were performed by AUSRIVAS accredited staff.

2.6 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 AUSRIVAS accreditation.

Table 4. AUSRIVAS Band -widths and interpretations for the ACT spring edge and riffle models

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

3 Results

3.1 Hydrology and rainfall

Sampling in spring was conducted in late October/early November to correspond to the same sampling period in 2008. A week into the sampling program (Novemebr 2nd) a high flow event of around 1600ML/d occurred. As a result sampling was delayed until the 12th and 13th* of November when the river had subsided to safe, wadable levels. Sites MUR 6 & 9 and all sites within Zone 1 were not subjected to the annual high flow event in November as they are all upstream of the Numeralla confluence form where it originated.

At the time of sampling, the new gauging site upstream of Angle Crossing (MURWQ09) had only just been installed and calibrations and final checks were being conducted. Water quality, rainfall and hydrological data will be reported on in autumn 2010. Permission for the Pilot Creek road station (near Cooma) are still being sort from the Department of Water and Energy.

During spring, total rainfall ranged from ~100 mm at Cooma to 177 mm at Burrinjuck Reservoir (Australian Government Bureau of Meteorology, 2009) (Table 5). In the lower regions of the catchment the wettest month was September, with 85.8mm and 79.7mm falling at Hall's Crossing and Burrinjuck Reservoir respectively. Lobb's Hole, Cooma and Yaouk all recorded the highest rainfall in October.

At Lobb's Hole, 90.6 mm was recorded in October, and the lowest, 11mm in November. There were 38 wet days in spring (compared to 19 in autumn), with 16 days recorded in October, 13 in September and 9 in November. Total daily rainfall ranged from the detectable minimum of 0.2mm to 28mm. There were four days in which the daily total exceeded 15mm two days in late October and two days in September. The two events in October (28mm and 17.8mm) occurred within three days of each other and triggered a high flow event* affecting all sites downstream of Bredbo. A high flow event occurred on the 2nd of November, which peaked at Lobb's Hole at 1605 ML/d. Flows decreased to pre-spate levels with 24 hours and steadily declined to below 60 ML/d by the end of November. The high flow event passed Mt. MacDonald on the 3rd of November where it peaked at 1690 ML/d. The recession curve followed a similar pattern to Lobb's Hole with flows receding rapidly to pre-event conditions. Following this event, rainfall subsided with only a further 8mm falling in November

As a result of the increase in rainfall, the average flow during spring was 277 ML/d (approximately 15 times higher than the autumn average flow) (Figure 2; Table 5) at Lobb's Hole (410761), while average flows recorded at Mt. MacDonald (410738) for spring were 418 ML/d (Table 5). Flows recorded at Hall's Crossing averaged 30.9 ML/d over this three month period. Highest flows were received in early October with daily averages ranging between 442 and 757 ML/d in the first two weeks. The increasing flows in October corresponded to increased flows in the Molonglo River (at Sturt Island: 410741).

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

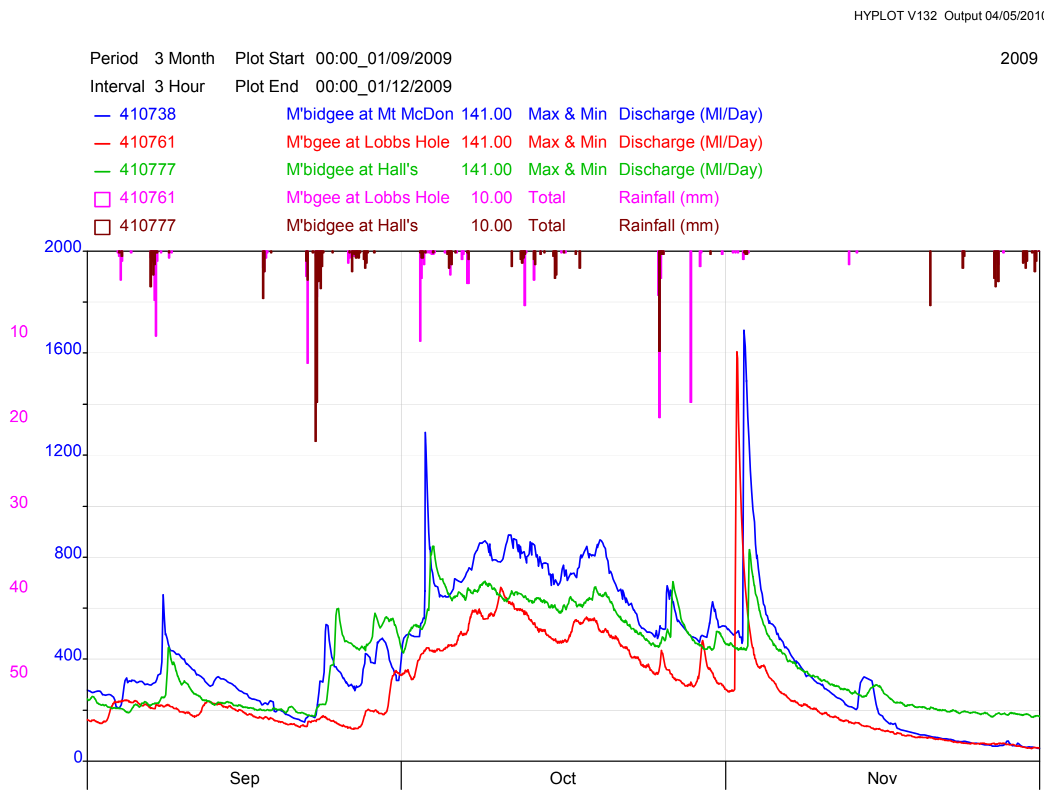


Figure 2. Spring hydrograph of the Murrumbidgee River at Lobb's Hole (red), Mount MacDonald (blue) and hall's Crossing (green). Total rainfall (mm) is shown in pink (Lobb's Hole) and brown for Halls Crossing.

Table 5. Average monthly flow and rainfall statistics for spring 2009 at Lobb's Hole (410761) and mount MacDonald (410738).

Flow values are medians (ML/Day). Rainfall values are totals (mm).

SITE (CODE) * Ecowise site # Bureau of meteorology site	September Average flow (ML/d)	October Average flow (ML/d)	November Average flow (ML/d)	Rainfall (mm) (spring total)
*Lobb's Hole (410761)	189.8	459.5	184.3	164.4
*Mt. MacDonald (410738)	307.9	682.1	265.9	Na
*Hall's Crossing † (410777)	290.3	589.3	293.2	175.4
#Yaouk (071040)	-	-	-	167.9
#Cooma (070278)	-	-	-	109.2
#Burrinjuck Reservoir (073007)	-	-	-	177.1

† The gauging station at Hall's Crossing (410777) appears to be underestimating flow during low flow conditions. The rating table for this site is currently being reviewed.

3.2 Water quality

Water quality results are summarised in **Table 6** (grab samples) and **Figures 4 & 5** (continuous records).

3.2.1 Grab samples

The water quality results from the grab samples show that many of the sites sampled are outside the recommended ANZECC and ARMCANZ guideline values for healthy ecosystems. Some of the parameters outside of the guidelines, such as Total Nitrogen (TN) and Total Phosphorus (TP) have been exceeded in previous sampling runs (Ecowise, 2008 and 2009). Electrical conductivity and turbidity have also been found to be below the recommended lower limits on both prior sampling runs in the upper reaches between the Tantangara dam wall and Yaouk.

Turbidity values in the upper reaches, were within guideline levels (despite MUR 1 and 2 only being 0.3 and 0.2 ntu under the lower limits respectively) (Table 6). Turbidity exceeded the upper limit of 25 NTU from Bredbo (MUR 12) downstream to MUR 37. All sites downstream of the Numeralla confluence were affected by the November high flow event, which originated in the Numeralla catchment near Chakola. Turbidity was highest at MUR 15 and 16 because these two sites were the first to be sampled following the high flow event. The gradual decline in NTU downstream of these sites occurs as a function of time since the event.

The strong electrical conductivity (EC) gradient evident in previous seasons was less apparent during this sampling round (Table 6). This is reflected in the comparatively low EC coefficient determined by the principal components analysis (**APPENDIX B**). Although the EC gradient was to some extent, masked by increased water volumes, there was still an obvious increase in EC downstream of the Molonglo River confluence and lower values in Zone 1, extending to MUR 6 and 9 in Zone 2. EC increases in Zone 2 downstream of Bredbo and remains almost identical through Zones 2 and 3 to MUR 30 (upstream of the LMWQCC).

There was a strong longitudinal gradient in TN and TP. There was some evidence to show the nitrogen oxides followed a similar pattern, but for the most part, nitrogen oxide levels were below detectable limits. TN steadily increased downstream of MUR 2 (Yaouk) and was outside of the recommended guidelines ant 93% of the sites sampled. TN reached ten times the recommend upper limit at MUR 31 (downstream of the LMWQCC). TP also exceeded guideline values at most of the sites (82%) sampled, except those in Zone 1. The upper sites have, until now, remained within the guidelines. The results of this sampling run indicate that agricultural runoff in this reach as a result of heavy and constant rainfall over the spring period mobilised phosphorus –based nutrients to the waterway.

The results from the Principal Components Analysis (PCA) show that the first component accounts for 51.5% of the variability in the water quality data set and the second principal component accounts for a further 25.4 %. The PCA-1 is an axis representing increasing nutrients (from right to left) (as TN,TP and Total Nox); whereas PCA-2 is an axis representing increasing turbidity and pH (Figure 3). The nutrient gradient begins upstream in Zone 1 with low concentrations of TP, TN and Total Nox progressively increasing to MUR 23, at which point TN becomes more influence at separating sites with Zone 4 from the others. Along the PC-2 axis, higher turbidity readings at MUR 15 and 16 separate these sites from the remaining sites; while MUR 31, 34 and 37 appear in the top left hand side of the plot firstly along the nutrient gradient (PC 1) and then as pH increases along PC 2 (the turbidity and pH gradient).

3.2.2 Continuous water quality

There were two factors resulting in missing or unreliable data points within the continuous water

Continuous water quality data are reported here from the stations 410761 (Lobb's Hole; Figure 4) and 410777 (hall's Crossing; Figure 5).

As mentioned in section 3.1, data from MUR WQ 09 are not available at this stage, but will be for the next round of sampling.

The continuous water quality data obtained from Lobb's Hole for the period 1/09/09-30/11/09 are presented in Figure 3. Hall's Crossing.

The four week gap in the pH data series is due to a lightening strike in late September. Electrical conductivity and turbidity were the most variable parameters throughout spring resulting from fluctuating flows and rainfall.

Turbidity exceeded the ANZECC and ARMCANZ (2000) guidelines (based on daily means) for 40 % of the spring monitoring period. Early September was only marginally over the 25 NTU upper limits for healthy ecosystems, with daily means reaching a maximum of 45 NTU, later in the month NTU recordings ranged form 1.8-3.3 NTU. These low values continued for most of October, but with the arrival of heavier rainfalls in the catchment, turbidity spiked to a daily mean of 1463 NTU and remained over the guideline limits, fluctuating between 26 -1660 NTU until mid-December, when the weather stabilised.

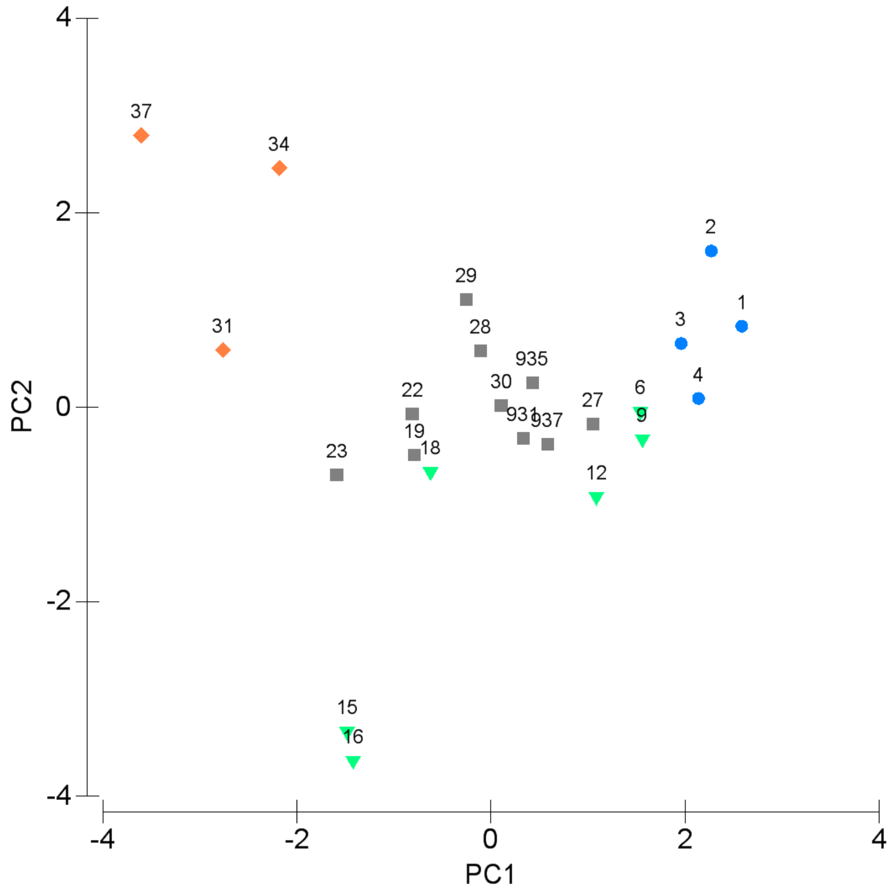
Temperature and electrical conductivity fluctuated with river flow (Figure 3). Water temperature increased with increasing ambient temperate and increased steadily over the coarse of spring from September (mean = 13.5 ^{o}C) to November (mean= 22.4^{o}C). EC was lowest during periods of high flow (Figure 3) but increased following the high flow event in early November from ~45 µs/cm in October to a monthly average of 91 µs/cm in November with daily means peaking at 104 µs/cm. There was very little variation in the pH levels taken from Lobb's Hole. Monthly means ranged from 7.7-7.9

quality records from Hall's Crossing. The storm that caused lighting damage the pH sensor at Lobb's Hole also damaged the multi probe at Hall's Crossing in late September (Figure 5), but unlike the Lobb's Hole data, there has been a unforeseen delay in repairing the pH sensor it. For this reason, pH data are not reported for this site. The second factor was the high flow event in early November, which increased bedload deposition around the Hall's Crossing sensor, blocking the turbidity sensor and causing dissolved oxygen to plummet (indicated by the arrows in Figure 5).

Outside of these issues, the water quality at this site followed the same general trend as Lobb's Hole and remained within the guidelines for the majority of spring. Electrical conductivity remained within the guideline limits 100% of the time (based on daily averages); and tended to increase towards the end of spring as flows decreased - meaning the influence of the Molonglo River inflows became more important. Temperature, like Lobb's Hole increased with time as ambient temperature increased and again, as flows decreased.

Diurnal variation in dissolved oxygen increased in magnitude as river flows decreased, which would have been a response to the interaction between low flows, increased temperatures and increased algal growth. Daily maximums exceeded the upper limits of the guidelines <1% of spring.

Figure 3. Correlation based Principal Components Analysis on water quality data collected in spring



2009.

The prefix "MUR" has been removed from the site labels for clarity however the numbers still refer to the site codes described in tables 1 and 2. (● = zone 1; ▼= zone 2; ■ = zone 3; ♦ = zone 4)

Table 6. In-situ water quality results from spring.. ANZECC & ARMCANZ guidelines are in bold parentheses. Values outside recommended guideline levels are highlighted yellow.

ZONE	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)	Total Phosphorus (mg/L) **(0.02)**	Total Nitrogen (mg/L) **(0.25)**
Tantangara - Cooma	**MUR 1**	14.20	18.6	9.3	1.7	7.3	102	8.9	14.7	<0.01	<0.01	<0.01	0.01	0.09
	MUR 2	12.40	17.5	7.8	1.8	7.9	100.4	8.9	13.6	<0.01	<0.01	<0.01	0.01	0.14
	MUR 3	10.30	18.8	9.3	5.6	7.4	98.8	8.6	15	<0.01	<0.01	<0.01	0.02	0.26
	MUR 4	08.30	16.3	10	9.5	7.3	86.5	7.9	16.6	<0.01	<0.01	<0.01	0.02	0.28
Cooma – Angle Crossing	**MUR 6**	08.30	20.3	12.8	11	7.2	88.6	7.45	17.6	<0.01	<0.01	<0.01	0.03	0.42
	MUR 9	10.50	20.7	13.3	13.9	7.01	89.7	7.5	18.8	<0.01	<0.01	<0.01	0.03	0.42
	MUR 12	12.00	20.9	24.6	58	6.9	80.6	6.7	30.8	0.05	0.04	0.01	0.04	0.46
	MUR 15	09.00	20.1	23.5	200	7.08	88.9	7.3	35	0.19	0.17	0.02	0.18	1.4
	MUR 16	13.05	21.6	31.1	220	6.8	95.3	7.8	28.7	0.31	0.05	0.05	0.19	1.1
	MUR 18	08.00	22.1	23.4	87	7.4	93.5	87	30.1	0.10	0.10	<0.01	0.14	0.78
Angle Crossing – LMWQCC	**MUR 19**	10.00	23.1	23.4	87	7.4	100.5	8.02	30.6	0.10	0.10	<0.01	0.15	0.73
	MUR 22	11.30	23	25.4	120	7.5	103.4	8.25	31.8	0.22	0.21	0.01	0.11	0.90
	MUR 23	12.05	24.7	27.1	130	7.3	105.3	8.15	33.3	0.20	0.18	0.02	0.18	1.00
	MUR 27	14.45	18.8	28.3	55	7.3	100.03	8.83	27.1	<0.01	<0.01	<0.01	0.05	0.49
	MUR931	07.00	21.3	22	54	7.4	92.4	7.6	28.2	<0.01	<0.01	<0.01	0.08	0.62
	MUR 28	14.00	24.7	19.1	60	7.7	107.4	8.3	26	<0.01	<0.01	<0.01	0.07	0.57
	MUR935	10.05	22.5	22.5	36	7.4	105.5	8.5	26	<0.01	<0.01	<0.01	0.07	0.57
	MUR937	06.00	22.8	22.3	41	7.2	90	7.3	33.2	<0.01	<0.01	<0.01	0.06	0.54
	MUR 29	14.30	26.4	20.9	37	7.8	113.2	8.5	27.8	<0.01	<0.01	<0.01	0.07	0.53
	MUR 30	09.00	23	20.6	46	7.5	96.4	7.7	40.8	<0.01	<0.01	<0.01	0.08	0.63

Table 6 (cntd.): In-situ water quality results for autumn 2009. ANZECC & ARMCANZ guidelines are in bold parentheses. Values outside recommended guideline levels are highlighted yellow.

ZONE	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)	Total Phosphorus (mg/L) **(0.02)**	Total Nitrogen (mg/L) **(0.25)**
LMWQCC – Taemas Bridge	**MUR 31**	10.35	19.5	44.6	54	7.5	101.4	8.7	37.5	1.5	14	0.12	0.1	2.6
	MUR 34	09.30	22.8	53.8	43	8.2	108.4	8.7	41.2	2.3	2.2	0.1	0.11	0.34
	MUR 37	11.30	25.6	50.2	43	8.8	130.5	9.95	40.9	0.95	0.85	0.10	0.13	2.2

Figure 4. Continuous water quality results for spring 2009 (Lobb's Hole: 410761)

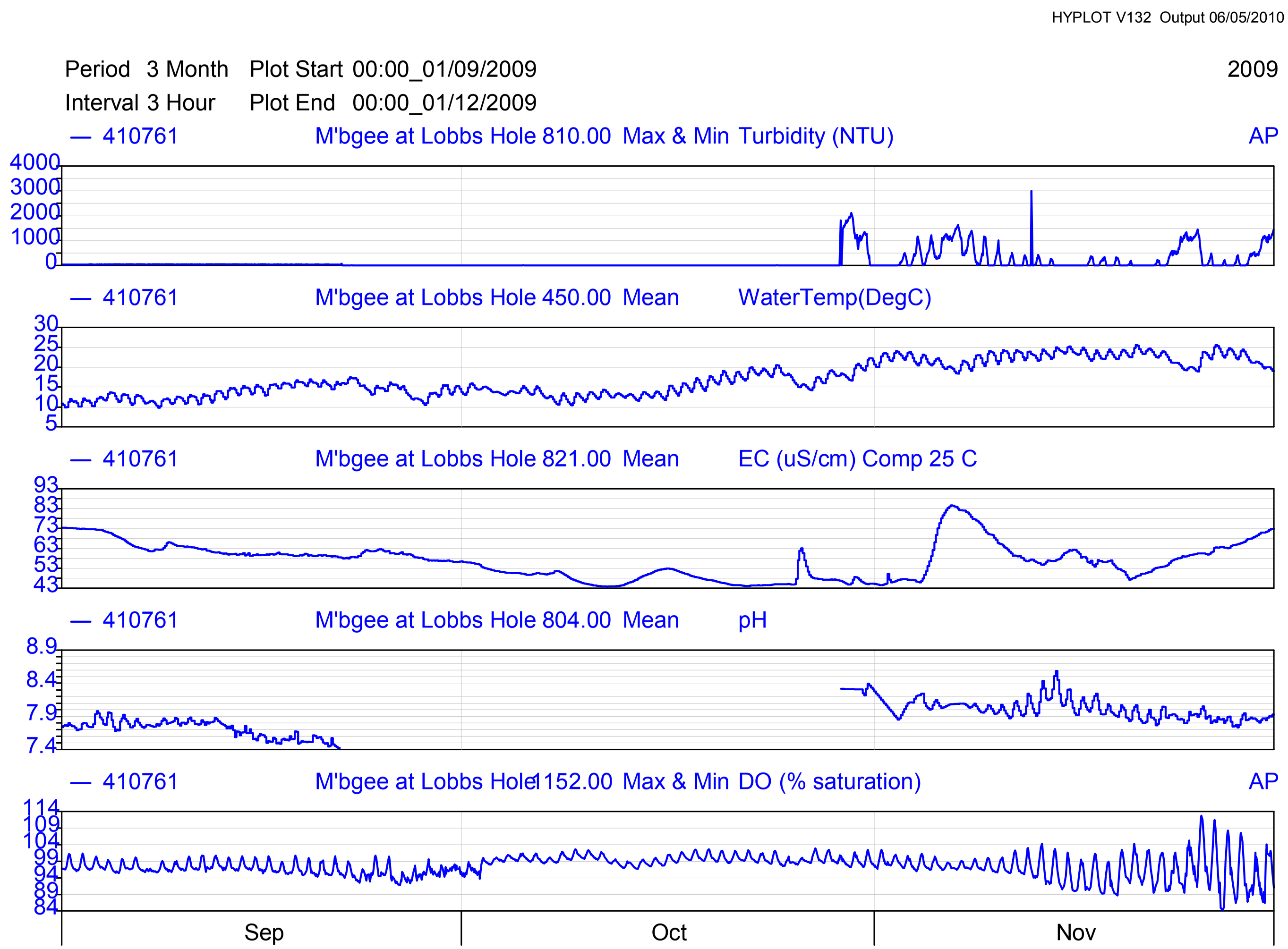
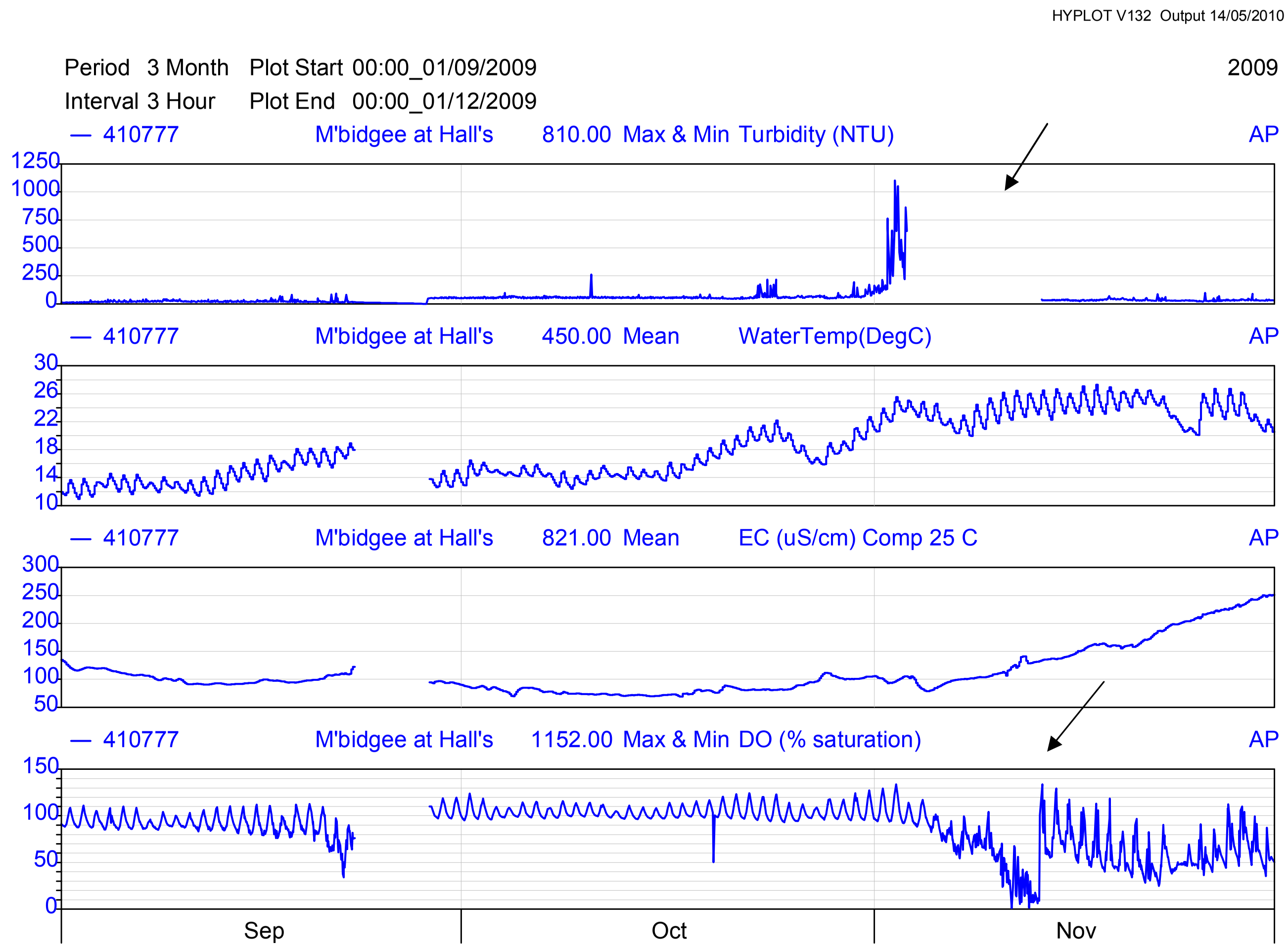


Figure 5. Continuous water quality results for spring 2009 (Hall's Crossing: 410777).Note the different limits on the y-axis to the Lobb's hole plots.



3.3 Macroinvertebrate communities

Macroinvertebrate assemblages varied significantly between zones based on both riffle habitat (Global R = 0.326; P= 0.04) and edge habitat (Global R = 0.465; P= 0.01) sample data. Pair-wise comparisons (Table 7) show that while riffle samples from Zones 3 & 4 were not significantly different from each other, all other pair-wise comparisons were. All comparisons between Zones were significantly different based on the edge sample data (Table 8).

Despite the probability values being smaller than the assigned significance level (alpha) of 0.05, the cluster analysis and NMDS plots show that the Zones are not forming distinct groups, which is further reflected in the low Global R values, particularly for the riffle samples. The NMDS of the riffle samples (Figure 7) shows that sites MUR 2, 3 and 4 are separated from all other samples are more similar to one another than samples from other sites or zones. MUR 6 & 9 also group together and almost forma gradient of change from sites in Zone 1. Sites MUR 6 & 9 and all sites within Zone 1 were not subjected to the annual high flow event in November as they are all upstream of the Numeralla confluence form where it originated.

The sites closest to downstream of the confluence (MUR 12 and 15) are grouped together with the remaining sites contained in one large group and several outlying sites. The outlying sites in this analysis, namely MUR 37, 27 and the MUR 23 & 34 group differed from other sites in terms of the relative abundance of several taxa. For instance, MUR 37 contained large numbers of Orthocladiinae (Chironomidae) and Baetids (Ephemeroptera), largely absent or in very low numbers at most sites downstream of the Numeralla confluence reappear at this site. Very high abundances of Hydropsychidae (Trichoptera) at MUR 23 and 34 combined with equally high abundances of Caenidae (Ephemeroptera) appear to have contributed to the high similarity percentage between these sites, while MUR 27 contains very few mayfly taxa and is dominated by Simulids and Chironomid (non-biting midges) and Oligochaetes (segmented worms). Even though the stress value is relatively high in the NMDS plot, the groupings are still apparent in the cluster analysis dendrogram (Figure 6).

The edge samples from two sites within Zone 1 displayed a similar pattern to the riffle samples in that they were strongly separated from the remaining sites. However, MUR 3 and MUR 4 formed a group with MUR 9, which was determined to be more similar to sites within zones 2 and 3 than to MUR 1 and 2. Sites tended to be on their own in ordination space in this sampling round, with 9 of the 23 sites being at least 40% dissimilar to all others in the ordination analysis. MUR 37, MUR 16 and MUR 19 in particular show no apparent relationship to any of the other sites. In the case of MUR 31 (downstream of the Molonglo River confluence) the edge sample was taxonomically poor, being devoid of animals using common in the edge habitat, including Corixidae, and all Trichoptera and all Ephemeroptera. These taxa were also poorly represented at MUR 16 and MUR 19, but not absent as they were at MUR 31.

Taxa characterising zone 1 were typically highly sensitive taxa that either disappeared downstream of Zone 1 or were in far fewer numbers. These taxa are summarised in Table 9 (riffle samples) and Table 10 (edge samples). The point to note is that there is a gradual replacement of dominant taxa between zones and a gradual decline in the abundances and richness of the sensitive (EPT and high SIGNAL scoring taxa) especially downstream of MUR 12.

The total number of macroinvertebrates from the riffle samples, ranged from 469 at MUR 931 (Fairvale) to ~ 7000 at MUR 27 (Kambah Pool). These estimates were lower than the riffle abundances recorded in autumn at 82% of the sites sampled; but increased or remained approximately the same in ~78% of the edge samples. For the riffle samples, this was particularly evident at MUR 937, where there was a five–fold decrease in estimated invertebrate abundance since autumn (declining form ~25000 individuals to less than 5000). Riffle samples taken from MUR 23 (Point Hut Crossing) had the only sizable increase in abundance since autumn, showing nearly a 70 % increase (from 1780 to 5600 individuals), while other sites including MUR 4and MUR showed 9% and 13 % increases respectively.

There was also considerable variation in the number of individuals in each edge sample; ranging from 702 at MUR 16 to >5000 individuals downstream of the Bredbo River confluence at MUR 12 (Zone 2). There were up to 7-fold increases in the estimated number of individuals at 65% (15/23) of the sites sampled in spring.

The number of families from the riffle samples ranged from 12 at sites MUR 27, MUR 30 and MUR 31 to 22 at MUR 23 (Figure 10). Overall all there was a 32 % decline in taxa richness (family level) since autumn in the riffle samples and a 35% decrease in the number of families recovered from the edge samples. In zone 1, there was a net gain in the number of taxa recorded since autumn, however downstream of the Numeralla and Bredbo confluences at MUR 12 through to MUR 22 (Point hut Crossing) there were between 4 and 16 fewer families than there were in the previous sampling run. There was an increase in taxa richness immediately downstream of the LMWQCC at MUR 31 and a further decline at sites MUR 34 and 37.

Across all of the riffle samples, the relative abundance of sensitive taxa (EPT) decreased by an average of 30%. The largest decreases since autumn were seen at MUR 19 (Angle Crossing: 58%) and MUR 22 (Tharwa Bridge: 50%) (Figure 11). The relative abundance analysis shows a decline in sensitive taxa (EPT) across 21 of the 23 sites sampled in spring.

Sensitive taxa (EPT) were in greater relative abundance in zone 1 (in particular at MUR 3 (37%)), and in Zone 4, with the highest being at MUR 31 (35%). However, downstream of the Molonglo confluence (Zone 4) there was an increase in the caddis fly family, Hydropsychidae, which has a moderate SIGNAL score of 6 and is considered to be mildly tolerant to pollution. On the other hand, the EPT taxa in Zone 1 were more diverse and were made up of highly sensitive taxa including: Leptophlebiidae and Coloburiscidae (Ephemeroptera) and Gripopterygidae (Plecoptera) – all with SIGNAL scores of 8. The point here is that although the group EPT is often used to approximate water and/ or habitat quality, there are taxa within this group that are resistant to certain stressors which can be misleading if not interpreted properly. In this case, the trend across these sites, in reference to Figure 11 can be summarised as follows: In Zone 1, highly sensitive taxa are common and diverse, although dipterans and lower SIGNAL-2 scoring mayflies dominate the samples numerically. Downstream through Zones 2 and 3 EPT taxa are sparse and are replaced by very high abundances of worms and Chironomids and Simulids (black fly larvae); the EPT richness decreases from an average of 9 (families) in zone 1 to 5 and 6 in Zones 2 and 3 respectively. In Zone 4, while the relative abundance of EPT taxa was high due to a sharp increase in the abundance of one Trichopteran family – Hydropsychidae; family richness in the EPT group was low, with an average of 4 EPT taxa across all sites in Zone 4.

Table 7. Pair-wise comparisons from the ANOSIM of the riffle samples

Zone	R-statistic	P-value
1,2	0.63	0.01*
1,3	0.71	0.003*
1,4	1	10†*
2,3	0.06	0.26
2,4	0.53	0.02*
3,4	0.03	0.42

Table 8. Pair-wise comparisons from the ANOSIM of the edge samples

Zone	R-statistic	P-value
1,2	0.52	0.037*
1,3	0.78	0.03*
1,4	0.43	0.05*
2,3	0.21	0.04*
2,4	0.52	0.01*
3,4	0.42	0.02*

†The small number of replicates is reflected in the relatively large p-value; more replicates allows for a more sensitive test in PRIMER because the p-value is generated through re-sampling and as such is directly related to

*significantly different at the σ= 0.05 level

the number of distinct permutations. In this case ten. Therefore the p-value can never be more than 1 in 10, or 10%.

Table 9. Discriminating taxa between zones based on the SIMPER analysis of riffle samples

Comparison	Discriminating taxa	SIGNAL-2	Comments
Zone 1 and 2	Gomphidae	5	Absent in zone 2
	Elmidae	7	Absent MUR 12,15,16 and 18
	Coloburiscidae	8	5 individuals only in Zone 2, collected at MUR 9
	Baetidae	5	Ten-fold decline in abundance from Bredbo downstream
	Gripopterygidae	8	decline in abundance from Bredbo downstream
Zone 1 and 3	Coloburiscidae	8	Absent in zone 3
	Gripopterygidae	8	Limited to 5-20 individuals in zone 3
	Elmidae	7	Reappearance at MUR 19, but <20 individuals at MUR 19,22,23,28 and 931
	Baetidae	5	Present in zone 3, but very few in number
	Gomphidae	5	Absent in zone 3
Zone 1 and 4	Tanypodinae	4	Absent in zone 4
	Gripopterygidae	8	Absent in zone 4
	Ecnomidae	4	Highly abundant in zone 4
	Gomphidae	5	Absent in zone 4
	Simuliidae	5	Highly abundant in zone 4
	Coloburiscidae	8	Absent in zone 4
	Hydropsychidae	6	Highly abundant in zone 4
Zone 2 and 3	Simuliidae	5	Sharp increase in abundance in zone 3
	Hydropsychidae	6	Sharp increase in abundance in zone 3
	Gripopterygidae	8	Abundant near Cooma. Disappears downstream of Bredbo, but re-emerges (in low umbers) near Point Hut Crossing
Zone 2 and 4	Hydropsychidae	6	Increased abundance in zone 4
	Oligochaeta	2	Increased abundance in zone 4
	Elmidae	7	Absent in zone 4
	Ecnomidae	4	Increases in zone 4

Table 10. Discriminating taxa between zones based on SIMPER analysis of edge samples

Comparison	Discriminating taxa	SIGNAL-2	Comments
Zone 1 and 2	Hydroptilidae	4	More common and abundant in zone 2
	Tanypodinae	4	50% decline in abundance in zone 2. Missing from MUR 16 & 18
	Baetidae	5	Absent from most sites in zone 2. Only a few individuals collected from MUR 6 & 9
	Leptoceridae	6	Ten fold decrease in zone 2
Zone 1 and 3	Gripopterygidae	8	Four fold decline in zone 3
	Corixidae	2	Increased abundance in zone 3
	Tanypodinae	4	Five fold decline in abundance in zone 3. Absent at 40% of sites
	Coloburiscidae	8	Absent from zone 3
	Baetidae	5	Ten fold decline in abundance and absent from 80% of sites
	Oligochaeta	2	Increased abundance in zone 3
Zone 1 and 4	Gripopterygidae	8	Absent in zone 4
	Tanypodinae	4	Absent in zone 4
	Physidae	2	Highly abundant in zone 4
	Conoesucidae	7	Absent in zone 4
	Leptophlebiidae	8	Absent in zone 4
	Baetidae	5	Very few individuals in zone 4
Zone 2 and 3	Oligochaeta	2	Increased abundance in zone 3
	Simuliidae	5	Increased abundance in zone 3
	Physidae	2	Increased abundance in zone 3
Zone 2 and 4	Physidae	2	Highly abundant in zone 4
	Hydroptilidae	4	Only collected at one site in zone 4
	Corixidae	2	Sharp decline in abundance in zone 4. Missing from MUR 31
	Simuliidae	5	Increased abundance in zone 4
	Tanypodinae	4	Absent in zone 4
Zone 3 and 4	Corixidae	2	Sharp decline in abundance in zone 4. Missing from MUR 31
	Caenidae	4	Decline in zone 4: collected at one site (n= 10)

3.3 AUSRIVAS assessment

The results from the AUSRIVAS assessment in spring 2009 show that of the 23 sites sampled in this program, 5 sites (22%) were classified as BAND A (similar to reference); 16 (69%) were determined to be BAND B, one site was BAND C (MUR 27) and MUR 31 had no reliable assessment due to large discrepancies between the BANDS assigned to each habitat (Table 11; Figures 12 & 13). BAND A sites were MUR 3 & MUR 4 (Zone 1), MUR 6 & 9 (Zone 2) and MUR 22 (Zone 3).

No reliable assessment was given to MUR 31 due to major discrepancies between the riffle assessment of BAND B and the edge assessment of BAND D. The assessment of BAND D was the lowest given to any site under the MEMP to date. The edge at MUR 31 was taxonomically poor. Only 8 families were recovered from the sample which consisted of relatively high abundances of very tolerant taxa including: Gastropods, Chironomids (particularly Orthocladiinae) and Muscidae (SIGNAL = 1). Most taxa predicted to occur, were missing including other tolerant taxa such as Corixidae (SIGNAL = 2).

The overall site assessments were based on the lower of the two BANDS taken from each habitat. Most of the sites had agreement in their AUSRIVAS assessments between habitats, but there were exceptions. Discrepancies between habitat assessments were encountered at five sites (discounting MUR 1, where only the edge habitat was sampled). Taxa predicted to occur from the ACT spring AUSRIVAS model with ≥50% probability, but absent from each habitat and site are presented in **APPENDIX D**. From the edge these taxa included: Elmidae (SIGNAL = 7), Leptophlebiidae (SIGNAL =8), Gripopterygidae (SIGNAL =8) and Hydrobiosidae (SIGNAL =8, which have high SIGNAL -2 sensitivity scores; and the tolerant taxa which included Amphipoda, Caenidae and Corixidae. Taxa missing from the riffle samples included the sensitive taxa such as: Elmidae, Leptophlebiidae, Conoesucidae, Glossosomatidae and Hydrobiosidae, but also included taxa with lower SIGNAL-2 scores such as: Oligochaeta, Baetidae and Ceratopogonidae.

The highest riffle SIGNAL-2 score was recorded at Yaouk (MUR 2 = 5.58) while the lowest was at MUR 30 (4.29) (Table 7). In the edge habitat the lowest SIGNAL-2 score was at MUR 31 (3), corresponding to the BAND D assessment by the AUSRIVAS model. The highest score was downstream of Tantangara Reservoir at MUR 1 (5.09). On average, the observed SIGNAL-2 scores were significantly different between Zones ($F_{3,40}$= 6.92; P<0.001; Table 12). Post Hoc tests, indicate that Zone 1 had higher SIGNAL -2 scores compared to all other Zones (P<0.01 in all cases; Table 14); however the SIGNAL -2 scores for Zones 2-4 did not differ from each other (Tukey's HSD: P>0.1 in all cases; Table 14). SIGNAL -2 scores were higher in the riffle habitat compared to the edge ($F_{1,40}$= 74.5, P<0.0001); but there was no difference in the family O/E scores between habitats (Table 13), suggesting that most of the tolerant taxa expected to occur generally had higher sensitivity scores in the riffle habitat. Post hoc tests conclude that there O/E Family scores differed between Zone1 and Zones 2-3, but there were no pair-wise differences between Zones 2-3 (Table 15), which is consistent with trends for the Signal – 2 score analysis results (Table 14).

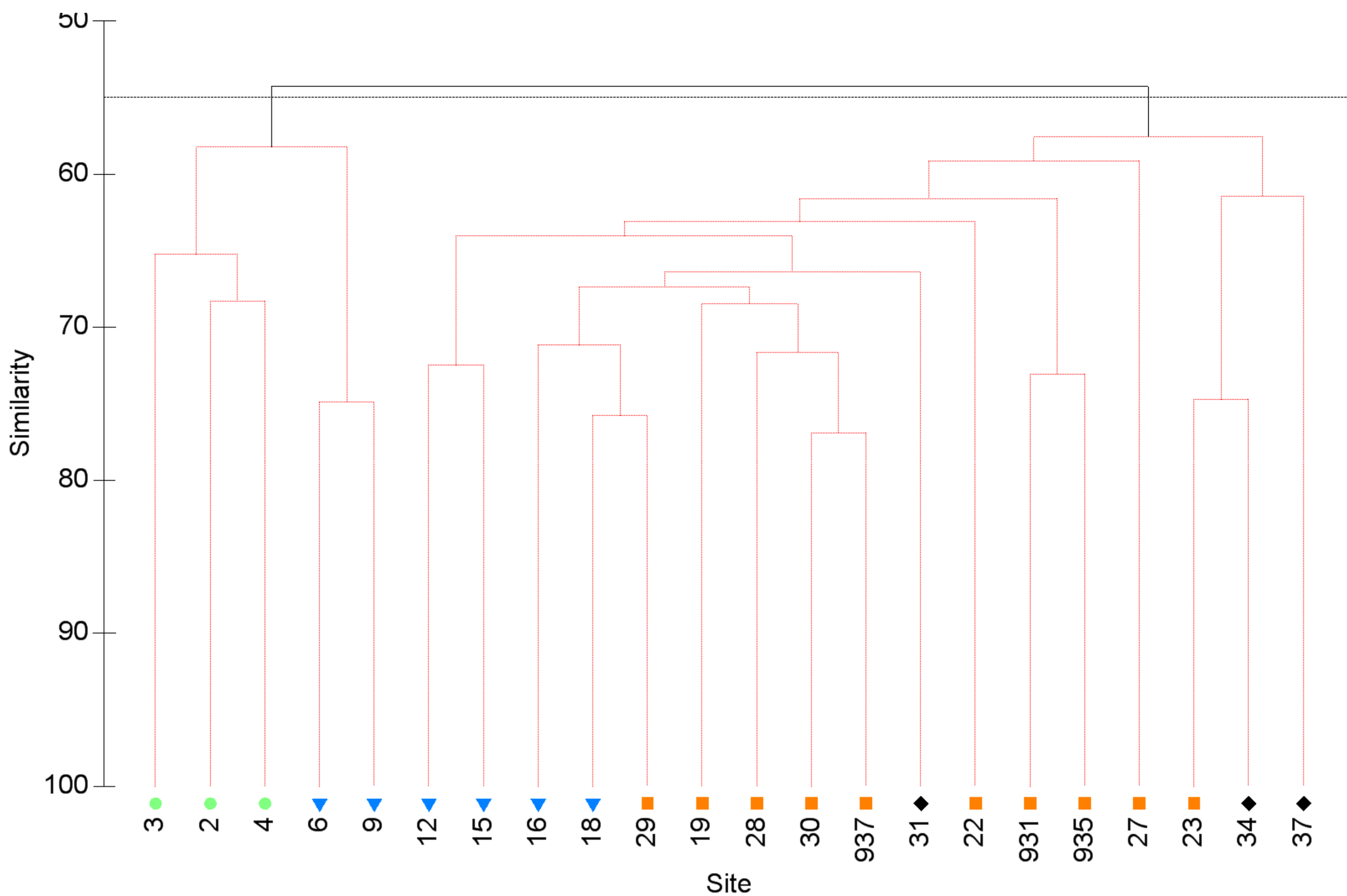


Figure 6. Cluster analysis of family level data for the spring riffle samples

● = Zone 1; ▼ = Zone 2; ■ = Zone 3; ◆ = Zone 4

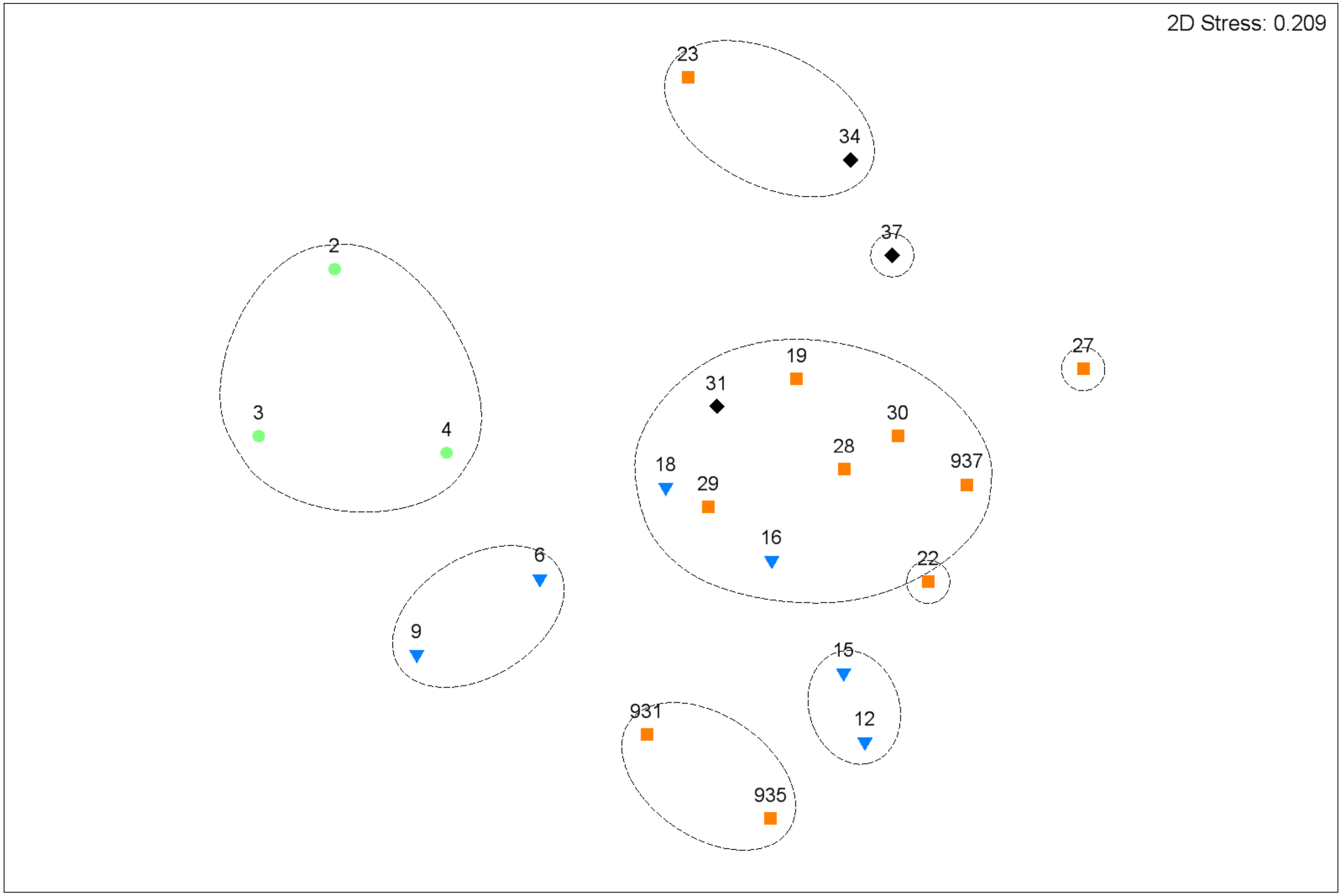


Figure 7. Non-metric multidimensional scaling of family level data for the spring riffle samples

Ellipses represent the 65% similarity groupings superimposed from the cluster analysis. ● = Zone 1; ▼ = Zone 2; ■ = Zone 3; ◆ = Zone 4

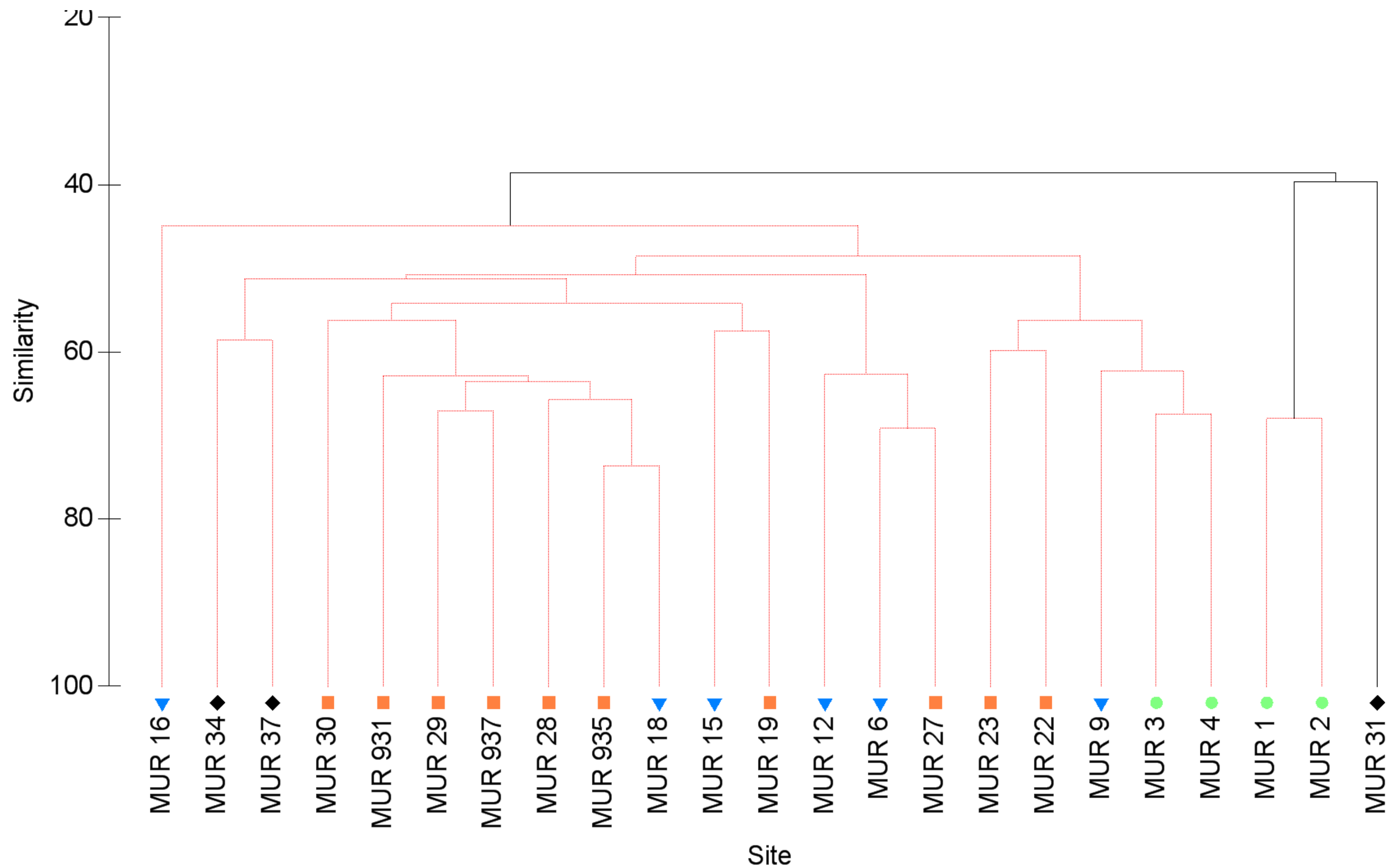


Figure 8. Cluster analysis of family level data for the spring edge samples

●= Zone 1; ▼= Zone 2; ■= Zone 3; ◆= Zone 4

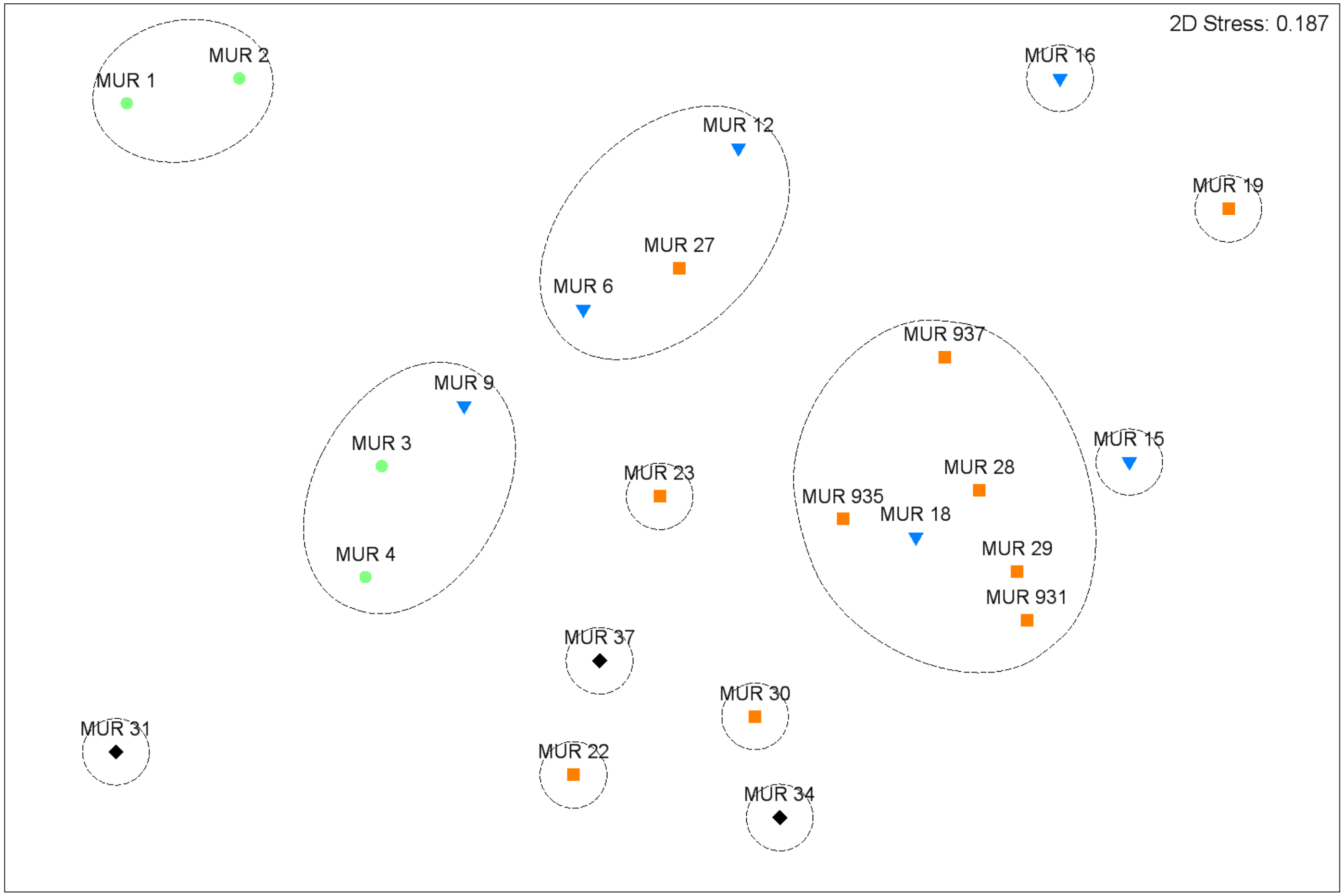


Figure 9. Non-metric multidimensional scaling of family level data for the spring edge samples

Ellipses represent the 65% similarity groupings superimposed from the cluster analysis. ●= Zone 1; ▼= Zone 2; ■= Zone 3; ◆= Zone 4

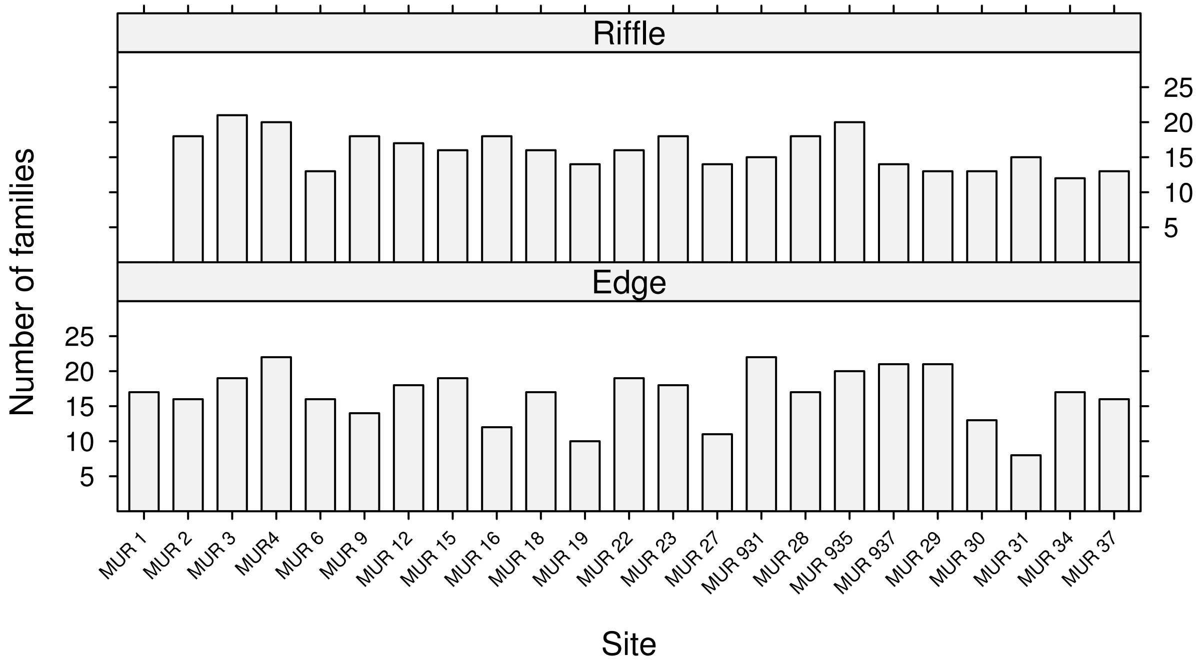


Figure 10. Taxonomic richness at the family level for all riffle (top) and edge sites

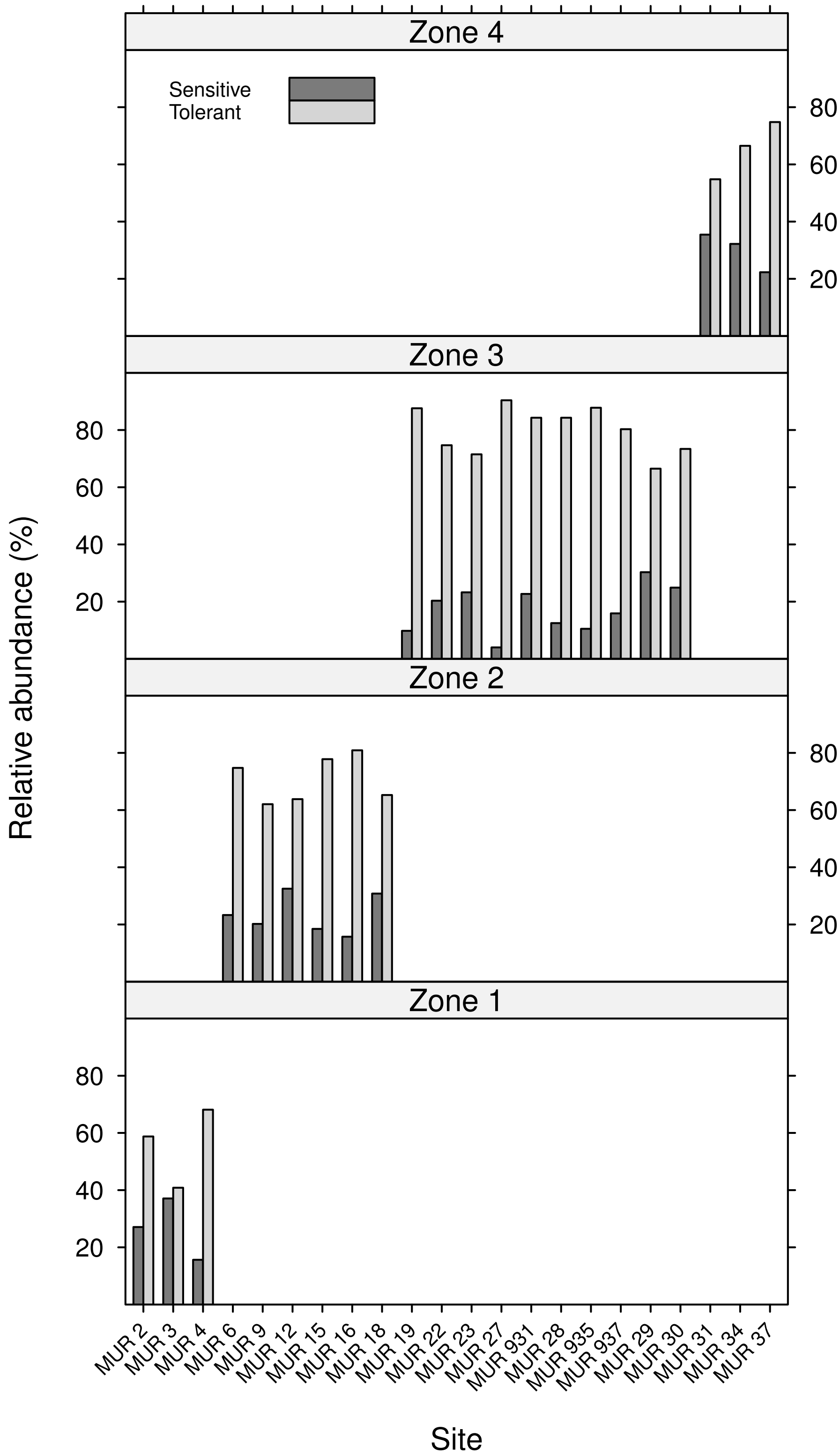


Figure 11. Relative abundances of sensitive and tolerant taxa at each riffle site.

Note: sites are grouped by zone (refer to Table 2 for site details)

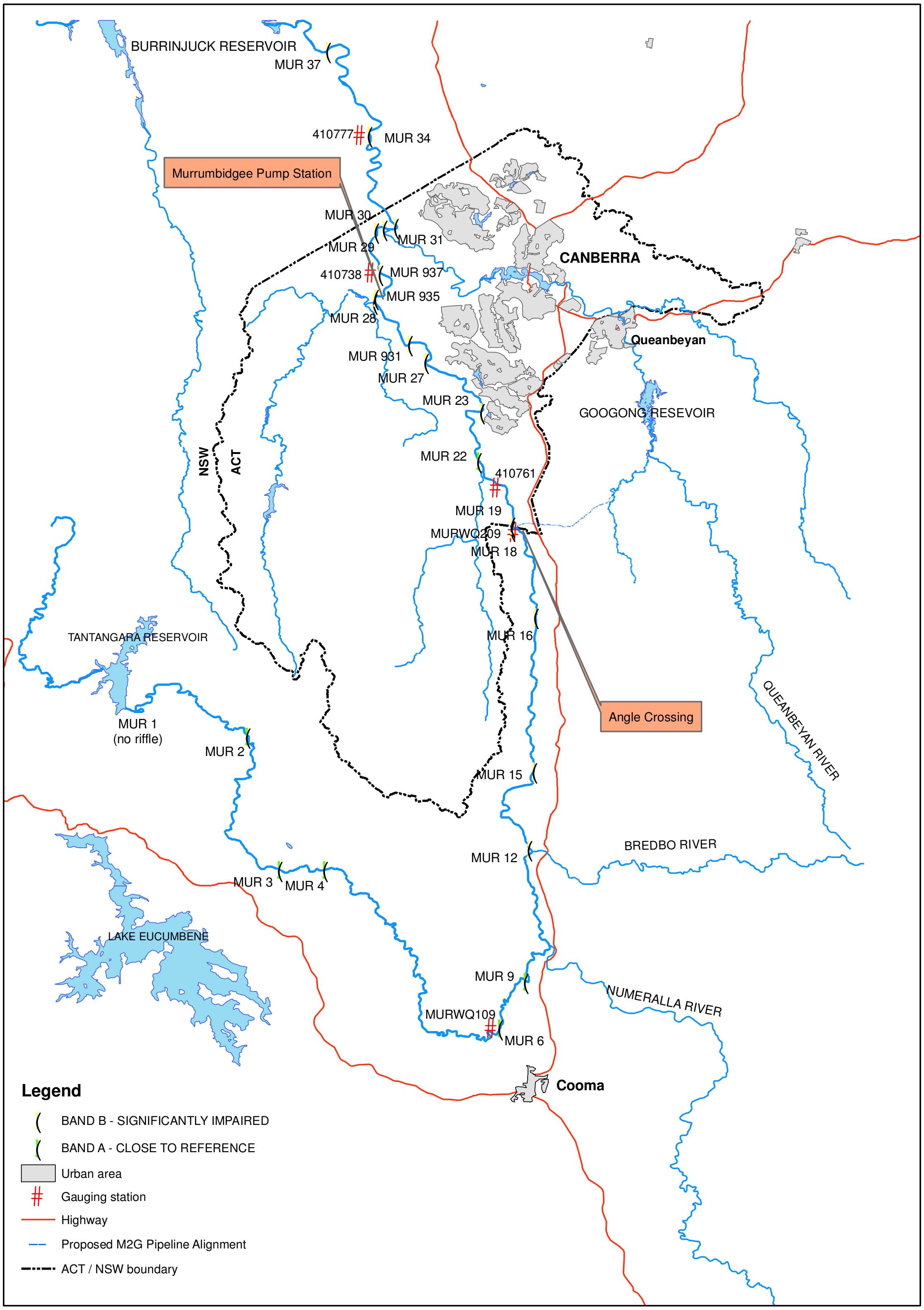


Figure 12. Spatial distribution of the AUSRIVAS bands for the riffle habitat

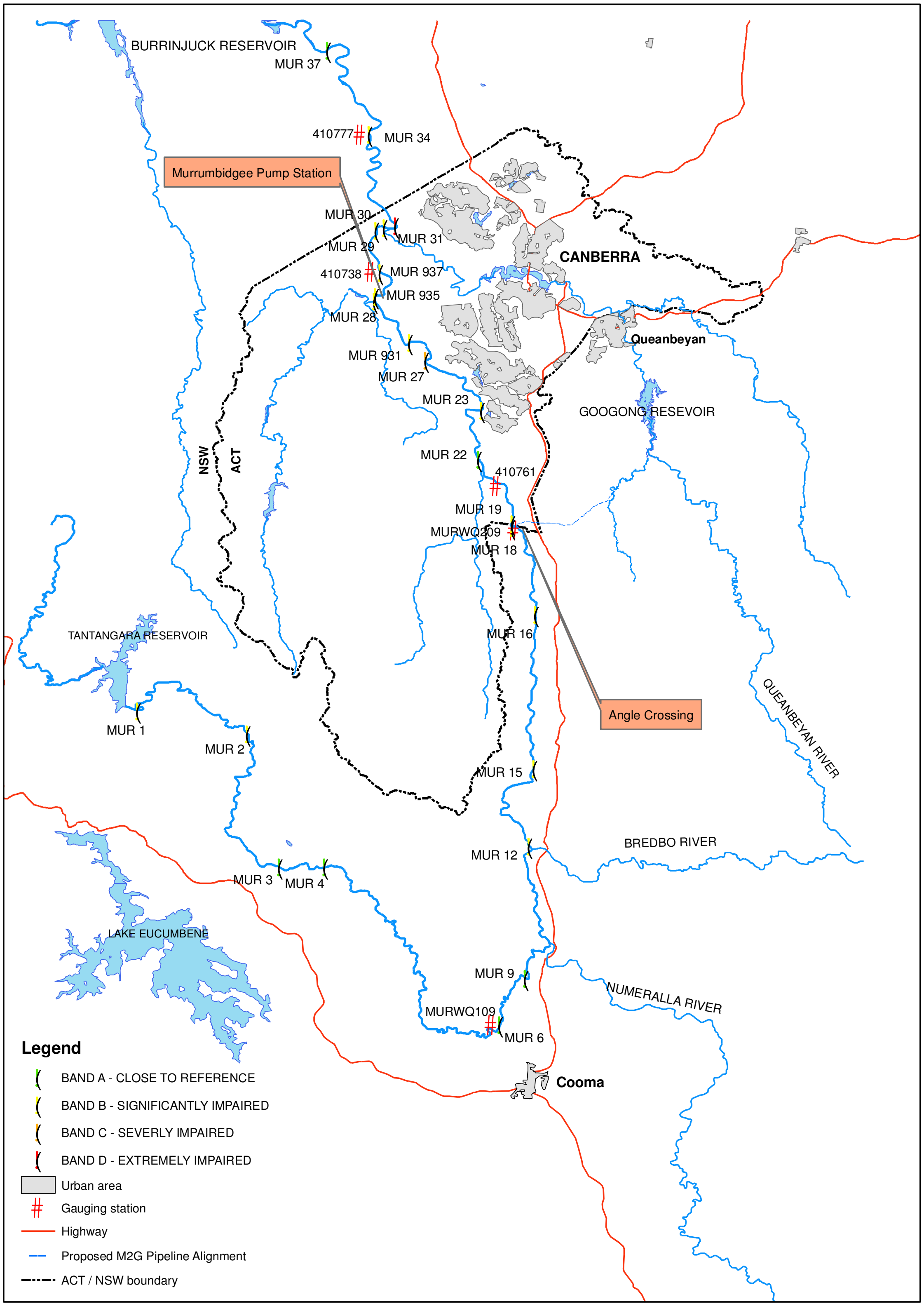


Figure 13. Spatial distribution of the AUSRIVAS bands for the edge habitat

Figure 14. Spatial distribution of the AUSRIVAS bands for the edge habitat

Table 11. AUSRIVAS and SIGNAL scores for spring 2009

*No reliable assessment

SITE	Location	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall site assessment
		Riffle	*Edge*	*Riffle*	*Edge*	*Riffle*	*Edge*	
MUR 1	D/S Tantangara Reservoir	na	5.09	na	0.85	**na**	**B**	**B**
MUR 2	Yaouk Bridge	5.58	5.00	0.91	0.83	**A**	**B**	**B**
MUR 3	Bobeyan Road Bridge	5.50	4.60	1.06	1.11	**A**	**A**	**A**
MUR 4	Camp ground of Bobeyan Road	5.43	4.50	1.04	0.94	**A**	**A**	**A**
MUR 6	D/S STP Pilot Creek Road	4.56	4.22	0.87	1.00	**A**	**A**	**A**
MUR 9	Murrells Crossing	5.25	4.00	0.91	0.89	**A**	**A**	**A**
MUR 12	Through Bredbo township	4.91	3.83	0.84	0.66	**B**	**B**	**B**
MUR 15	Near Colinton - Bumbalong Road	5	3.17	0.64	0.66	**B**	**B**	**B**
MUR 16	The Willows - Near Michelago	4.7	4.83	0.77	0.66	**B**	**B**	**B**
MUR 18	U/S Angle Crossing	5.5	3.17	0.84	0.66	**B**	**B**	**B**
MUR 19	D/S Angle Crossing	5.22	3.33	0.69	0.66	**B**	**B**	**B**
MUR 22	Tharwa Bridge	5.18	4.11	0.94	0.88	**A**	**A**	**A**
MUR 23	Point Hut Crossing	4.67	4.14	0.79	0.78	**B**	**B**	**B**
MUR 27	Kambah Pool	4.75	3.80	0.62	0.55	**B**	**C**	**C**
MUR 931	“Fairvale” ~4km U/S of the Cotter Confluence	4.8	4.14	0.74	0.78	**B**	**B**	**B**
MUR 28	U/S Cotter River confluence	5.1	3.86	0.75	0.78	**B**	**B**	**B**
MUR 935	Casuarina sands	4.38	4.14	0.67	0.78	**B**	**B**	**B**
MUR 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	4.75	4.14	0.67	0.78	**B**	**B**	**B**
MUR 29	Uriarra Crossing	5.18	4.14	0.82	0.78	**B**	**B**	**B**
MUR 30	U/S Molonglo Confluence	4.29	3.17	0.67	0.66	**B**	**B**	**B**
MUR 31	D/S Molonglo Confluence	4.63	3.00	0.59	0.33	**B**	**D**	**NRA***
MUR 34	Halls Crossing	4.88	3.71	0.77	0.78	**B**	**B**	**B**
MUR 37	Boambolo Road	4.50	3.75	0.64	0.89	**B**	**A**	**B**

Table 12. Results from ANOVA of SIGNAL - 2 scores

SIGNAL 2	Df	Sum of squares	Mean squares	F value	Pr (>F)
Zone	3	3.935	1.312	9.04	0.0001
Habitat	1	10.809	10.809	74.03	0.0001
Residuals	40	5.803	0.145		

Table 13. Results from ANOVA of O/E Family scores

O/E Family	Df	Sum of squares	Mean squares	F value	Pr (>F)
Zone	3	0.342	0.114	6.92	0.00007
Habitat	1	0.005	0.005	0.34	0.56
Residuals	40	0.661	0.016		

Table 14. Tukey's HSD post-hoc analysis of Zone comparisons for SIGNAL-2 scores

Zone	1	2	3	4
1	-	0.004	0.0006	0.0001
2	-	-	0.968	0.285
3	-	-	-	0.397
4	-	-	-	-

Table 15. Tukey's HSD post-hoc analysis of Zone comparisons for O/E family scores

Zone	1	2	3	4
1	-	0.05	0.033	0.015
2	-	-	0.749	0.173
3	-	-	-	0.441
4	-	-	-	-

4 Discussion

4.1 Water Quality

The PCA analysis indicates two gradients influencing the water quality between sampling sites (Figure 3; APPENDIX B). The first gradient (along the x-axis) represents changes in nutrient concentrations – increasing from right to left, from MUR 1 & 2 to MUR 37. The second gradient, although not so apparent is along the y-axis (PC-2) with increasing pH and secondarily, turbidity. The separation of sites MUR 15 and 16 is caused by a spike in Murrumbidgee River turbidity which occurred four days after the hydrograph peaked. Other sites sampled in this program had considerably lower turbidity readings (Table 6) because they were located upstream of the Numerella River (MUR 1- 9) or because they were sampled just prior to the spring high flow event occurring. 4100110

results are probably due to seasonal fluctuations. The range of EC values recorded upstream of the Molonglo confluence in this study were similar to these recorded in spring 2008. However, in spring 2008 EC levels downstream of the Molonglo Confluence were > four times those recorded upstream of the confluence. . In this sampling round, an EC gradient was still evident, but EC levels only increased from 20.6 us/cm upstream of the confluence to 44.6 us/cm downstream of the confluence, probably due to the dilution effect of the spring high flow event. .

The majority of the sites (all sites in Zones 2-4) sampled recorded nutrient values outside of the recommended guidelines (Table 6). In contrast, sites within Zone 1 have consistently been within the guideline values (Ecowise, 2008 & 2009), with the exception of this sampling run, where results were no doubt influenced by agricultural runoff associated with heavy rainfall around the time of sampling. Site MUR 4 is possibly more expose to such impacts compared to sites upstream due to the lack of riparian vegetation along the reach separating MUR 3 and 4 (Tabacchi *et al.*, 2000), which would otherwise have served as a buffer against agricultural runoff. The remaining sites all exceeded the upper target thresholds for both TP and TN. As it was with the EC data, there was a gradient of increasing change from upstream to downstream, but the sharp increase downstream of the Molonglo confluence was barely noticeable compared to previous sampling occasions due to the dilution effects of the high flow event.

4.2 Macroinvertebrates communities

The macroinvertebrate data show an overall decline in total abundance, family richness and the relative abundance of EPT taxa since the autumn sampling period (comparisons with spring 2008 are avoided because of the different sampling techniques employed – see Ecowise, 2008). The AUSRIVAS assessment shows some improvement in the condition of sites MUR 3, 4, 6, 9 and MUR 37; while obvious declines in condition were seen at MUR 27, 1, 2 and MUR 31 (Table 11: Figures 12 & 13) since autumn.

Overall, based on the range of indices used in this study, the macroinvertebrate community in Zone 1 was in the best condition of the macroinvertebrate communities monitored as part of this study. Downstream of this, there was a loose gradient of higher to lower condition with distance downstream. The most degraded macroinvertebrate communities observed in this sampling run were associated with sites were downstream sites close to residential areas or immediately downstream of wastewater treatment plants. However, water quality and habitat quality conditions at these sites may not necessarily have contributed solely to this observation (see discussion in Section 4.3).

There were more sensitive taxa in Zone 1 than in Zones 2-4, which is indicated by the higher SIGNAL-2 values for sites in Zone 1 (Table 11) and the higher EPT diversity and relative abundance at these sites (Figure 11). The NMDS plot for the riffle samples (Figure 7) reflects the gradual decline of EPT taxa (but in particular Ephemeroptera) with a gradient of changing abundance and richness from left to right, further emphasised by the significant ANOSIM results between groups (Table 7). Downstream of Zone 1, there was a noticeable absence of Coloburiscidae (SIGNAL = 8), Gripopterygidae (SIGNAL = 8) and Glossosomatidae (SIGNAL = 9) and much lower numbers of Leptophlebiidae (SIGNAL = 8), Baetidae (SIGNAL = 5) and Hydropsychidae (SIGNAL =6). This trend was evident for both riffle and edge habitats (Tables 9 & 10). The absence of Coloburiscidae downstream of Zone 2 is due to their preference for upland reaches with cooler, faster flowing waters (to date, Coloburiscidae has not been collected downstream of MUR 6). Caenidae (SIGNAL =4) were present at all sampling sites and in relatively high numbers, which likely due to their resistance to high flows (Miller & Gollady, 1996) and tolerance to certain amounts of suspended sediments (Gibbins *et al.*, 2010).

Declines in EPT taxa can be attributed to various factors including: pollution, poor water quality and habitat, including sedimentation (Gafner & Robinson, 2007) and substrate composition (Griffith *et al.*, 2005; Gibbins *et al.*, 2010). In this study, pollution and poor water quality are unlikely factors accounting for the sharp decline in EPT taxa given that a) there is no evidence from the water quality records to indicate this and b) there is a mixture of both sensitive and tolerant taxa missing from most of the samples suggesting other factors determining these patterns. There is, however, some evidence of nutrient enrichment downstream of Point Hut crossing and Hall's Crossing in response to Point Hut pond spillages (reported in Ecowise, 2009a) and urbanised creek runoff from Jerrabomberra Creek. Numbers of Hydropsychidae (SIGNAL = 6) were elevated at these sites and there was also a higher periphyton and filamentous algae cover observed at these sites. In addition, the position of these two sites in the ordination plots suggests a relatively high similarity in their community composition (Figure 7).

While site specific factors, such as those mentioned above affect macroinvertebrate assemblages at the site scale, the overall pattern in the data are consistent with the effects of the spring high flow event that occurred during this sampling run (Figure 2). Similar effects of floods and high flow events on macroinvertebrate communities have been observed in other studies (Molles JR., 1985; Wallace, 1990; Lake, 2000). Hydrological disturbance can affect macroinvertebrate communities through scour and dislodgement and smothering of benthic habitats through sediment deposition and bedload movement and the clogging of gill apparatuses by suspended sediment particles (Resh *et al.*, 1988; Lake, 2000; Collier & Quinn, 2003; Gibbins *et al.*, 2010). Such impacts can result in lower diversity and reductions in relative abundances by as much as 99% compared to pre-disturbance conditions (Fritz & Dodds, 2004).

The high proportion of Oligochaetes collected at each site highlights the fact that because they are sediment dwellers, they are less likely to be affected by the smothering of benthic habitats as a result of sediment mobilisation associated with high flow conditions. On the other hand, free living taxa such as mayflies are more prone to dislodgement and as such were poorly represented (and often absent) in the samples collected and both of these results are consistent with Molles Jr. (1985) who found very similar assemblage patterns following a flash flood. Black fly larvae (Simulids) have a high propensity to drift following a disturbance (Minshall & Petersen, 1985) making them likely to also be early colonists, and as such, the very high numbers (ranging from 1400 – 3500 individuals downstream of the tributaries) might suggest the early stages of succession.

Although macroinvertebrate abundance have been shown to decline following high flow disturbances (Molles JR., 1985; Voelz *et al.*, 2000; Robinson *et al.*, 2003), they also show strong seasonal patterns with the autumn and summer months tending to show higher numbers than winter and spring (Hynes, 1970; Feminella, 1996; Suren & Jowett, 2006). There is little evidence at this stage to directly link the high flows encountered in spring to lowered abundances because despite there being significant declines across most of the monitoring sites, these declines were also seen (and to a similar relative scale) at the sites upstream of the impacted tributaries. This would suggest that either seasonality was the main driver interacting with high flows downstream of the tributaries, or there were prior events in the upper catchment that affected all of sites, not just those downstream of MUR 12. For instance, the event gauged in early October (Figure 2) only affected sites downstream of Lobb's Hole, highlighting the fact that there tends to be considerable spatial variation in rainfall patterns and therefore, some spatio-temporal variation in hydrological disturbance regimes within the study area. Currently, the gauging station at Pilot Creek road is not operational, but the addition of this site will clarify hydrological trends in these upper reaches.

4.3 AURIVAS assessment

Sites upstream of MUR 12 were all assessed as being close to reference (BAND A) based on riffle habitat samples and all except MUR 1 & 2 were close to reference based on edge habitat samples. The overall site assessment for sites MUR 1 & MUR 2 based on edge habitat data was BAND B. This was due to the absence of two or three taxa which were reported at these sites in spring 2008 (Ecowise, 2008). The edge habitat at MUR 1 & 2 was 50cm and 15 cm shallower than they were in the previous spring respectively. These sites had particularly poor habitat quality including a notable absence of large woody detritus, CPOM or riparian cover and the substrate was predominantly silt. These factors are likely to account for the number of missing taxa predicted by the AUSRIVAS model, particularly Elmidae and Amphipoda, which require decaying vegetation as a food resource, and the former tend to burrow into decaying submerged logs (absent from both sites) for shelter (Gooderham & Tsyrlin, 2005).

The Band D assessment given to MUR 31 is likely due to sampling error because two of the taxa noted as missing but expected to occur (APPENDIX D), namely Corixidae (SIGNAL = 2) and Leptoceridae (SIGNAL = 6) were noted in the field notes as being seen in the sample following collection. Furthermore, sampling effort was restricted to only a small proportion of the previously habitat due to high water levels at the time. We recommend taking the conservative approach in this case, which is one of no reliable assessment from the overall site assessment and edge habitat assessments, but to assign the BAND B assessment to the riffle.

The edge habitat at MUR 27 (Kambah pool) was assessed as BAND C having macroinvertebrate communities in much poor condition to reference. The total number of taxa missing (but predicted by the AUSRIVAS model) was 6 (APPENDIX D) and included taxa with water quality sensitivity scores ranging from 2 (Corixidae) to 8 (Leptophlebiidae and Gripopterygidae). The absence of a broad range of taxa including the tolerant Corixidae suggests that the edge habitat at this site was affected by high flows, rather than a water quality impact. Corixidae prefer slow moving or still water (Gooderham & Tsyrlin, 2005) and have previously been one of the five dominant species found at this site. The elevated velocity readings during spring sampling (0.36 m/s^{-1}) suggest that they were displaced by high flow. Similarly, as discussed in section 4.2, the absence of the usually common Baetidae family is probably due to high flows. Baetids tend to have a high propensity to drift following disturbance (Minshall & Petersen, 1985; Giller & Malmqvist, 1998) and have been shown to be sensitive to increases in total suspended solids, which usually accompany high flow events (Gibbins *et al.*, 2010).

Tharwa Bridge (MUR 22) was assessed as BAND A for both habitats. This assessment has not changed since Spring 2008 despite low flows affecting other sites in autumn, construction works having had mild impacts on the water quality adjacent to this site, and extended high flows coupled with a 1 yr ARI event impacting the majority of sites in this sampling run. Barmuta *et al.* (2003) explain that O/E scores can be over-estimated at sites located downstream of even small tributaries because fauna residing in the tributaries can be washed downstream and collected in the main channel sample - when in fact the fauna collected are unlikely to be resident at the given main channel site under base flow conditions. This would explain the consistent BAND A assessments given to this site since the program began; however as noted in Ecowise (2009b), MUR 22 has high quality edge and riffle habitat, which might offer more secure refuge to resident taxa during times of environmental stress.

Improvements were seen at MUR 37 and MUR 937 in the edge habitat increasing from BAND C to BAND A and BAND C to BAND B respectively. The BAND C assessment in the previous round of sampling was considered to be a result of low flow conditions, poor habitat quality resulting in low

D.O and increasing water temperatures. The improved assessments, suggests that despite there being fewer sensitive taxa in the sample (indicated by the low SIGNAL-2 scores) the improved habitat quality has allowed taxa previously absent to recolonise. Most notably these taxa include: Corixidae, Leptoceridae and Leptophlebiidae which were all absent from the samples in autumn. Their presence in this study (albeit in limited numbers) suggests that the increase in flows is facilitating the colonisation of more taxa through an increase in habitat diversity and complexity – either through providing depth in the water column, or through the downstream transport of woody debris and other organic matter, which increase microhabitat diversity and complexity within a given site.

These changes described above for sites MUR 37 and MUR 937 are probably not specific to these sites, but were highlighted at these sites because they were sampled 10 days after the high flow event. It is likely that provided the reoccurrence of hydrological disturbances is reasonably low and flows continue as they are, most sites should see a re-emergence of sensitive taxa from all major groups.

It is impossible to determine the exact impacts of the high flow event on the sample quality from spring 2009, because even under baseflow conditions, macroinvertebrate assemblages have been highly variable through the catchment due to variations in landuse, altitude and position in relation to major tributaries. However, the results presented here are consistent with a flood disturbance based on the results from the multiple metrics used in this assessment. Pre-flood data would be necessary to isolate high flows as the key driver of these assessments, but is it almost certain that the large catchment area combined with varying landuse and site specific processes are also key components determining the status of macroinvertebrate assemblages at individual sites.

5 Conclusions

The results from this sampling run should be considered with caution since the sampling program was interrupted by a high flow event originating in the Tinderry ranges in late October / early November. Sites upstream of the Bredbo confluence were un-affected by this event and are considered to be accurate assessments of their current condition.

Nutrient levels exceeded ANZECC & ARMCANZ (2000) water quality guidelines at most of the sites sampled, but were generally lower than for the same period in 2008, probably due to a dilution effect because of the high flows. Despite the dilution effect on the nutrient concentrations, only four sites were inside the upper trigger limits for TP and only two sites for TN. EC and turbidity also seem to have been affected by the high flows. Turbidity was higher than the recommended upper limits downstream of the Bredbo confluence, while EC was diluted by the high flow event such that EC levels were generally below ANZECC & ARMCANZ (2000) guideline limits.

The continuous water quality trends for spring are consistent with temporal changes induced by changes in ambient temperatures and high flows for the period. Electrical conductivity for example was below the recommended minimum values at all but 5 of the sampling sites, which is likely to be again, a dilution effect of increased flows and a lower groundwater contribution.

Despite the effects of the high flow event, there was no change in the river health assessment at the majority of the sites sampled. Most riffle sites in the mid and lower reaches were assessed as BAND-B by the AUSRIVAS model. These results reflect the fact that all sites were dominated by Oligochaetes (worms), Simuliidae (blackfly larvae) and Chironomids (non-biting midges). The make up of these community assemblages are consistent with communities that have recently been impacted by hydrological disturbance as is the case in this study.

In this monitoring program to date, the effects of drought (autumn) and high flows (spring) have probably masked any site specific impacts because of their widespread impacts on the ecosystem. The impaired health rating given to all sites in this study resulted from a loss of many of the sensitive EPT taxa being missing from most, if not all of the samples at a given site. Despite the important influence of the high flow evenrt on the current site assessments, there are indications that outside of this natural impact, the sites under assessment are in relatively good condition given that some of the sites contained some very sensitive Mayflies and Caddisflies. There are two exceptions however (MUR 27 and MUR 31), which should be approached with caution as it is likely that sampling error as a function of rising water levels was the contributing factor in these anomalous results. Should these assessments be seen in future sampling runs, then special attention will be paid to the physical and chemical parameters at these sites to ascertain potential causes of these poor assessments.

6 Recommendations

This is the third round of sampling where the impacts of naturally occurring disturbances (i.e. autumn: drought; this report: seasonal high flow event) have probably masked any site specific anthropological impacts. In light of this, the recommendations from the autumn report (which follow) stand.

1) Sometimes the difference between the discrete Band-widths (i.e. from Band A to B) can be a matter of a single family (as was the case in several sites in this study) resulting in misleading interpretations, especially if the missing family or families are tolerant and/or other wise common. This could imply sampling error or patchy distributions of certain taxa rather than an impacted site.

2) Following on from (1), a single sample may not be representative of a given site. With the Hess sampling protocols implemented in spring, not all taxa were found in all of the samples, suggesting that replication was the best option to represent the biodiversity at a given site – particular if the site has a variety of microhabitats or a heterogeneous substratum. Nichols *et al.*(2006) found that a single sample was adequate for bioassessment at sites with a uniform substrate and was in good condition (which is the case for all sites in Zones 1); while at sites in poorer condition different interpretations of biological condition could result.

3) Continuous water quality and flow monitoring is restricted to Lobb's Hole (410761) and Mount MacDonald (410738) and Halls Crossing (410777) which misses the potential impacts of water entering the Murrumbidgee River at upstream of Angle Crossing and further up the catchment in Zone 1. Plans are in place for sites at these locations to be included, and at least one should be operational by the time sampling commences in autumn 2010.

7 Literature Cited

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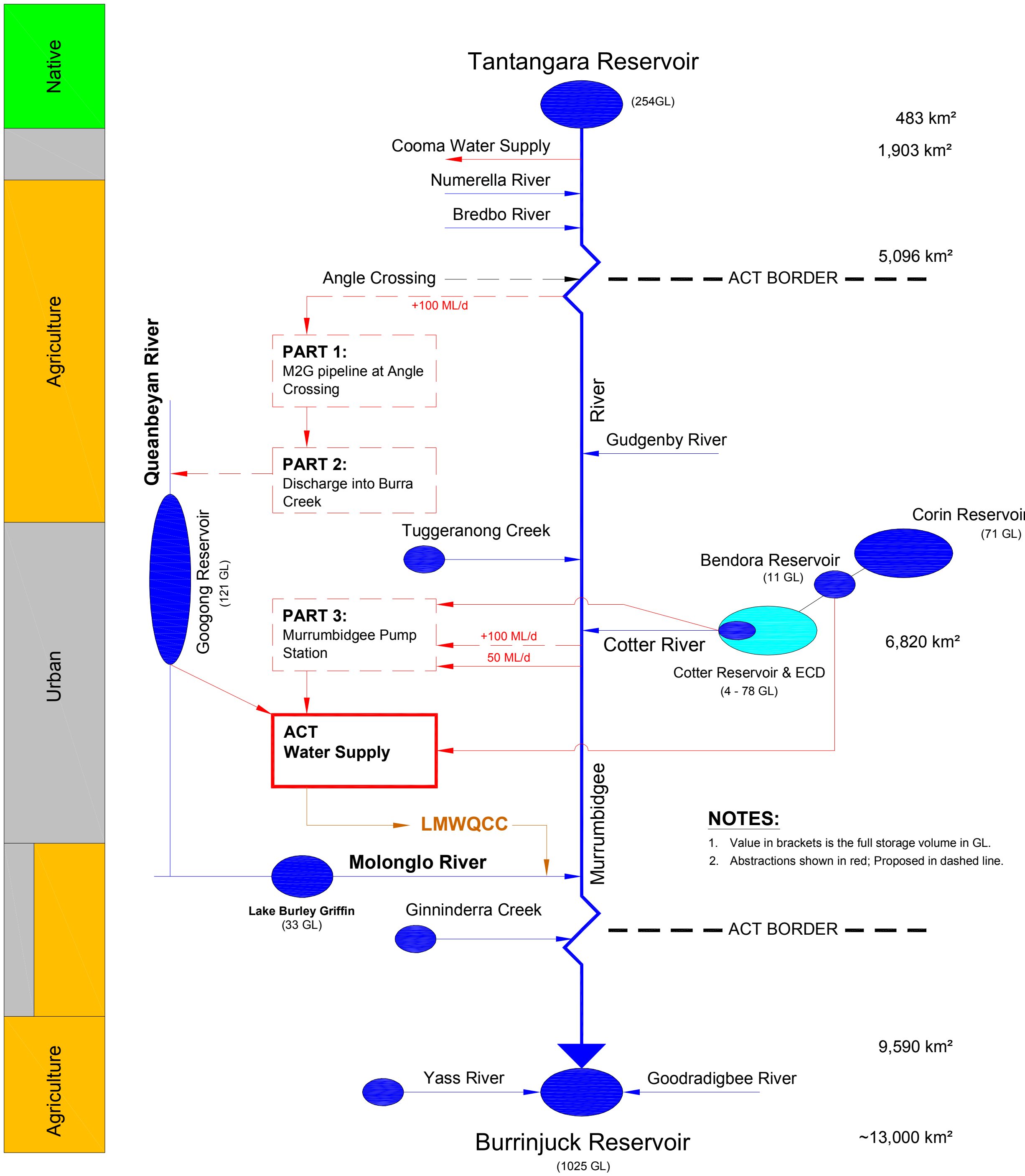
I

Appendix A –

Schematic representation of the Murrumbidgee Catchment and ACTEW's major water projects

Main Land Use	Catchment Overview	Murrumbidgee Catchment Area



Appendix B–

Principal Components Analysis of water quality variables

Appendix C. Principal Components Analysis detailing the eigenvectors and values for the analysis of water quality grab samples: autumn 2009.

Principal Component Analysis

Eigenvalues

PC	Eigenvalues	%Variation	Cumulative variation
1	2.81	40.7	40.7
2	2.1	30.5	71.2
3	0.969	14.1	85.3
4	0.503	7.3	92.6
5	0.288	4.2	96.7

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	0.319	-0.086	-0.648	-0.159	-0.065
EC	0.034	-0.009	0.013	-0.015	-0.021
pH	0.258	-0.587	-0.059	-0.001	0.675
D.O (% Sat.)	-0.022	-0.604	-0.314	0.191	-0.520
Turbidity	0.361	0.302	-0.244	-0.118	-0.312
Total Nox	0.426	-0.297	0.574	-0.523	-0.315
TP	0.498	0.319	-0.151	-0.176	0.255
TN	0.520	0.047	0.257	0.787	-0.085

Appendix C–

Taxonomic inventory from round one (edge and riffle): spring 2009

Appendix C. Taxonomic inventory of the macroinvertebrate taxa collected in the EDGE spring 2009.

CLASS Order	Family *Sub family*	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR28	MUR93 1	MUR93 5	MUR93 7	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	
AMPHIPODA	Ceinidae		✓																					
BIVALVIA	Corbiculidae/ Sphaeriidae			✓	✓																			
Coleoptera	Dytiscidae			✓	✓		✓							✓		✓								
Coleoptera	Elmidae												✓								✓		✓	
Coleoptera	Gyrinidae													✓					✓					
Coleoptera	Hydrochidae							✓																
Coleoptera	Hydrophilidae			✓	✓		✓		✓		✓		✓	✓		✓	✓	✓					✓	
Coleoptera	Psephenidae			✓																				
Coleoptera	Scirtidae		✓																					
Coleoptera	Cyclopoida							✓																
Cladocera								✓																
Decapoda	Atyidae					✓		✓	✓	✓	✓				✓	✓	✓	✓	✓	✓			✓	
Decapoda	Palaemonidae																✓							
Diptera	Ceratopogonidae	✓			✓		✓		✓	✓			✓			✓	✓			✓			✓	✓
Diptera	*Chironominae*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	Dolichopodidae	✓																						
Diptera	Empididae	✓																						✓
Diptera	Ephyridae								✓															
Diptera	*Orthocladiinae*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	Muscidae				✓								✓									✓		
Diptera	Simuliidae	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	*Tanypodinae*	✓	✓	✓	✓	✓	✓		✓				✓	✓		✓	✓	✓			✓			
Diptera	Tipulidae								✓							✓								
Ephemeroptera	Baetidae	✓	✓	✓	✓	✓	✓									✓			✓				✓	✓
Ephemeroptera	Caenidae		✓	✓		✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓
Ephemeroptera	Coloburiscidae	✓	✓																					
Ephemeroptera	Leptophlebiidae	✓		✓						✓			✓	✓			✓		✓	✓				
Ephemeroptera	Oniscigastridae	✓																						

CLASS Order	Family *Sub family*	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR28	MUR931	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
GASTROPODA	Ancylidae					✓				✓			✓			✓							✓	
GASTROPODA	Lymnaeidae			✓		✓	✓	✓	✓			✓		✓	✓									
GASTROPODA	Physidae							✓	✓		✓	✓				✓	✓	✓	✓	✓			✓	
GASTROPODA	Planorbidae			✓	✓							✓	✓	✓	✓		✓			✓	✓	✓	✓	✓
Hemiptera	Corixidae			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Hemiptera	Gelastocoridae				✓																			
Hemiptera	Gerridae				✓																			
Hemiptera	Mesoveliidae															✓	✓							
Hemiptera	Notonectidae												✓			✓	✓	✓			✓			
Hemiptera	Veliidae												✓			✓						✓		
Isopoda		✓		✓																				
Lepidoptera	Pyralidae												✓											
Odonata	Coenagrionidae				✓		✓	✓					✓				✓					✓		
Odonata	Epiproctophora													✓								✓		
Odonata	Gomphidae																		✓					
Odonata	Telephlebiidae																							
Odonata	Zygoptera			✓							✓		✓	✓								✓		
OLIGOCHAETA									✓	✓	✓	✓		✓		✓	✓		✓	✓				
Plecoptera	Gripopterygidae	✓	✓	✓	✓	✓	✓	✓		✓				✓					✓					
Trichoptera	Calamatoceridae			✓																				
Trichoptera	Conoesucidae	✓	✓																					
Trichoptera	Ecnomidae			✓	✓						✓			✓			✓		✓	✓			✓	✓
Trichoptera	Glossosomatidae							✓																✓
Trichoptera	Hydrobiosidae		✓												✓				✓					
Trichoptera	Hydropsychidae										✓			✓					✓		✓		✓	
Trichoptera	Hydroptilidae			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Trichoptera	Leptoceridae	✓	✓	✓	✓	✓					✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Trichoptera	Limnephilidae				✓																			
Trichoptera	Polycentropodidae																							✓
Turbellaria	Dugesiidae															✓					✓			✓

Appendix C. Taxonomic inventory of the macroinvertebrate taxa collected in the RIFFLE spring 2009

CLASS Order	Family *Sub family*	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR0931	MUR28	MUR0935	MUR0937	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		✓		
BIVALVIA	Sphaeriidae		✓		✓	✓				✓	✓		✓	✓					✓		✓		
BIVALVIA	Corbiculidae			✓				✓					✓										
Coleoptera	Elmidae	✓	✓	✓	✓	✓					✓	✓	✓		✓	✓					✓	✓	✓
Coleoptera	Gyrinidae											✓											
Coleoptera	Hydrophilidae						✓																
Coleoptera	Psephenidae		✓																				
Cladocera		✓												✓						✓			
Copepoda		✓												✓									
Ostracoda		✓																					
Decapoda	Palaemonidae																	✓					
Decapoda	Parastacidae												✓										
Diptera	Ceratopogonidae			✓	✓		✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓
Diptera	Dolichopodidae						✓	✓				✓		✓			✓						
Diptera	Empididae						✓																
Diptera	*Aphroteniinae*	✓																					
Diptera	*Chironominae*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	*Orthocladiinae*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	*Tanypodinae*	✓	✓	✓		✓	✓					✓			✓		✓						
Diptera	Simuliidae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	Tipulidae											✓	✓			✓		✓	✓			✓	
Ephemeroptera	Baetidae	✓	✓	✓	✓	✓			✓	✓		✓			✓	✓	✓		✓				✓
Ephemeroptera	Caenidae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ephemeroptera	Coloburiscidae	✓	✓	✓		✓																	
Ephemeroptera	Leptophlebiidae	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	

CLASS Order	Family *Sub family*	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR0931	MUR28	MUR0935	MUR0937	MUR29	MUR30	MUR31	MUR34	MUR37
GASTROPODA	Physidae														✓								
GASTROPODA	Planorbidae			✓																			
GASTROPODA	Ancylidae					✓	✓								✓	✓	✓	✓	✓	✓	✓		✓
GASTROPODA	Lymnaeidae																						✓
Isopoda			✓																				
Megaloptera	Corydalidae					✓																	
Odonata	Epiproctophora															✓							
Odonata	Gomphidae	✓	✓	✓																			
OLIGOCHAETA		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Plecoptera	Gripopterygidae	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		✓		✓						
Trichoptera	Conoesucidae		✓	✓											✓								
Trichoptera	Ecnomidae		✓	✓	✓	✓		✓	✓			✓	✓		✓	✓			✓	✓	✓	✓	✓
Trichoptera	Glossosomatidae	✓	✓		✓	✓				✓									✓				
Trichoptera	Hydrobiosidae	✓		✓						✓				✓	✓		✓						
Trichoptera	Hydropsychidae	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trichoptera	Hydroptilidae			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓		✓
Trichoptera	Leptoceridae		✓											✓	✓	✓							
Trichoptera	Polycentropodidae						✓														✓		
Turbellaria	Dugesiidae												✓								✓	✓	

Appendix D

Macroinvertebrate taxa expected to occur but missing from riffle and edge habitats

Appendix D. Macroinvertebrate taxa expected to occur but missing from the riffle habitat.

Site	Taxa	Sphaeriidae	Elmidae	Ceratopogonidae	Oligochaeta	Baetidae	Psephenidae	Tipulidae	Leptophlebiidae	Hydrobiosidae	Tanypodinae	Glossosomatidae	Gripopterygidae	Hydropsychidae	Acarina	Conoesucidae	
	Signal score	5	7	4	2	5	6	5	8	8	4	9	8	6	6	7	Total number of missing taxa
MUR2			×			×	×	×								×	5
MUR3			×					×		×							3
MUR4			×					×				×					3
MUR6			×						×		×			×			4
MUR9							×	×	×	×						×	5
MUR12		×	×			×											3
MUR15			×			×	×	×		×	×	×		×		×	9
MUR16			×	×			×	×		×		×		×		×	8
MUR18						×	×	×			×	×				×	6
MUR19						×	×	×		×	×	×			×	×	8
MUR22					×		×			×		×	×			×	6
MUR23			×			×		×			×	×	×				6
MUR27			×			×	×	×	×		×	×	×			×	9
MUR931			×				×	×		×	×	×	×			×	8
MUR28			×				×	×		×	×	×				×	7
MUR935			×				×	×	×	×	×	×	×			×	9
MUR937			×			×	×	×		×	×	×	×			×	9
MUR29			×				×			×	×		×			×	6
MUR30		×	×			×		×			×		×		×		7
MUR31						×	×	×	×	×	×	×	×			×	9
MUR34		×				×					×		×		×		5
MUR37							×	×	×	×	×	×	×		×	×	9

Appendix D (cntd.) Macroinvertebrate taxa expected to occur but missing from the edge habitat

Site	Taxa	Amphipoda	Sphaeriidae	Baetidae	Caenidae	Scirtidae	Elmidae	Tipulidae	Ceratpogoninae	Tanypodinae	Leptophlebiidae	Corixidae	Synlestidae	Gripopterygidae	Hydrobiosidae	Leptoceridae	Total number of missing taxa
	Signal score	3	5	5	4	6	7	5	4	4	8	2	7	8	8	6	
MUR1		×	×			×	×	×									5
MUR2		×	×				×		×		×						5
MUR3									×								1
MUR4					×						×						2
MUR6									×		×						2
MUR9					×						×			×			3
MUR12				×					×	×	×					×	5
MUR15				×	×						×			×		×	5
MUR16				×	×					×		×				×	5
MUR18				×	×									×		×	4
MUR19									×	×				×		×	4
MUR22				×													1
MUR23				×					×	×							3
MUR27				×					×		×	×		×		×	6
MUR931				×	×					×	×						4
MUR28				×					×							×	3
MUR935				×					×					×			3
MUR937									×	×				×			3
MUR29				×	×					×				×			4
MUR30				×	×				×		×			×	×	×	6
MUR31				×	×				×	×	×	×		×		×	8
MUR34					×					×	×					×	4
MUR37										×	×			×			3