ACTEWAGL

MURRUMBIDGEE ENVIRONMENTAL MONITORING PROGRAM

PART 4: TANTANGARA TO BURRINJUCK

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Prepared by:	Environmental Scientist	Zoe Lagerroth		26/09/2011
Internal Review by:	Principal Scientist	Jamie Corfield		27/09/2011
Peer Review by:				
Approved by:	Manager, Water Sciences ACT	Norm Mueller		30/09/2011

For further information on this report, contact:
Name: Phil Taylor
Title: Environmental Project Manager
Address: 16B Lithgow Street, FISHWICK ACT 2609
Phone: 02 6202 5422
E- mail: phil.taylor@alsglobal.com

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List of abbreviations

ACT – Australian Capital Territory

ACTEW – ACTEW Corporation Limited

ANZECC – Australian and New Zealand Environment and conservation Council

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

MANOVA – Multivariate ANOVA (statistics)

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

PERMANOVA – Permutational MANOVA (statistics)

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)

SIMPROF – Similarity Profile (statistics)

TN – Total Nitrogen

TP – Total Phosphorus

Temp. Water temperature (°C)

WAE – Water Allocation Entitlement

WL – Water Level

Executive Summary

In light of the recent drought in the Australian Capital Territory ACTEW Corporation, the major water utility company for the ACT, developed a water security program that encompassed the upgrading of existing, and the development of new infrastructure in order to secure long term water for the ACT. One of the new water security projects put forward was the "Tantangara transfer" which would 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 Ecological Monitoring Program was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It was designed to address concerns raised by both Government and non-Government stakeholders; and to provide ACTEW Corporation with relevant information regarding any beneficial and/or detrimental ecological effects of the abstraction. The MEMP was set up to be implemented prior to the commencement of the Murrumbidgee to Googong transfer project (M2G), allowing ACTEW to collect pre-abstraction baseline data to compare against post-abstraction data once the M2G project is in operation. The proposed timeline for the MEMP study was to undertake pre-abstraction sampling in spring and autumn over a three year period commencing in spring 2008 and concluding in spring 2011. Due to minor delays in commencement of the M2G project, the autumn 2012 sampling run may also be in the pre-operational phase.

There are four component areas being considered as part of the MEMP. This report focuses on Part 4: Tantangara to Burrinjuck. In particularly, it focuses on results of autumn 2011 monitoring carried out as part of the MEMP Tantangara to Burrinjuck area study.

The key aims of this sampling run were to:

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

b. *Undertake in-situ water quality sampling – including nutrient analysis as a baseline for future condition assessments;*

c. *Provide AUSRIVAS assessments of riffle and edge habitats between Tantangara Reservoir and Burrinjuck* Reservoir *on the Murrumbidgee River.*

This report contains the results of the autumn 2011 sampling event conducted on the Murrumbidgee River at sites between Tantangara Dam and Burrinjuck Dam delta.

The impacts of high flow events throughout spring and summer 2010 were still evident in the catchment during the autumn 2011 sampling period.

Several exceedances of nutrient guidelines (Total Nitrogen and Total Phosphorous) were observed at several sites, presumably as a result of run-off from agricultural land and urban contributions from the Molonglo River, Tuggeranong and Ginninderra Creeks and other tributaries. The Lower Molonglo Water Quality Control Centre (LMWQCC) discharges treated effluent into the system. Total nitrogen was extremely high at sites downstream of LMWQCC. The water quality appeared to be better in the upstream areas where the land use is predominantly native vegetation and light grazing. Low Electrical Conductivity (EC) levels at upstream sites were observed in autumn 2011 and were also observed in spring

2010 but these values are just slightly outside of the ANZECC recommended range. Peaks and troughs in EC and pH recorded at the continuous monitoring stations largely corresponded with, and are considered to be due to, high rainfall events.

Multivariate analyses determined that there were significant differences in the macroinvertebrate community collected from Riffle and Edge samples between Zone 1 (Tantangara to Cooma) and Zone 2 (Cooma to Angle Crossing) and between Zone 1 and Zone 3 (Angle Crossing to LMWQCC). The differences were generally characterised by higher numbers of sensitive taxa in Zone 1 samples compared to Zone 2 and Zone 3 samples.

Macroinvertebrate richness was moderate across all sites. SIGNAL2 and EPT richness was generally higher in Zone 1 compared to Zone 4. There were a significantly greater absolute number of sensitive taxa collected from edge samples when compared to riffle samples but the proportion of sensitive taxa was greater within riffle samples.

AUSRIVAS results were moderate to good with scores generally varying between Band-A ("similar to reference condition") and Band-B ("significantly impaired"). There was only one instance of a Band-C ("severely impaired") grade at site MUR 3 near Bobeyan Road Bridge. Little difference in AUSRIVAS health score was discernable between the four Zones. AUSRIVAS banding for riffle samples was found to be significantly higher at Zone 3 compared to Zone 1. However, the number of sensitive taxa was highest in Zone 1 sites so the AUSRIVAS results should not be considered in isolation.

1 Introduction

The drought in the ACT, which began in the year 2000, progressively caused declines in the ACT's dam storage volumes to unprecedented levels. ACTEW Corporation, the major water utility company in the ACT, developed a water security program that encompassed upgrading the existing Cotter Dam, and development of new infrastructure to pump water from the Murrumbidgee River in order to secure water for the Australian Capital Territory (ACT). One of the new water security projects put forward was the "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.

In order to use water from the Tantangara Reservoir, ACTEW has commenced the construction of a river offtake pumping structure, and pipeline from Angle Crossing (southern border of the ACT) to the Googong catchment. 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 flow into the Googong Reservoir. The system is designed to enable pumping of up to 100 ML/d, and is expected to be in operation by mid-2012. Abstraction will be dictated by the storage level in Googong reservoir, the level of demand for the water, and by the availability of water in the Murrumbidgee River. The abstraction infrastructure is referred to as the Murrumbidgee to Googong project (M2G). A schematic overview of the proposed operations is given in Appendix A.

Required baseflows to be maintained in Murrumbidgee River will be regulated through the *ACT Environmental Flows Guidelines (currently 2006) and associated water licence*. ACT & 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 Ecological Monitoring Program was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It was designed to address concerns raised by both Government and non-Government stakeholders; and to provide ACTEW Corporation with relevant information regarding any beneficial and/or detrimental ecological effects of the project. The MEMP was set up to be implemented prior to the commencement of the M2G project, allowing ACTEW to collect pre-abstraction baseline data to compare against and post-abstraction data once the M2G project is in operation. The proposed timeline for the MEMP study was to undertake pre-operational sampling in spring and autumn over a three year period commencing in spring 2008 and concluding in spring 2011. Due to minor delays in the M2G project commencement, autumn 2012 sampling may also now be pre-operational.

There are four component areas covered as part of the MEMP:

Part 1: Angle Crossing;

Part 2: Burra Creek (discharge point for Angle Crossing abstraction);

Part 3: Murrumbidgee Pump Station; and

Part 4: Tantangara to Burrinjuck

This report focuses on Part 4: Tantangara to Burrinjuck. In particularly, it focuses on results of autumn 2011 monitoring carried out as part of the MEMP Tantangara to Burrinjuck area study.

1.1 Objectives

The overall objectives of the MEMP are to monitor the 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) and macroinvertebrate monitoring based on the Australian River Assessment System (AUSRIVAS) sampling and assessment framework.

With these procedures in place, ALS will be able to provide ActewAGL with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this program will also support ActewAGL'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 ActewAGL's operational requirements.

1.2 Scope of Work

The works outlined in the proposal (Ecowise, 2009) included the following:

- Bi-annual sampling to commence in spring 2008
- Macroinvertebrate sampling of both the riffle and edge habitats as per 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 ALS's NATA accredited laboratory.

2 Materials and Methods

2.1 Study Sites

As stated in the objectives of this program, macroinvertebrate community composition and water quality is to be monitored along the Murrumbidgee River between the Tantangara and Burrinjuck reservoirs, with the aim of obtaining baseline information about ecological condition. Ecological monitoring was conducted in accordance with ANZECC and ARMCANZ (2000) guidelines.

The upper Murrumbidgee River is impacted by a range of land-use practices throughout the catchment. Consequently, it was important to sample a sufficiently large number of sites to provide a realistic snap-shot of the current macroinvertebrate community across all existing land-use impacts. Both riffle and edge habitats were sampled, where possible, to provide a more complete picture of the macroinvertebrate community at each site.

Sites are the same as previous sampling runs and were chosen based on several criteria including:

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 (e.g. 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 10 sites upstream and 13 sites downstream of Angle Crossing (ACT), locations upstream and downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC) and several of the Murrumbidgee Rivers major tributaries (Table 1; Figure 1). The sites were divided up into four macro-reaches (zones) which represent geographic or hydrological changes (Allan and Castillo, 2008) throughout the system; and obvious changes in terms of land-use, 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. Hynes, 1970a; Frissell *et al*., 1986; Allan and Castillo, 2008). Details of the four zones are provided in Table 2.

During the previous sampling event, spring 2010, large amounts of rainfall received across the region resulted in increased flows at many of the targeted systems. Sites below the Murrumbidgee Pump Station (MPS), except MUR 29, could not be sampled safely during this sampling event (i.e. no sites from Zone 4 were sampled in spring 2010). In autumn 2011, two habitats (edge and riffle) were successfully sampled at all 23 sites except the furthest downstream site MUR 37. The riffle habitat at MUR 37 was inundated at the time of autumn sampling due to Burrinjuck Dam being at high capacity such that ponding impacted stream habitat upstream. Accordingly, a macroinvertebrate sample was only collected from the edge habitat at this site.

Table 1: Sampling site locations and details

Site Code	Location	Alt. (m)	Landuse	Habitat sampled
Mur 1	D/S Tantangara Reservoir	1200	Native	Riffle and Edge
Mur 2	Yaouk Bridge	1070	Grazing	Riffle and Edge
Mur 3	Bobeyan Road Bridge	968	Grazing	Riffle and Edge
Mur 4	Camp ground off Bobyon Road	968	Recreation / 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	Edge

Note: U/S – upstream, D/S - downstream

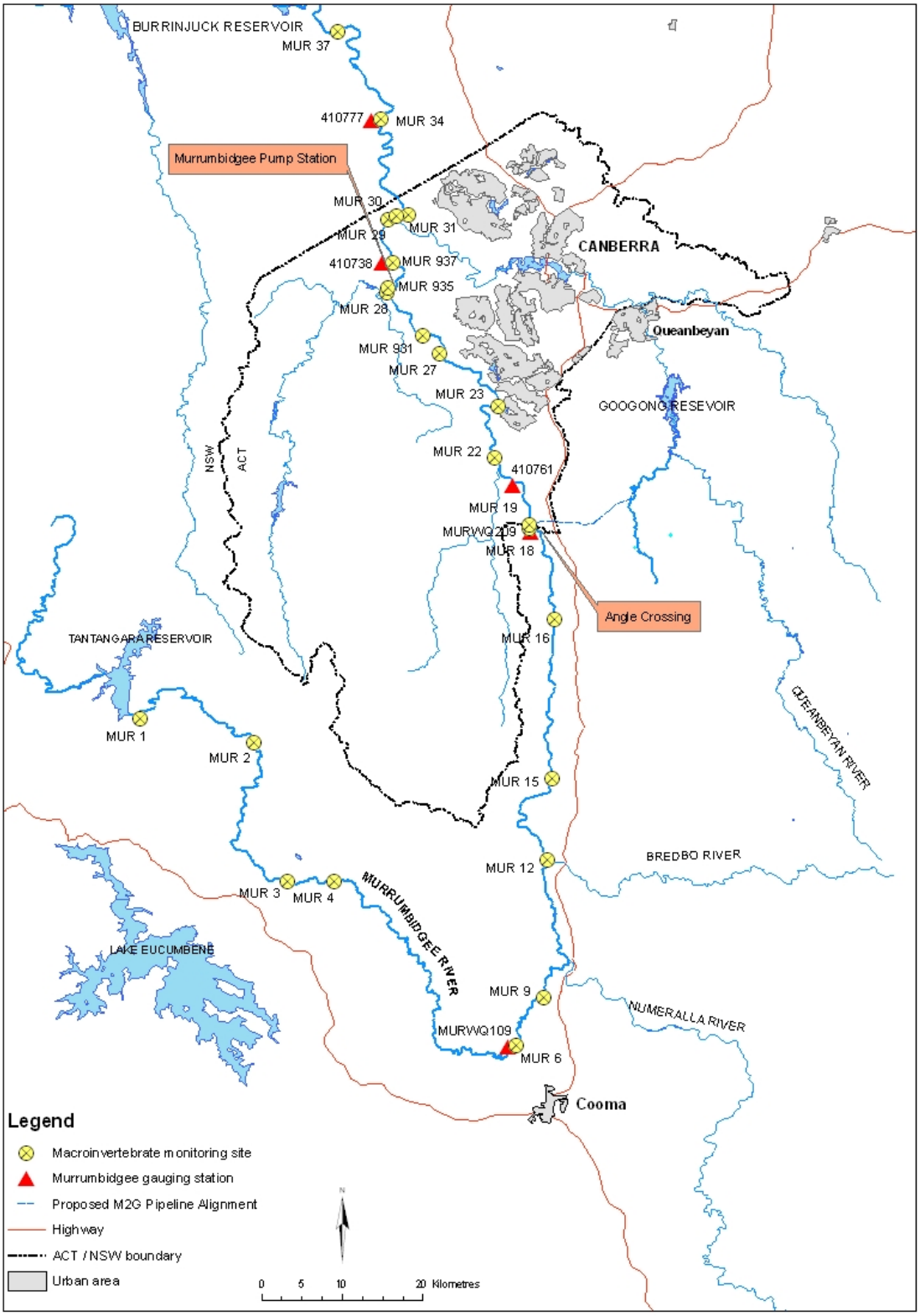


Figure 1: Location map of macroinvertebrate monitoring sites on the Murrumbidgee River

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 land-use. Downstream of LMWQCC. Previous work has shown a marked change in water quality downstream of the treatment plant

2.1.1 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS operated gauging stations located at: upstream of Angle Crossing (MURWQ09); Lobb's Hole (downstream of Angle Crossing: 410761); Mount MacDonald (downstream of the Cotter River Confluence: 410738) and Halls Crossing (located at MUR 34: 410777). Gauging locations and codes are given in Table 3. Stations were calibrated monthly and data were downloaded and verified before quality coding and storage in the database. Water level data was manually verified by comparing the logger value to staff gauge value and adjusted accordingly. Rain gauges were calibrated and adjusted as required. Records were stored on the HYDSTRA© database management system.

Table 3: River flow monitoring locations and parameters

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	MURWQ09	M'bidgee River, upstream of Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.5907	E 149.1179
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	410738	M'bidgee River @ Mt. MacDonald	WL, Q	S 35.2917	E 148.9565
4	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).

2.1.2 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 with 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.*, 2000b) for HYDROLAB® verification and nutrient analysis. All samples were placed on ice, returned to the ALS laboratory and analysed for various water quality parameters in accordance with the protocols outlined in A.P.H.A (2005). Collectively, this information on the water quality parameters will assist with the interpretation of biological

data and provide a basis to gauge changes that can potentially be linked to flow reductions at these key sites following water abstractions.

2.1.3 Macroinvertebrate sampling

Macroinvertebrate samples were collected and analysed in accordance with the ACT AUSRIVAS protocols for riffle and edge habitats (Coysh *et al*., 2000b). Samples were collected using a framed net (350 mm wide) with 250 µm mesh. Riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm) (Coysh *et al*., 2000b) 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. Edge habitat (backwaters or areas of low flow within 0.5m of the bank) was sampled 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 containers showing site codes, habitat and date information.

The purpose of this biannual seasonal report is to convey the results of the macroinvertebrate and water quality sampling from Tantangara Reservoir to Burrinjuck Reservoir in autumn 2011. Several sites within this report are also key components of the three main sub-sections of the 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 reported here, mainly in that replicate macroinvertebrate samples were collected for ecological assessment in the other sub-sections and a higher level (Genus) of identification was sometimes applied. This means that a more comprehensive list of macroinvertebrate taxa is likely to be captured for those sub-sections. For the Tantangara to Burrinjuck component of the MEMP, only one macroinvertebrate sample was included for each habitat type at each site and identification was only to Family level. In order to compare data from the Tantangara to Burrinjuck study to those collected as part of other study components as part of this report, the first sub-sample from the first replicate macroinvertebrates sample taken at each site from those other studies was selected for inclusion in the data analysis. As a result of this process, it should be recognised that there are small discrepancies between the taxonomic inventories, taxonomic richness measurements and presence / absence of taxa reported here and those reported in relation to other sub-sections of the MEMP.

2.2 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 extracted, one at a time. Macroinvertebrates were examined under a microscope until a total of 200 animals were collected. If 200 animals were identified before a cell had been completely analysed, identification continued until all animals within the cell were identified. Macroinvertebrates present in each sample were identified to family level except for some groups such as Chironomidae (identified to sub-family), Oligochaeta (identified to class) and Acarina (identified to order). Macroinvertebrate identification was undertaken using a range of published and working keys. QA/QC procedures for macroinvertebrate sample processing are described in Section 2.3.

Upon the completion of macroinvertebrate identification, the samples were transferred to robust vials with evaporation-proof rubber seals for long-term archiving. Samples can 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).

2.3 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. Voucher specimens were also used when required.
- ACT AUSRIVAS QA/QC protocols were followed.
- 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 (i.e. data that were not identified past Order level).
- 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).

2.4 Data analysis

2.4.1 Water quality

Principal Components Analysis (PCA) - based on Euclidean distances - was used to determine which physico-chemical variables were most strongly associated with differences among sites. PCA is a multivariate analysis technique that is commonly used on environmental data as an exploratory procedure. 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 and Keough, 2002); PCA summarises 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 (NMDS) 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 Components Analysis was performed in PRIMER version 6 (Clarke and Gorley, 2006) using normalised water quality variables collected in autumn 2011. The analysis began with 15 variables however nitrate and nitrite records were removed from the analysis because they did not provide any information beyond that available from NOx. Dissolved Oxygen (mg/L) was also removed in favour of Dissolved Oxygen (% saturation). Care must be taken with interpreting the results of NOx, nitrate, nitrite, phosphorus and ammonia as the Level of Reporting (LOR) for these variables are 0.01. This means that most values for these analytes are censored (i.e. their values were below detectable limits) and could produce misleading results. However, NOx and ammonia were included in the

analysis as the raw data indicated key differences between sites. Prior to multivariate analysis, total phosphorus, total nitrogen and turbidity values were log (x+1) transformed and NOx was square root transformed. Variables were only transformed where an improvement in "normality" was evident.

Water quality parameters were also examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams of temperate Australia (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. The model uses site-specific information to predict the macroinvertebrate fauna expected (E) in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics which cannot 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 ratios derived from this analysis are converted to Bandwidths (i.e. X, A-D; Table 4) which indicate the overall health of each site (Coysh *et al*. 2000a). Data are presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence base on site location and habitat conditions) and the previously mentioned rating bands (Table 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 condition from the two habitats. 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*., 2000a). This approach accords with the precautionary principle.

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; the presence or absence of these taxa might be a function of sampling effort rather than truly reflecting ecological change.

Table 4: AUSRIVAS Band- widths and interpretations for the ACT autumn edge and riffle models

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

2.4.3 Univariate indices

Several additional metrics to the AUSRIVAS were utilised. This included: taxa richness (the number of taxa recorded in a sample –based on the applied taxonomic resolution level); EPT richness (number of Ephemeroptera, Plecoptera and Trichoptera families in a given sample) and the Stream Invertebrate Grade Number – Average Level (SIGNAL 2) index.

SIGNAL is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families. The sensitivity values for each family have been determined 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.

Comparisons between zones based on the various univariate metrics applied were done 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.

2.4.4 Macroinvertebrate communities

The macroinvertebrate data were examined separately for riffle and edge habitats, as these habitats are well known to support different macroinvertebrate taxa. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006). Univariate statistics were performed using STATISTICA version 9 (StatSoft Inc, 1984-2010).

Non- metric multidimensional scaling (NMDS)

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 simplifies 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 and Warwick, 2001). The number of dimensions (axes) used in the NMDS procedure was based on the resultant Stress levels. Stress is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions (i.e. it is a measure of goodness

of fit of the ordination plot relative to patterns in the original data matrix) and will increase as the number of dimensions is reduced (Kruskal, 1964).

Classification

Classification or cluster analysis is a mathematical method of grouping entities according to the relative similarity of their attributes. In an ecological setting these techniques can be used to group sites according to how similar their macroinvertebrate community is. The key to this technique is the Bray-Curtis similarity matrix which is constructed from the individual similarities between all possible pairs of sites (Bray & Curtis, 1957; Clifford & Stephenson, 1975). From this matrix, a classification using Hierarchical Agglomerative Clustering is obtained and represented visually as a dendrogram. The dendrogram displays sites in groups of varying size according to the similarities between them. In other words, sites which are similar in macroinvertebrate assemblage will be grouped together on the dendrogram.

Cluster analysis can be useful in detecting patterns within complex data sets but it is not without limitations. The nature of this technique is such that linkages will often be made between sites based on chance similarities. The SIMPROF test (described below) can be used in conjunction with the cluster analysis to prevent misinterpretation of random similarities as "true" patterns.

SIMPROF (SIMilarity PROFile)

The SIMPROF test determines whether a dataset contains a "multivariate structure. It can be used as a safeguard against misinterpreting chance similarities as meaningful patterns. SIMPROF works by rearranging observations (i.e. taxa counts) across the samples to simulate random data and then recalculating the similarities between the samples. The similarities from the 'random' data are then compared to the similarities from the observed data. This process is replicated several times, each time with the observed data being compared to a different 'random' set of data. If the similarities calculated from the actual observations are found to be significantly different from those calculated from the simulated 'random' data then it is concluded that any pattern detected is 'real' and not just a chance occurrence (Clarke and Warwick, 2001). When used in conjunction with cluster analysis, the SIMPROF test will indicate meaningful clusters within the dendrogram by outlining them in red.

PERMANOVA (Permutational MANOVA)

PERMANOVA is an extension to the PRIMER multivariate software package for biological and environmental data. The PERMANOVA procedure is based on the principals of a MANOVA (multivariate analysis of variance) with some differences. The key to PERMANOVA is the use of permutation to determine differences between categorical groups. This is done by randomly rearranging the observations to different sample labels and reanalysing the data to obtain the distribution of data that may be expected "by chance" if no multivariate patterns exist. This distribution of permuted data replaces the theoretical distribution which is generally utilised by parametric statistics such as MANOVA. The calculated test statistic (pseudo F) is compared to the permutational distribution in order to determine whether the observed pattern is likely to have occurred by chance or whether there are "true multivariate patterns" within it. The use of permutation to create the null distribution means that many of the assumptions which exist for MANOVA are avoided. For example, there is no assumption that the test data follows a normal distribution. Also, there is no necessity for data cells to be equal as long as an appropriate Sum of Squares (SS) calculation method is used. PERMANOVA was used to test for differences in the macroinvertebrate communities between groups (Zones).

SIMPER (SIMilarity PERcentages)

The SIMPER routine was used to identify taxa that contributed strongly to the average dissimilarity between site groups identified from the cluster analysis (classification). SIMPER computes the average dissimilarity (Bray-Curtis) between all pairs of inter-group samples (every sample in Group 1 with every sample in Group 2 etc.) and then breaks this average down into the separate contributions from each taxon. In addition to calculating the average dissimilarity between groups, SIMPER also calculates the average similarity within a group.

BEST

BEST is a multivariate statistical technique that allows the user to evaluate the match between the community assemblage data and a set of corresponding environmental variables. It does this by determining all possible combinations of environmental variables (each on its own, each paired with one other, each paired with two others etc.) and calculating the similarities for each combination. Each matrix of environmental variable similarities is then correlated with the resemblance matrix of biotic assemblage. The BEST procedure selects the subset of environmental variables which produces the highest correlation coefficient. These variables are those which best explain the community composition seen across the sites (Clarke and Warwick, 2001). This technique was only employed where cluster (and SIMPROF) analysis suggested a difference between zones.

2.5 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))-03.

ALS field staff maintains current ACT AUSRIVAS accreditation.

3 Results

3.1 Hydrology and rainfall

Figure 2 below shows flows during autumn 2011 at the four river flow monitoring locations (Table 3). Flows were generally higher at Hall's Crossing and Mt MacDonald monitoring locations compared to Angle Crossing and Lobb's Hole sites. Figure 2 also indicates rainfall in the area. For clarity, total rainfall (mm) is only shown from the Lobb's Hole gauging site. Rainfall records are usually similar between Lobb's Hole, Angle Crossing and Halls Crossing. Accordingly, Lobb's Hole rainfall results are considered to provide a fair representation of the broad scale patterns occurring during autumn. The patterns in flow measured at the four monitoring locations appear to reflect a delayed response to peaks and troughs in rainfall as measured at Lobb's Hole (Individual station statistics are presented in Table 5).

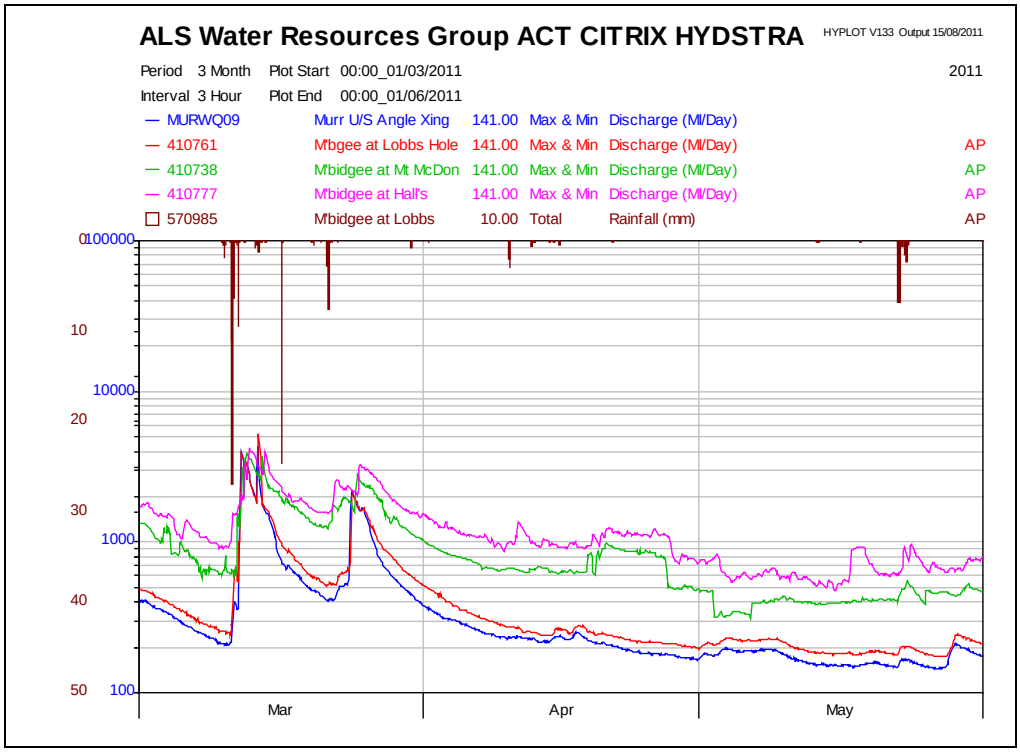


Figure 2: Autumn hydrograph of the Murrumbidgee River at Angle Crossing (upstream) (blue); Lobb's Hole (red), Mount MacDonald (green) and Halls Crossing (pink).

During autumn 2011 there was periodic rainfall, with the majority of this occurring in mid-March (Figure 2). Some periods of rainfall were observed during April and May 2011 but the magnitude of the rainfall events was much smaller and less frequent during these months than in March. Table 5 indicates that flows were highest at Hall's Crossing and lowest upstream of Angle Crossing. In response to rainfall patterns, flows were much higher at all monitoring sites in March 2011 compared to April and May (Table 5). Flows during autumn 2011 were lowest in May.

Table 5: Average monthly flow and rainfall statistics for autumn 2011 at MURWQ09, Lobb's Hole, Mount MacDonald and Hall's Crossing. Flow values are averages (ML/Day). Rainfall values indicate total rainfall (mm).

Site Code	March Average flow (ML/d)	April Average flow (ML/d)	May Average flow (ML/d)	Rainfall (mm) (autumn total)
Upstream of Angle Crossing (MURWQ09)	775	231	169	105.2
Lobb's Hole (410761)	870	276	201	126.8
Mt. MacDonald (410738)	1520	729	418	-
Hall's Crossing (410777)	1920	1060	661	59.8

3.2 Water Quality

3.2.1 *In- situ* and grab samples

Water quality results recorded at Murrumbidgee River sites in autumn 2011 are presented in Table 6. These values were either analysed from grab samples (nutrients, TSS) or recorded by a probe, *in-situ* (Dissolved oxygen (DO), pH, temperature). Levels of Electrical Conductivity (EC), turbidity, DO and pH were within the recommended range (ANZECC and ARMCANZ, 2000) for almost all sites. EC and turbidity were slightly below recommended levels at MUR 1 and MUR 2. DO was also slightly lower than recommended at MUR 1. Values of pH were around or slightly above the maximum recommended range at MUR 29, MUR 31, MUR 34 and MUR 37. NOx levels were well above the recommended range at all three sites in Zone 4.

Table 6: *In- situ* and grab sample water quality results for autumn 2011. ANZECC & ARMCANZ guidelines are in bold parentheses. Values outside recommended guideline levels are highlighted yellow. Borderline values are highlighted in orange.

Zone	Site	Time	Temp. (˚C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	DO (% Sat.)	DO (mg/L)	Alkalinity	NOX (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
ANZECC Guideline levels			**N/A**	**30- 350**	**2- 25**	**N/A**	**6.5- 8**	**90- 110**	**N/A**	**N/A**	**<0.015**	**N/A**	**N/A**	**N/A**	**<0.02**	**<0.25**
Tantangara - Cooma	MUR 1	11.30	4.9	27.6	1.2	2	7.0	89.6	11.4	15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05
	MUR 2	13.30	6.2	25.8	1.5	2	7.2	91.1	11.5	17	<0.01	<0.01	<0.01	<0.01	<0.01	0.06
	MUR 3	14.45	7.9	30.3	3.0	4	7.3	94.4	11.4	18	<0.01	<0.01	<0.01	<0.01	0.01	0.15
	MUR 4	15.30	7.4	36.1	5.0	5	7.4	92.5	11.3	20	<0.01	<0.01	<0.01	<0.01	0.01	0.18
Cooma – Angle Crossing	MUR 6	13.00	9.6	49.2	3.1	4	7.5	97.3	11.2	25	<0.01	<0.01	<0.01	0.02	0.02	0.15
	MUR 9	14.00	10.0	50.8	2.6	4	7.5	95.5	10.9	27	<0.01	<0.01	<0.01	<0.01	0.02	0.16
	MUR 12	13.00	12.6	92.4	6.2	11	7.7	93.3	10.1	40	<0.01	<0.01	<0.01	<0.01	0.04	0.27
	MUR 15	11.00	12.9	97.4	6.2	10	7.7	96.6	10.3	43	<0.01	<0.01	<0.01	<0.01	0.04	0.26
	MUR 16	10.10	10.9	105.7	7.5	10	7.8	95.5	10.7	46	<0.01	<0.01	<0.01	<0.01	0.03	0.28
	MUR 18	14.00	12.2	107.9	5.4	10	7.8	98.8	10.7	47	<0.01	<0.01	<0.01	0.03	0.04	0.26

Table 6: continued…

Zone	Site	Time	Temp. (˚C)	EC(µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	DO (% Sat.)	DO (mg/L)	Alkalinity	NOx (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
ANZECC Guideline levels			N/A	30- 350	2- 25	N/A	6.5- 8	90- 110	N/A	N/A	<0.015	N/A	N/A	N/A	<0.02	<0.25
Angle Crossing – LMWQCC	MUR 19	15.30	12.3	108.7	5.2	9	7.8	99.3	10.7	46	<0.01	<0.01	<0.01	<0.01	0.03	0.27
	MUR 22	13.35	11.7	103.4	8.6	27	7.9	102.2	11.2	47	<0.01	<0.01	<0.01	<0.01	0.03	0.28
	MUR 23	11.50	9.8	107.1	5.7	7	7.8	96.8	11.1	48	<0.01	<0.01	<0.01	0.02	0.02	0.26
	MUR 27	10.50	10.7	109.8	5.6	8	7.9	99.8	11.2	49	<0.01	<0.01	<0.01	0.02	0.03	0.27
	MUR 931	09.30	13.3	110.1	6.5	11	7.6	97.3	10.3	47	<0.01	<0.01	<0.01	0.04	0.03	0.27
	MUR 28	12.00	13.9	111.6	6.9	11	7.8	100.0	10.5	48	<0.01	<0.01	<0.01	0.04	0.03	0.27
	MUR 935	13.30	14.3	112.1	6.0	10	7.9	106.0	11.0	48	<0.01	<0.01	<0.01	<0.01	0.03	0.27
	MUR 937	16.05	14.8	114.6	4.3	9	7.9	109.1	11.2	48	<0.01	<0.01	<0.01	0.01	0.02	0.27
	MUR 29	15.05	15.7	107.3	5.4	6	8.0	103.9	10.4	49	<0.01	<0.01	<0.01	0.01	0.02	0.25
	MUR 30	09.00	9.5	100.5	4.6	5	7.8	96.1	11.1	46	<0.01	<0.01	<0.01	0.02	0.02	0.23
D/s Mol. c/f to ~ 5km u/s Taemas Bridge	MUR 31	14.00	15.6	218.6	8.4	10	8.1	107.3	10.8	57	4.5	4.5	<0.01	<0.01	0.04	4.7
	MUR 34	09.30	15.3	189.6	7.6	11	8.0	103.4	10.5	55	2.8	2.8	<0.01	0.01	0.03	3.2
	MUR 37	11.50	16.3	198	7.1	9	8.0	100.3	9.9	59	2.3	2.3	<0.01	0.02	0.02	2.7

There were several exceedances of the ANZECC and ARMCANZ (2000) water quality guidelines for nutrients. Total phosphorus levels were equal to or above the recommended level at all sites in Zone 2, 3 and 4. Total nitrogen levels were also higher than recommended at all sites in Zone 2, 3 and 4 except for MUR 6, MUR 9 and MUR 30. Total nitrogen values were lowest at sites within Zone 1 sites; with mid-range values occurring within Zone's 2 and 3. Total nitrogen was extremely high at MUR 31, MUR 34 and MUR 37 and far above guideline (ANZECC and ARMCANZ, 2000) limits.

Results show a steady increase in total phosphorus, temperature, alkalinity and EC between furthest upstream site MUR 1 and MUR 9 (see Figure 3 to Figure 8). No distinctive or consistent trend was observed for these measurements between MUR 12 and MUR 30 (excepting temperature). Water temperature seemed to increase between MUR 931 and MUR 29 and then again at sites downstream of the Molonglo River (Zone 4 sites). Levels of alkalinity, NOx, pH, turbidity and EC were also notably higher at MUR31, MUR 34 and MUR 37 compared to most other sites but the most noteworthy increase was in total nitrogen.

Total suspended solids were quite variable between sites. As with most other parameters, levels of TSS were lowest at Zone 1 sites but the highest value was observed at MUR 22 (Tharwa bridge). A possible cause in noted in the discussion.

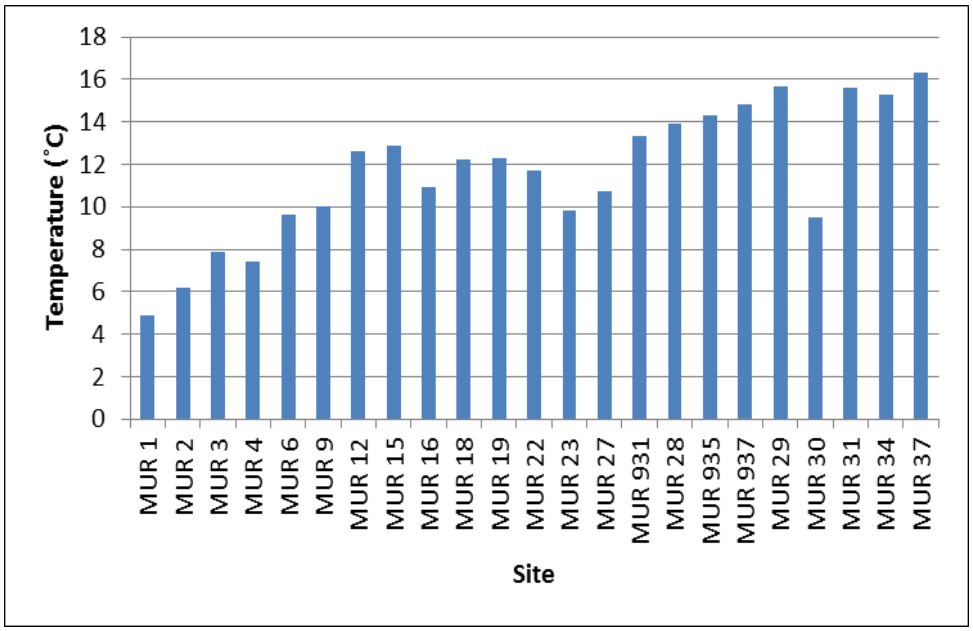


Figure 3: *In- situ* water temperature in autumn 2011

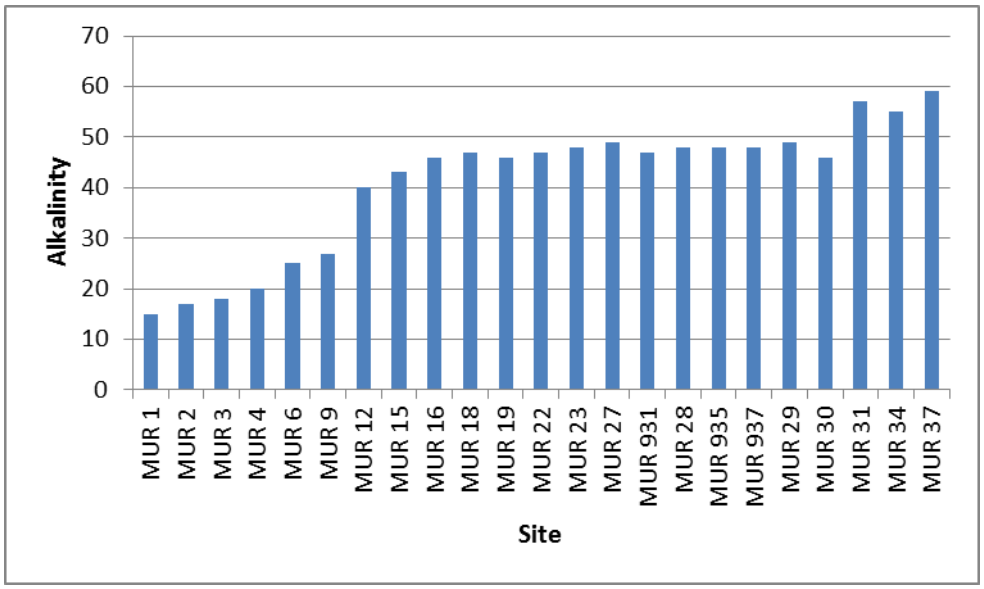


Figure 4: *In- situ* Alkalinity at Murrumbidgee River sites in autumn 2011

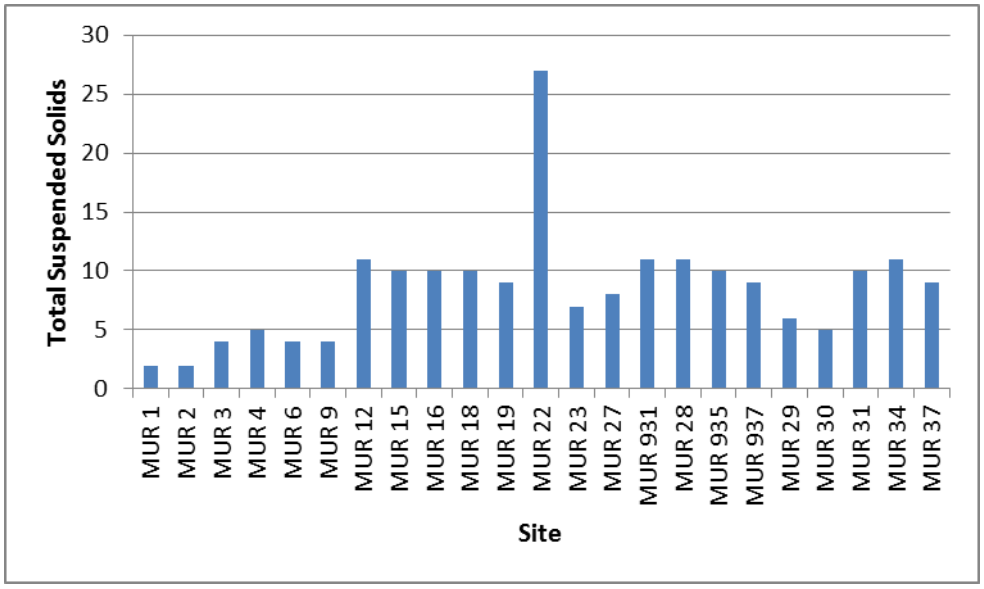


Figure 5: Total Suspended Solids at Murrumbidgee River sites in autumn 2011

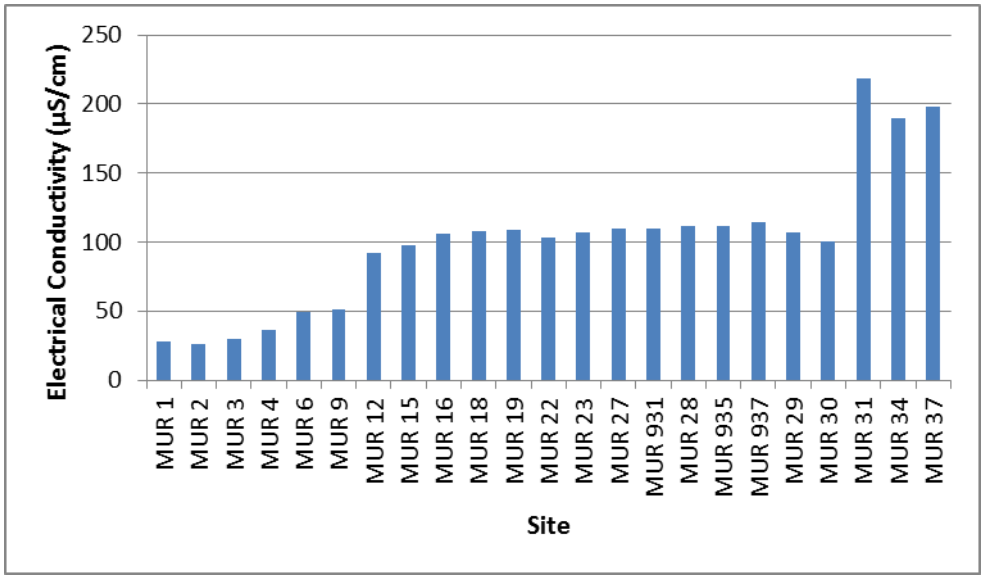


Figure 6: *In- situ* Electrical Conductivity at Murrumbidgee River sites in autumn 2011

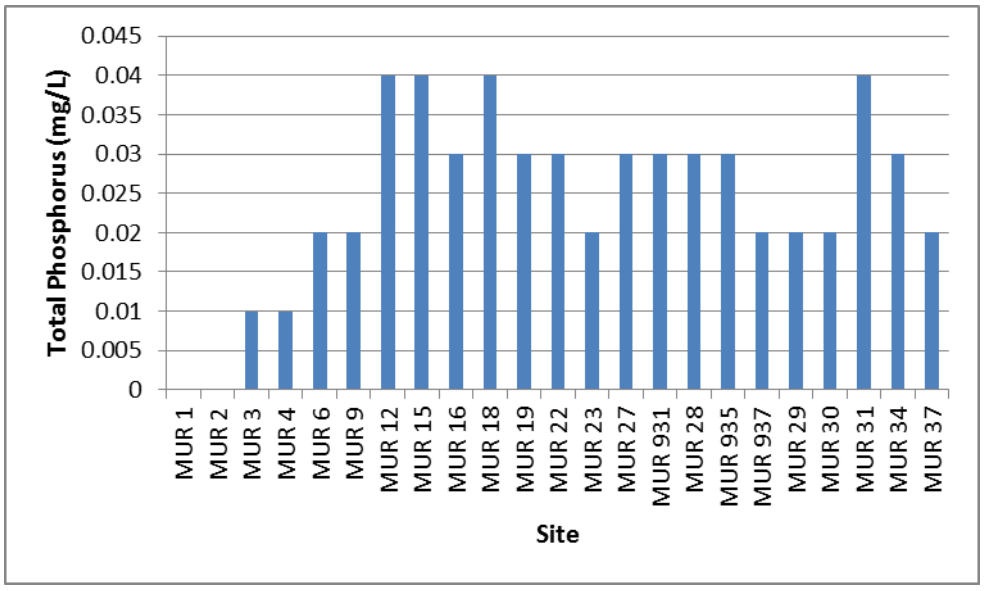


Figure 7: Total Phosphorus at Murrumbidgee River sites in autumn 2011

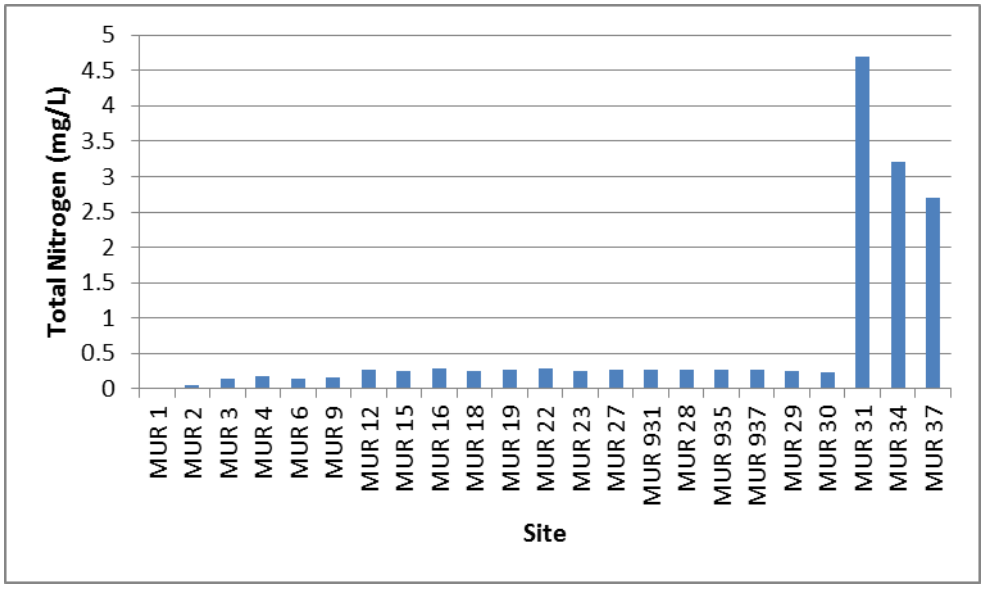


Figure 8: Total Nitrogen at Murrumbidgee River sites in autumn 2011

The results of Principal Components Analysis conducted on the in-situ water quality results are shown in the ordination plot in Figure 9. The PCA indicates a separation of the data points according to zone. In particular, sites in Zone 4 are most clearly separated from the other sites. The arrangement of data points for MUR 1 to MUR 9 suggests a possible longitudinal gradient of change in one or more water quality parameters, at least within the upstream sites. The two principal components account for approximately 72.2% of the variation in water quality between sites. The first principal component (PC1) is characterised most strongly by decreasing temperature, pH, EC, TKN, turbidity, alkalinity and DO. Principal component two (PC2) is characterised by decreasing NOx and total nitrogen and increasing TSS and ammonia. This suggests that the sites from Zone 1 and the furthest upstream two sites of Zone 2 (MUR 6 and MUR 9) have a lower temperature, and lower values of pH, EC, TKN, turbidity, alkalinity and DO compared to the remaining sites. This trend is in keeping with the graphs above.

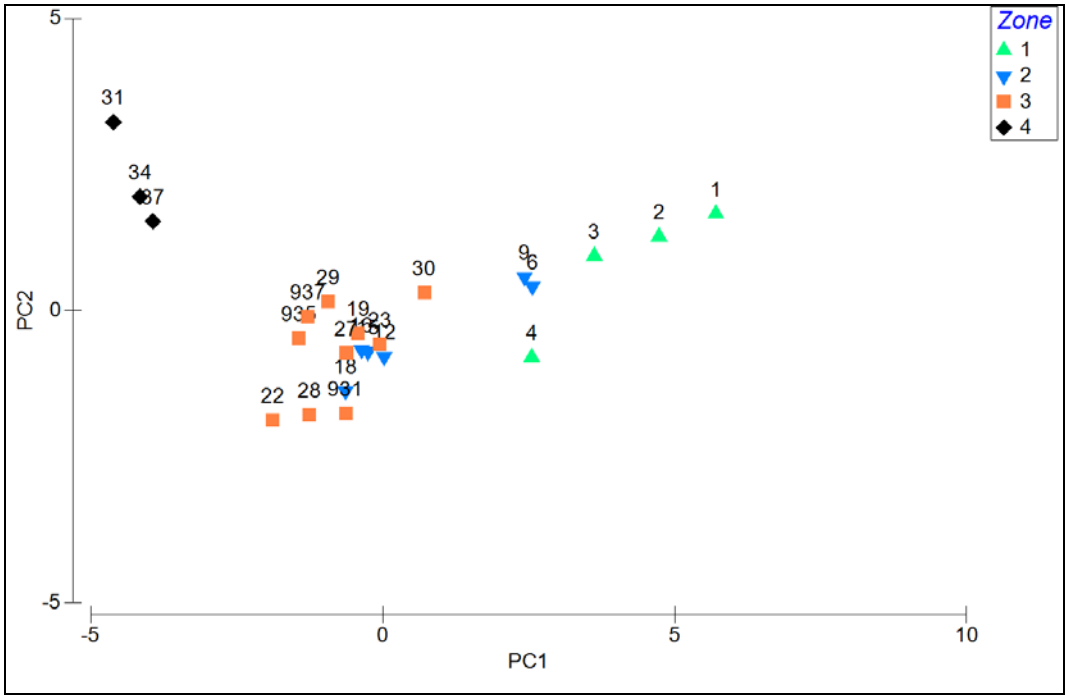


Figure 9: Correlation based Principal Components Analysis on water quality data collected in autumn 2011.

Note: Numbers relate to site codes outlined in Table 1.

3.2.2 Continuous water quality

The continuous trends in water quality for the three hydrological monitoring stations are captured in Figure 10 to Figure 12. Turbidity, EC and pH were highly variable in March 2011 and much more stable between April and May. Dissolved Oxygen readings were fairly stable at Angle Crossing compared to the fluctuating values measured at Lobb's Hole and Hall's Crossing. There were several instances in which DO was lower than recommended (ANZECC and ARMCANZ, 2000) at Hall's Crossing, especially in May 2011. Turbidity levels peaked at all three sites in early March before settling into a low and stable level for the remainder of the season.

EC and pH levels exhibited distinctive peaks and troughs, particularly early in the season. These fluctuations were most distinctive at Angle Crossing and Lobb's Hole. EC levels were elevated for a period of several days in late March to early April. pH followed an almost identical pattern to EC, although in reverse. Despite fluctuating levels, EC and pH remained within the guideline limits at all three sites during the majority of autumn 2011. pH records at were not available for Lobb's Hole for most dates in autumn 2011 due to sensor mal-function and a delay in availability of spare parts.

Water temperatures declined steady at all three monitoring sites during the autumn period. The slight increase in temperature of Zone 4 sites compared to Zone 3 sites observed from *in-situ* monitoring was not replicated in the plots of continuous water quality. Only minor differences in temperature were evident between Lobb's Hole (upstream of confluence with Molonglo River) and Halls Crossing (downstream of confluence with Molonglo River) monitoring stations. Temperatures in May were generally higher at Halls Crossing compared to Lobb's Hole but the reverse was true in early autumn.

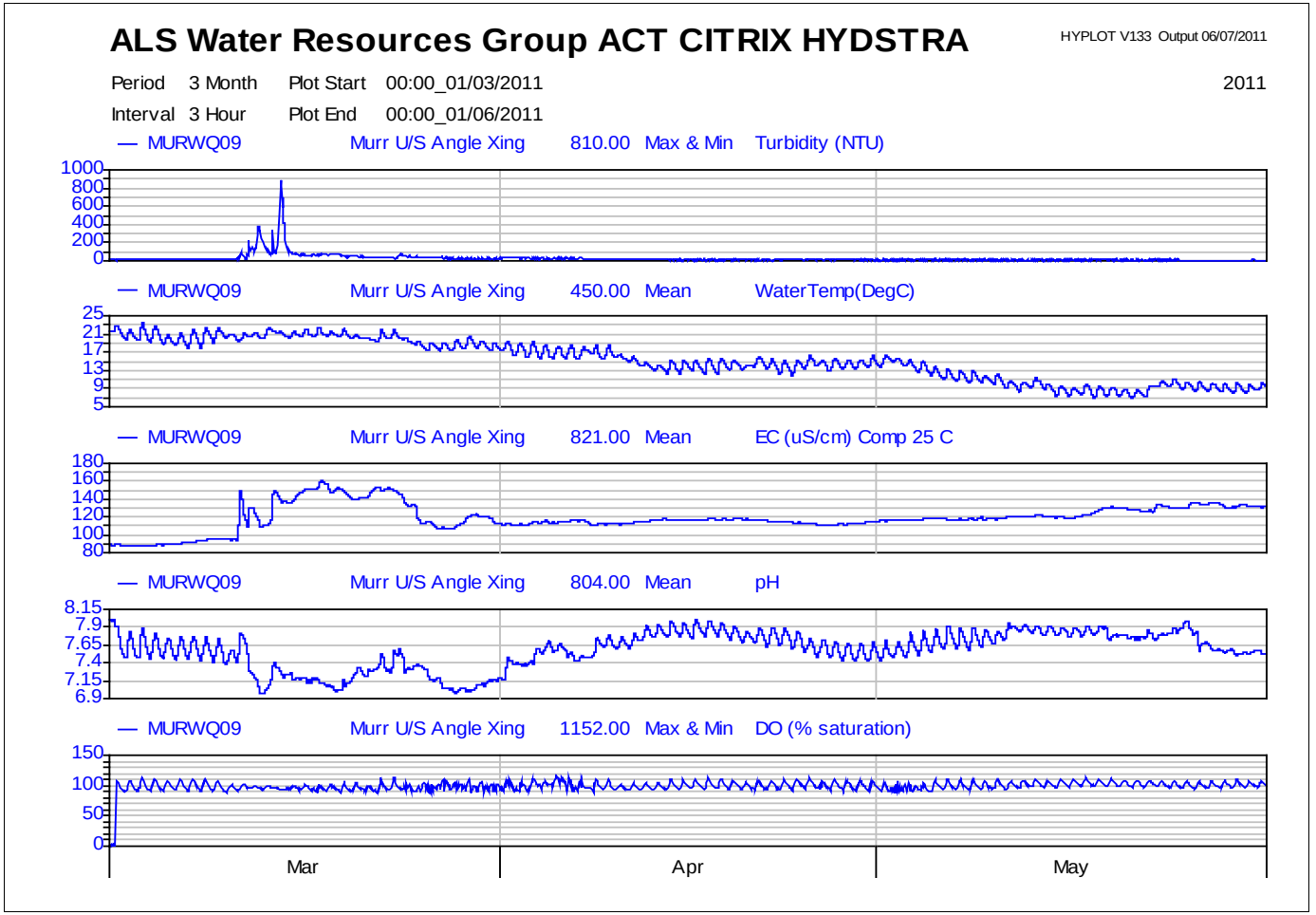


Figure 10: Continuous water quality results recorded upstream of Angle Crossing in autumn 2011 (MURWQ09)

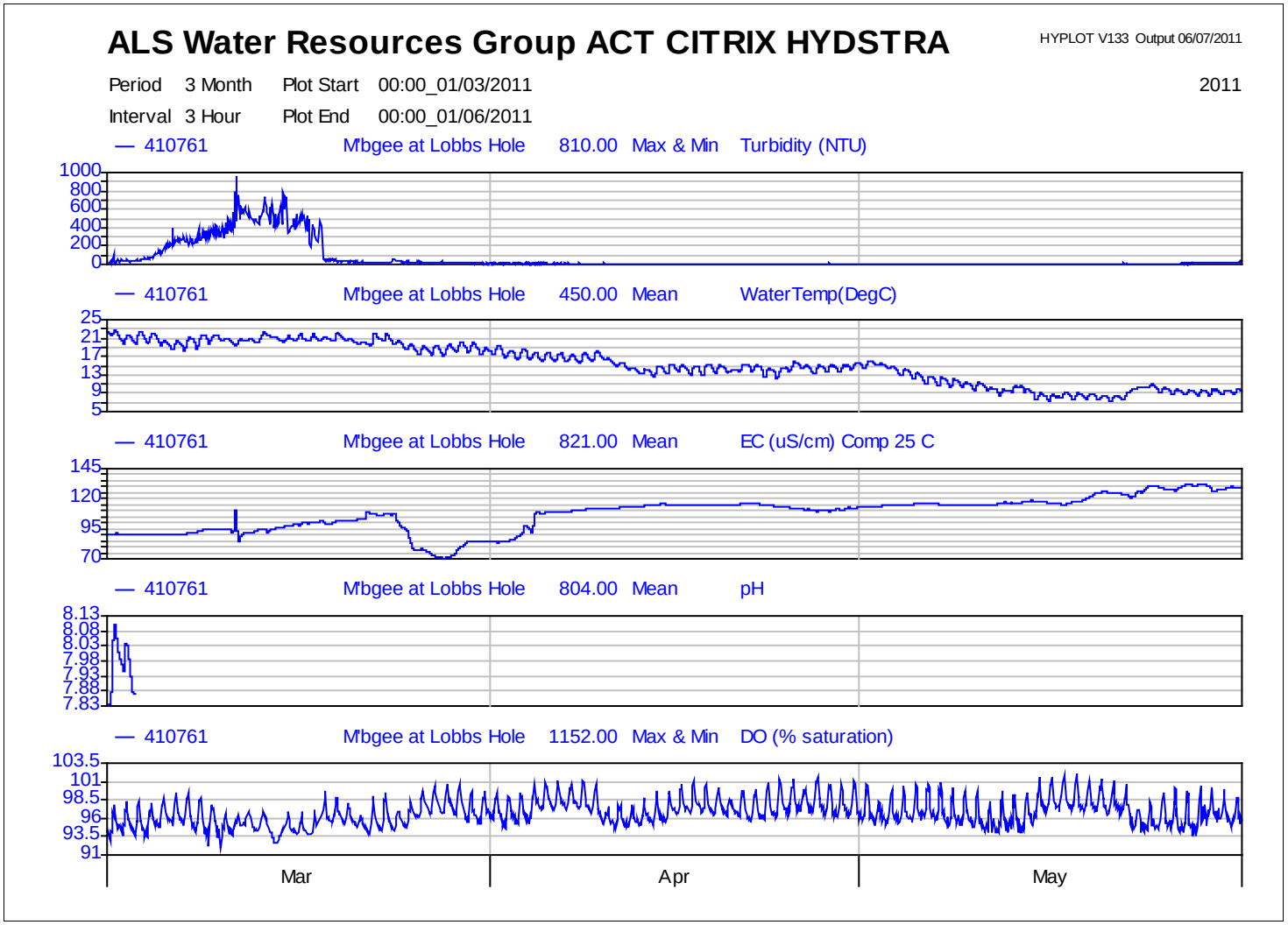


Figure 11: Continuous water quality results for Lobb's Hole in autumn 2011 (410761)

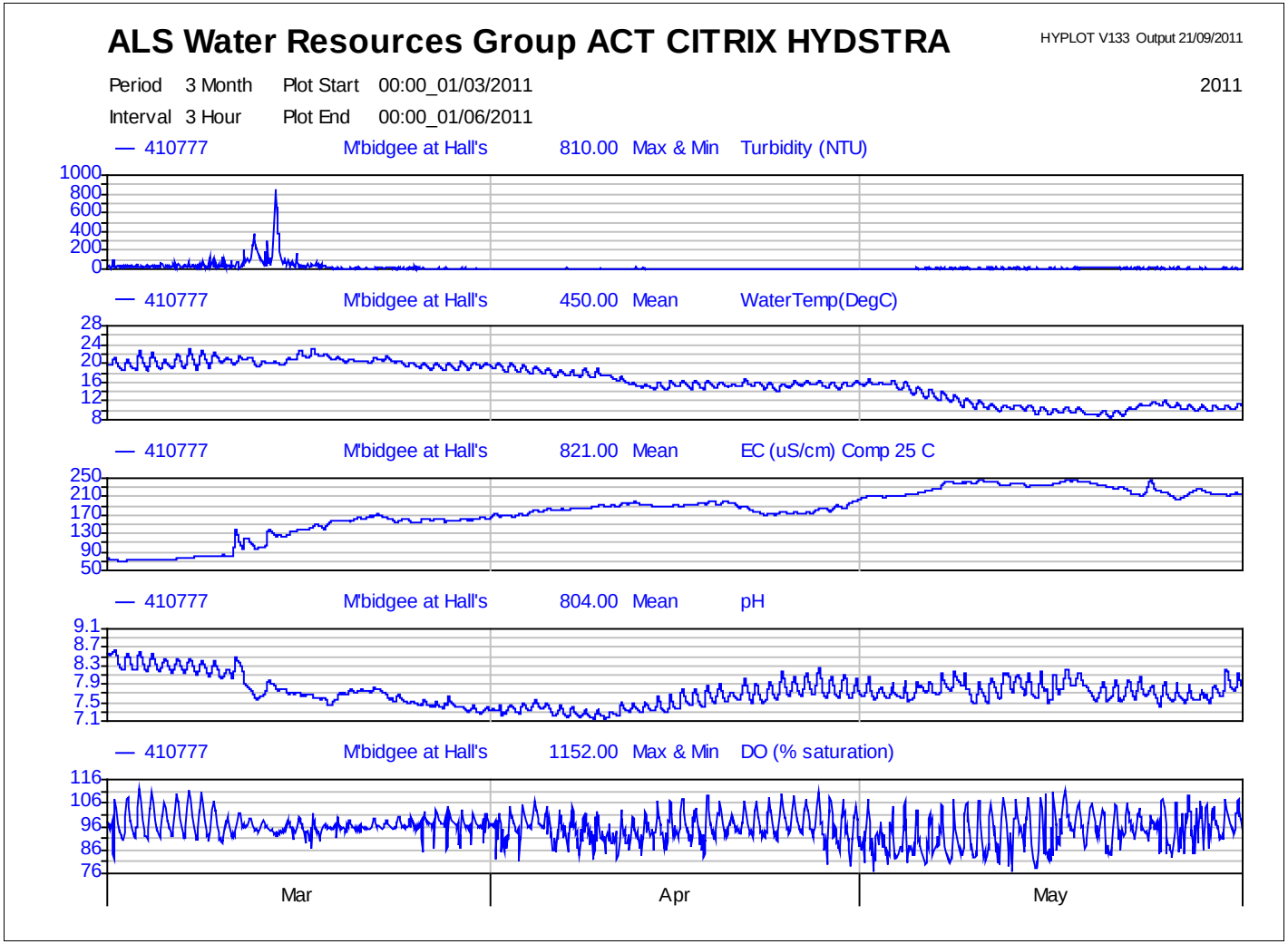


Figure 12: Continuous water quality results for Hall's Crossing in autumn 2011 (410777)

3.3 Macroinvertebrate communities

The relative similarity of the macroinvertebrate community collected from Riffle habitat in autumn 2011 is shown in Figure 13. The stress score for the MDS is <0.2 indicating that the diagram provides a fairly realistic representation of the relative similarity between macroinvertebrate samples from riffle habitat. The plot suggests some separation of the macroinvertebrate samples between zones but not to the extent that samples scores for each zone form distinct clusters in this plot. Samples from the same zone were generally more similar to each other within zones 3 and 4 than within zones 1 and 2 based on the spread of sample scores in Figure 13. Macroinvertebrate riffle samples from MUR 1, MUR 2 and MUR 3 are more strongly separated from the other samples and each other in ordination space, suggesting limited consistency in macroinvertebrate taxonomic composition among zone 1 sites.

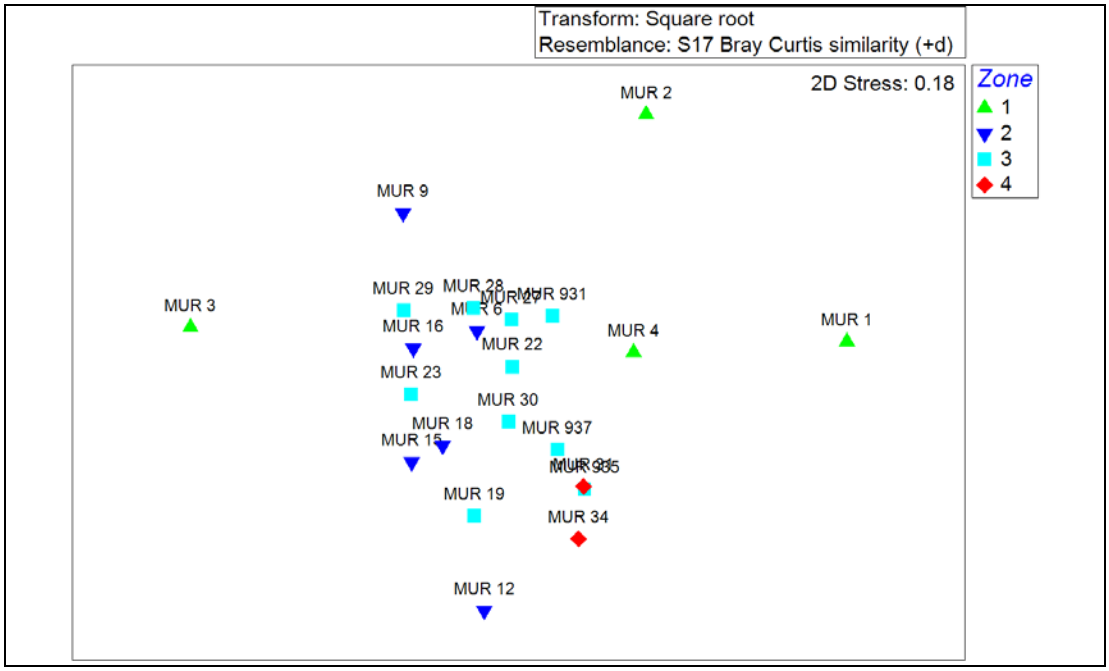


Figure 13: Non- metric multidimensional scaling of family level data for the autumn riffle samples.

Cluster analysis was used as a secondary method to analyse differences in the riffle macroinvertebrate community between samples. The dendrogram in Figure 14 provides the results of the cluster analysis. A SIMPROF test was conducted in order to validate any groups identified in the Cluster analysis. Significant groupings are considered to be those which contain "true" multivariate structure rather than chance similarities. The branches highlighted in red represent those groups that were determined to be significant based on the SIMPROF procedure. This diagram indicates two significant groups which contain multivariate structure. The first of these groups includes MUR 2 and MUR 4 from Zone 1. The macroinvertebrate community collected from the riffle habitat at these two sites were found to be approximately 70% similar. The other significant group contains all samples from zones 2, 3 and 4. The sites within this group are a minimum of 58% similar and a maximum of 85% similar (MUR 935 and MUR 31). Additionally, MUR 1 and MUR 3 are separated from all other sites and from each other. The sample which was most different to all others is MUR 1 having approximately 42% similarity with the closest site.

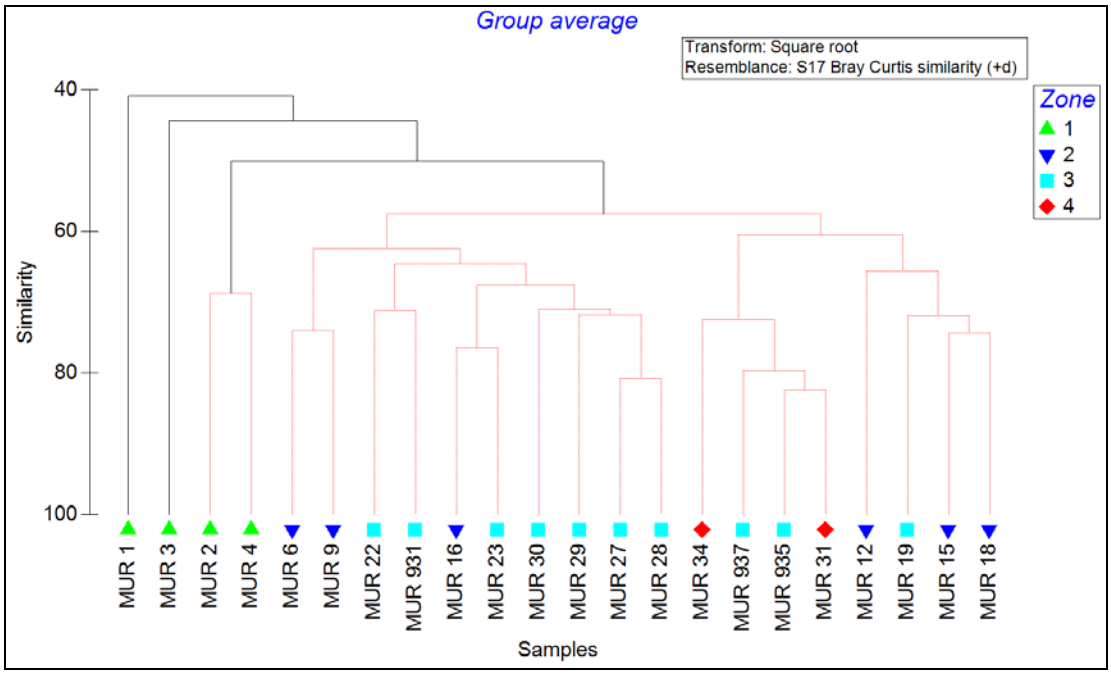


Figure 14: Cluster analysis of family level data for the autumn riffle samples. Branches marked in red denote significant groupings based on SIMPROF.

PERMANOVA was used to detect significant differences in the community composition of the macroinvertebrate community of riffle habitat between zones. PERMANOVA detected significant (p<0.05) differences in the community composition of riffle samples between zones. The results of multiple comparisons testing for pairwise differences in zones are provided in Table 7. This table indicates significant differences in macroinvertebrate riffle community between Zone 1 and both Zone 2 and Zone 3. A significant difference in macroinvertebrate riffle community was also detected between Zone 2 and Zone 3 sites (p<0.05).

Table 7: p- values for multiple comparisons between Zones for riffle macroinvertebrates. Significant p- values are highlighted in red (p< 0.05). p- values were determined using permutation

Zone	1	2	3
1			
2	0.01		
3	0.00	0.02	
4	0.13	0.06	0.12

PERMANOVA also quantified the average similarity between samples in different zones (Table 8). The highest intra-zone similarity was between samples from Zone 4 sites while the lowest intra-zone similarity was between samples within Zone 1. Inter-zone similarity was lowest between samples from Zone 1 and Zone 4 and highest between samples from Zone 3 and Zone 4.

Table 8: Average similarity in riffle macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	44.86%			
2	46.63%	62.51%		
3	47.03%	60.35%	64.40%	
4	43.75%	54.18%	62.40%	66.87%

SIMPER analysis was used to determine taxa which contributed most to the differences observed between zones. Table 9 indicates that dissimilarity between Zone1 and Zone 4 macroinvertebrate assemblages was based on differences in the relative abundance of five key taxa. There were smaller numbers of Oligochaeta, Hydropsychidae and Caenidae in Zone 1 sites (compared to Zone 4 sites) and higher numbers of Simuliidae and Gripopterygidae.

Table 9: Major differentiating taxa between Zone 1 and Zone 2 riffle samples

Family	Av abundance		Contribution to group differences
	Zone 1	Zone 2	
Oligochaeta sp.	3.39	36.33	7.51%
Hydropsychidae	18.13	30.47	4.52%
Simuliidae	14.48	13.19	3.78%
Caenidae	9.91	23.09	3.74%
Gripopterygidae	21.19	4.95	3.64%

Numbers of Gripopterygidae were also higher in Zone 1 compared to Zone 3; while the abundance of Oligochaeta and Hydropsychidae was lower (Table 10). Additionally, the numbers of Baetidae and Simuliidae were lower in Zone 1 compared to Zone 3.

Table 10: Major differentiating taxa between Zone 1 and Zone 3 riffle samples

Family	Av abundance		Contribution to group differences
	Zone 1	Zone 3	
Gripopterygidae	21.19	1.40	4.73%
Baetidae	15.21	28.41	4.23%
Simuliidae	14.48	18.26	4.01%
Hydropsychidae	18.13	24.03	3.62%
Oligochaeta sp.	3.39	14.90	3.44%

The key differences between Zone 2 and Zone 3 were the higher abundance of Oligochaeta and Hydropsychidae and lower abundance of Simuliidae, Baetidae and Chironominae at Zone 2 (Table 11).

Table 11: Major differentiating taxa between Zone 2 and Zone 3 riffle samples

Family	Av abundance		Contribution to group differences
	Zone 2	Zone 3	
Oligochaeta sp.	36.33	14.90	6.21%
Simuliidae	13.19	18.26	4.02%
Baetidae	25.24	28.41	3.72%
Hydropsychidae	30.47	24.03	3.63%
Chironominae	9.19	17.90	2.84%

The MDS plot in Figure 15 portrays the relative similarity of the macroinvertebrate community collected from edge habitat at the 23 sites. This plot shows a more widely dispersed pattern than was seen in the plot for riffle sampling. There is no clear separation between zones although sites are often most closely linked to at least one other site from the same zone. As was seen with the MDS for riffle samples, sample scores for zone 1 sites are the most dispersed within the MDS plot.

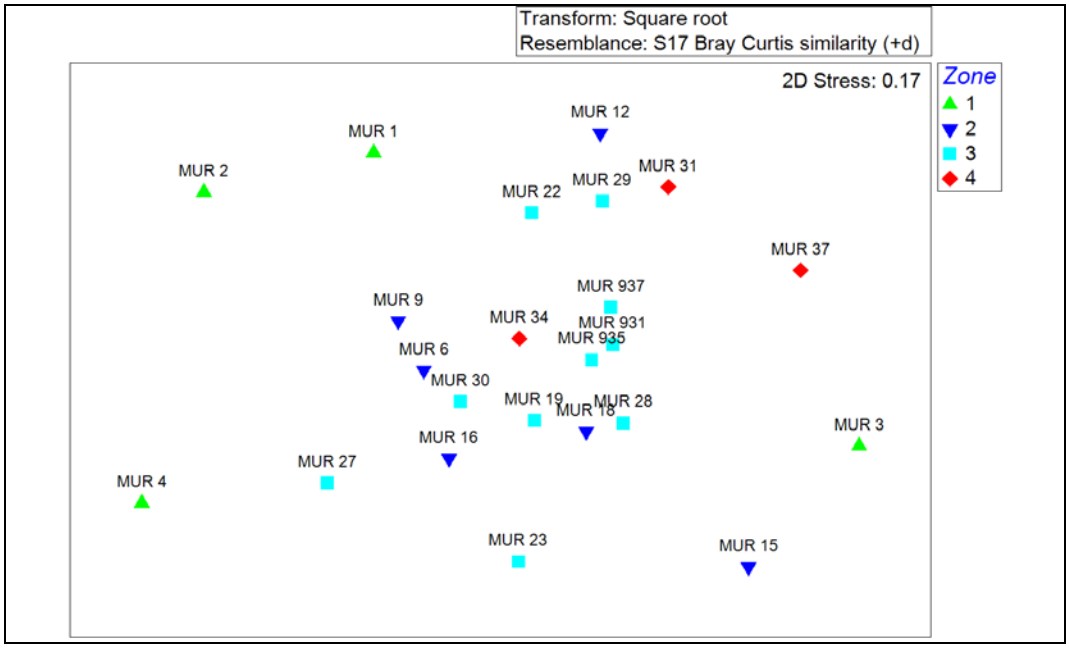


Figure 15: Non- metric multidimensional scaling of family level data for the autumn edge samples.

The cluster diagram in Figure 16, with input from SIMPROF, indicates four groupings which contain multivariate structure. The first group links MUR 4 with MUR 27 with approximately 60% similarity between these samples. The edge-dwelling community from MUR 1 and MUR 2 was most closely related to each other than to other samples (approximately 50%). The third group includes MUR 15 and MUR 37 which are approximately 52% similar. The final group contains the samples from all remaining sites with the exception of MUR 3 which is separated in the dendrogram from all other sites.

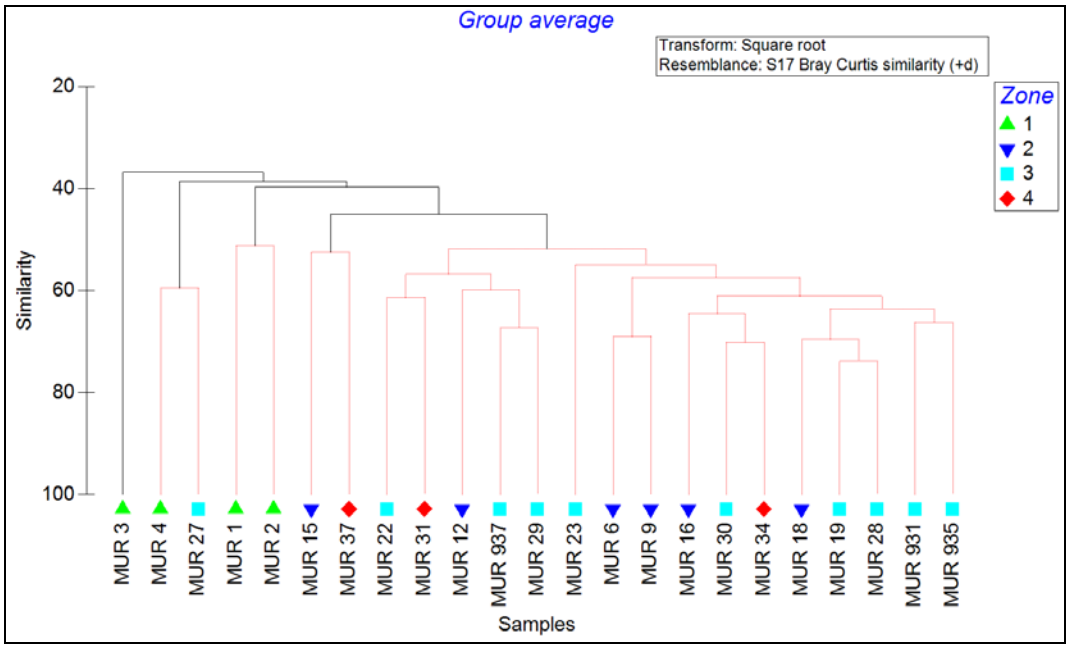


Figure 16: Cluster analysis of family level data for the autumn edge samples. Branches marked in red denote significant groupings based on SIMPROF.

PERMANOVA was used to test the hypothesis that there is a significant difference in the edge macroinvertebrate community between macro-reach zones. Based on 9999 permutations, PERMANOVA determined a significant (p<0.05) difference between zones. Multiple comparisons testing between pairs of zones indicated that differences in community composition are evident between Zone 1 and both Zone 2 and Zone 3 sites (Table 12). Unlike the riffle samples, no significant difference in edge community composition was detected between Zones 2 and 3.

Table 12: *p*- values for multiple comparisons between Zones for edge macroinvertebrates. Significant *p*- values are highlighted in red (<0.05). *p*- values were determined using permutation

Zone	1	2	3
1			
2	0.039		
3	0.005	0.478	
4	0.111	0.082	0.281

PERMANOVA also provided an estimate of the similarity within and between zones. The results provided in Table 13 indicate a particularly low similarity between sites within Zone 1. Both inter-zone and intra-zone similarity is low. Even the most strongly related sites (Zone 3) are only 55.69% similar in their macroinvertebrate community.

Table 13: Average similarity in edge macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	34.44%			
2	37.28%	50.79%		
3	38.75%	53.43%	55.69%	
4	34.18%	47.30%	53.52%	51.66%

SIMPER analysis was used to determine the taxa differences which contributed most strongly to the dissimilarities between edge macroinvertebrate samples collected from different zones. The five taxa which contributed most strongly to these differences are listed in Table 14. The taxon contributing most strongly to differences between Zone 1 and Zone 2 sites is Oligochaeta. Average numbers are slightly higher within Zone 1 sites compared to Zone 2. However, the raw data indicates that the higher average number of Oligochaetes which were in Zone 1 samples are largely due to high numbers at a single site (MUR 4) and this pattern does not extend across all Zone 1 sites. The contribution of all taxa is very low with even the varying numbers of Oligochaeta only accounting for approximately 5% between Zone 1 and Zone 2 sites (Table 14). The remaining key differences were higher abundance of Simuliidae, Orthocladiinae and Hydroptilidae and lower abundance of Corixidae at Zone 1 sites compared to Zone 2 sites.

Table 14: Major differentiating taxa between Zone 1 and Zone 2 edge samples

Family	Av abundance		Contribution to group differences
	Zone 1	Zone 2	
Oligochaeta sp.	12.08	9.31	5.12%
Simuliidae	13.49	1.46	4.49%
Orthocladiinae	13.62	5.22	3.76%
Hydroptilidae	11.78	8.19	3.47%
Corixidae	3.70	9.38	3.38%

The five taxa which contributed most to the differences between Zone 1 and Zone 3 sites are outlined in Table 15. The key differences between zones were an increased abundance of Oligochaeta, Simuliidae and Orthocladiinae and a decreased abundance of Corixidae and Tanypodinae within Zone 1 sites compared to Zone 3 sites.

Table 15: Major differentiating taxa between Zone 1 and Zone 3 edge samples

Family	Av abundance		Contribution to group differences
	Zone 1	Zone 3	
Oligochaeta sp.	12.08	10.49	5.46%
Simuliidae	13.49	2.87	4.28%
Corixidae	3.70	10.51	3.82%
Orthocladiinae	13.62	6.05	3.53%
Tanypodinae	7.04	0.94	3.20%

BEST analysis was performed to compare environmental variables to patterns in the macroinvertebrate community. BEST analysis of edge data determined a fairly strong (0.604) relationship between the macroinvertebrate community and varying levels of pH and alkalinity. BEST analysis of edge data determined a 0.598 correlation between the multivariate set of temperature, pH and total phosphorus with the macroinvertebrate community. This means that changes in macroinvertebrate assemblage of riffle habitat are best explained by changes in pH and alkalinity and changes in macroinvertebrate assemblage of edge habitats are best explained by changes in temperature, pH and total phosphorus.

3.4 Univariate indices

The results of overall taxa richness, EPT richness, SIGNAL-2 (sensitivity) and AUSRIVAS analysis are outlined in Table 17. SIGNAL-2 score was averaged across all taxa collected for each sample to produce an average SIGNAL-2 score for each site and each habitat. An ANOVA was conducted to determine whether SIGNAL-2 varied significantly between Habitats (edge v. riffle) and Zones (1-4). ANOVA detected a significant difference (p<0.05) in SIGNAL-2 score between habitats and zones (Table 16). Post-hoc multiple comparisons testing was used to perform pair-wise comparisons in SIGNAL-2 between the two habitats and four zones. The results indicated that average SIGNAL-2 score was significantly higher in riffle samples compared to edge samples (Figure 17). A significant difference in SIGNAL-2 score was detected between Zone 1 and Zone 4 (Table 18). The means plot in Figure 18 shows a decrease in SIGNAL-2 between Zone 1 and Zone 4. In summary, these results indicate that the highest proportions of pollution-sensitive taxa were recorded within riffle habitat assemblages and within the most upstream zone assemblage.

Table 16: ANOVA of SIGNAL2 scores between Zones and Habitats. Significant results highlighted in red.

Source	*df*	Sum of squares	Mean squares	F value	*p*- value
Habitat	1	4.9851	4.9851	43.951	**0.000**
Zone	3	1.8841	0.6280	5.537	**0.003**
Zone*Habitat	3	0.4646	0.1549	1.365	0.268
Residual	37	4.1967	0.1134		

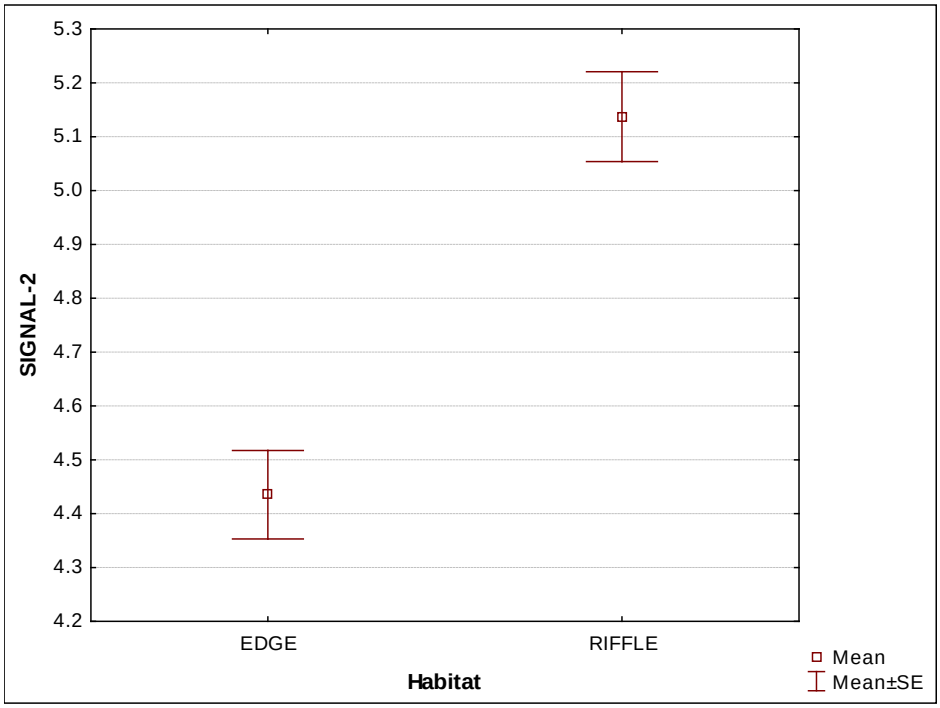


Figure 17: Means plot indicating differences in average SIGNAL- 2 between edge and riffle samples

Table 17: Taxa richness, AUSRIVAS Bands and SIGNAL scores for autumn 2011

Site	Location	Richness		EPT Richness		SIGNAL- 2		AUSRIVAS O/E50 score		AUSRIVAS BAND		Overall AUSRIVAS assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
MUR 1	D/S Tantangara Reservoir	20	25	8	7	5.05	4.35	0.82	1.06	B	A	B
MUR 2	Yaouk Bridge	22	21	10	12	5.91	5.06	0.89	0.82	A	A	A
MUR 3	Bobeyan Road Bridge	10	20	8	7	6.00	3.95	0.59	0.81	C	B	C
MUR 4	Camp ground off Bobeyan Road	21	14	11	7	5.90	5.23	0.95	0.76	A	B	B
MUR 6	D/S STP Pilot Creek Road	19	21	10	8	5.21	4.47	1.11	0.93	A	A	A
MUR 9	Murrells Crossing	15	20	8	9	5.33	4.89	0.89	0.88	A	A	A
MUR 12	Through Bredbo township	11	15	7	6	5.18	4.01	0.89	0.71	A	B	B
MUR 15	Near Colinton - Bumbalong Road	14	15	6	6	4.64	4.27	0.89	0.78	A	B	B
MUR 16	The Willows - Near Michelago	17	14	7	8	4.88	4.93	0.89	0.7	A	B	B
MUR 18	U/S Angle Crossing	12	21	6	9	5.00	4.55	0.78	0.93	B	A	B
MUR 19	D/S Angle Crossing	14	21	6	8	5.07	4.19	1.11	0.85	A	A	A
MUR 22	Tharwa Bridge	15	13	8	7	5.13	4.46	1	0.78	A	B	B
MUR 23	Point Hut Crossing	14	18	6	7	5.07	4.53	1	0.7	A	B	B
MUR 27	Kambah Pool	16	16	8	8	5.25	5.00	1	0.7	A	B	B
MUR 931	“Fairvale” ~4km U/S of the Cotter Confluence	15	18	6	8	4.60	4.42	0.89	0.86	A	A	A
MUR 28	U/S Cotter River confluence	16	21	8	8	5.25	4.48	1.11	0.85	A	A	A
MUR 935	Casuarina sands	15	15	6	7	4.53	4.20	1	0.78	A	B	B
MUR 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	16	19	8	7	5.25	4.12	1	0.86	A	A	A
MUR 29	Uriarra Crossing	14	15	7	6	4.86	4.51	0.89	0.86	A	A	A
MUR 30	U/S Molonglo Confluence	14	19	6	7	5.14	4.36	1	0.93	A	A	A

MUR 31	D/S Molonglo Confluence	13	17	6	5	4.85	3.76	1	0.78	A	B	B
MUR 34	Halls Crossing	12	17	4	8	4.92	4.51	0.89	0.78	A	B	B
MUR 37	Boambolo Road	NS	19	NS	3	NS	3.76	NS	0.62	NS	B	B

Note: NS = not sampled

Table 18: Tukey's HSD post- hoc analysis of pairwise comparisons of SIGNAL- 2 score between Zones. Text in red indicates significant differences ($p < 0.05$).

Zone	1	2	3
1			
2	0.294		
3	0.131	0.987	
4	0.027	0.388	0.466

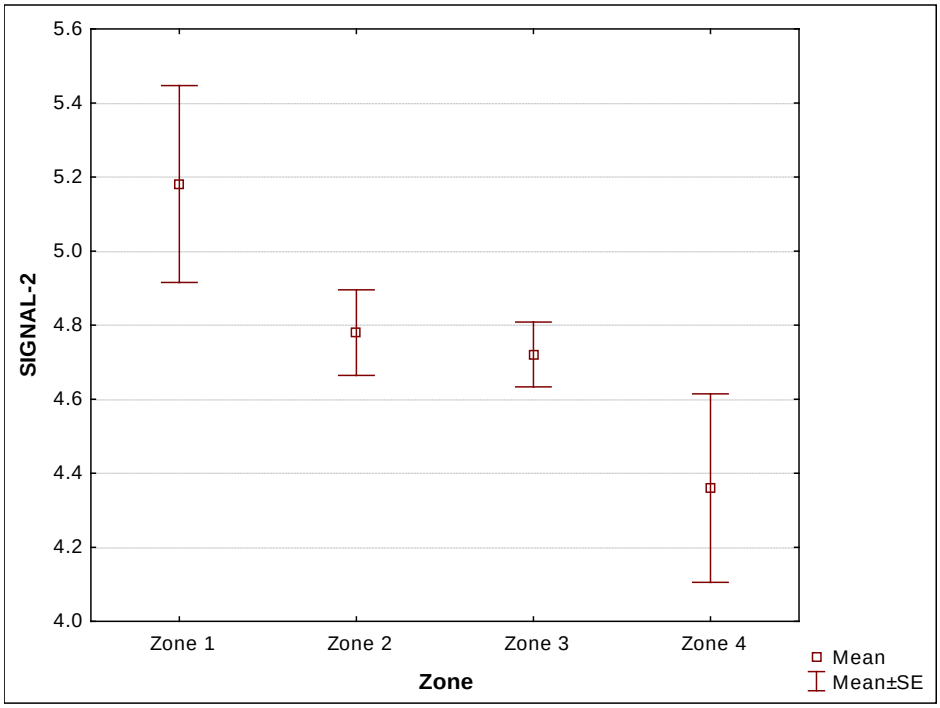


Figure 18: Means plot of SIGNAL- 2 scores for macroinvertebrate samples between Zones

Taxa richness within riffle samples ranged between 12 (MUR 3) and 22 (MUR 2). Overall richness in edge samples ranged between 14 (MUR 4, MUR 16) and 25 (MUR 1). The results of an ANOVA comparing overall taxa richness is provided in Table 19 below. The ANOVA indicates no significant interaction in overall taxa richness between Habitat and Zone factors. No significant difference was found in overall richness between Zones. A significant (p<0.05) difference was detected between Habitats. The difference in overall richness between habitats is portrayed by the means plot in Figure 19. This figure shows that overall taxa richness was higher, on average, in edge habitat than riffle habitat during the autumn 2011 sampling event.

Table 19: Results from the ANOVA model of Overall Taxa Richness. Significant results highlighted in red.

Source	*df*	Sum of squares	Mean squares	F value	*p*- value
Habitat	1	83.929	83.929	9.411	**0.004**
Zone	3	67.498	22.499	2.523	0.072
Zone*Habitat	3	9.236	3.079	0.345	0.792
Residual	37	329.983	8.918		

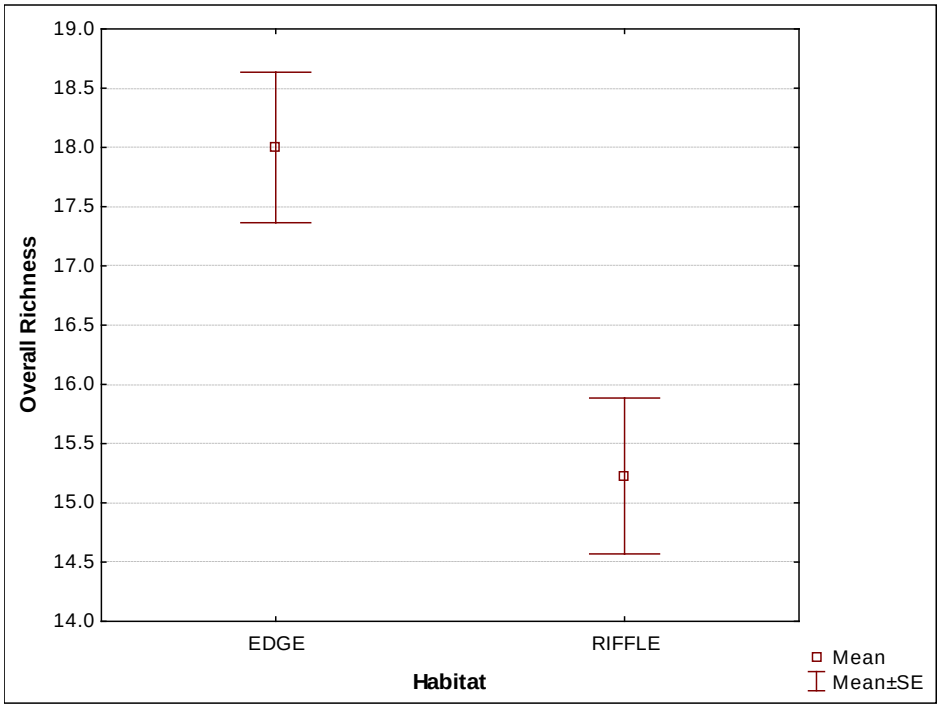


Figure 19: Means plot indicating differences in overall taxa richness between riffle and edge habitats.

EPT richness is the number of families from the Ephemeroptera, Plecoptera, Trichoptera orders, the members of which are generally considered as being more sensitive to disturbance than those taxa in other groups. EPT richness of riffle samples ranged between 4 (MUR 34) and 11 (MUR 4). EPT richness of edge samples ranged between 3 (MUR 37) and 12 (MUR 2). Table 20 below provides the results of the ANOVA in EPT richness between Habitats and Zones. This analysis shows that EPT richness was significantly different (p<0.05) between Zones but not Habitats. Post-hoc multiple comparisons testing showed that, similar to SIGNAL 2, EPT richness varied significantly between Zone 1 and Zone 4, only (Table 21). The means plot in shows that EPT taxa decreased between Zone 1 and Zone 4 (Figure 20). This underlines the finding that upstream zone featured a much greater array of pollution-sensitive taxa compared to the most downstream zone.

Table 20: ANOVA of EPT Richness between Zones and Habitats. Significant results highlighted in red.

Source	*df*	Sum of squares	Mean squares	F value	*p*- value
Habitat	1	0.002	0.002	0.0012	0.972
Zone	3	39.944	13.315	6.6724	**0.001**
Zone*Habitat	3	3.092	1.031	0.5164	0.673
Residual	37	73.833	1.995		

Table 21: Tukey's HSD post- hoc analysis of pairwise comparisons of EPT richness between Zones. Text in red indicates significant differences (p<0.05).

Zone	1	2	3
1			
2	0.277		
3	0.091	0.890	
4	**0.001**	0.053	0.143

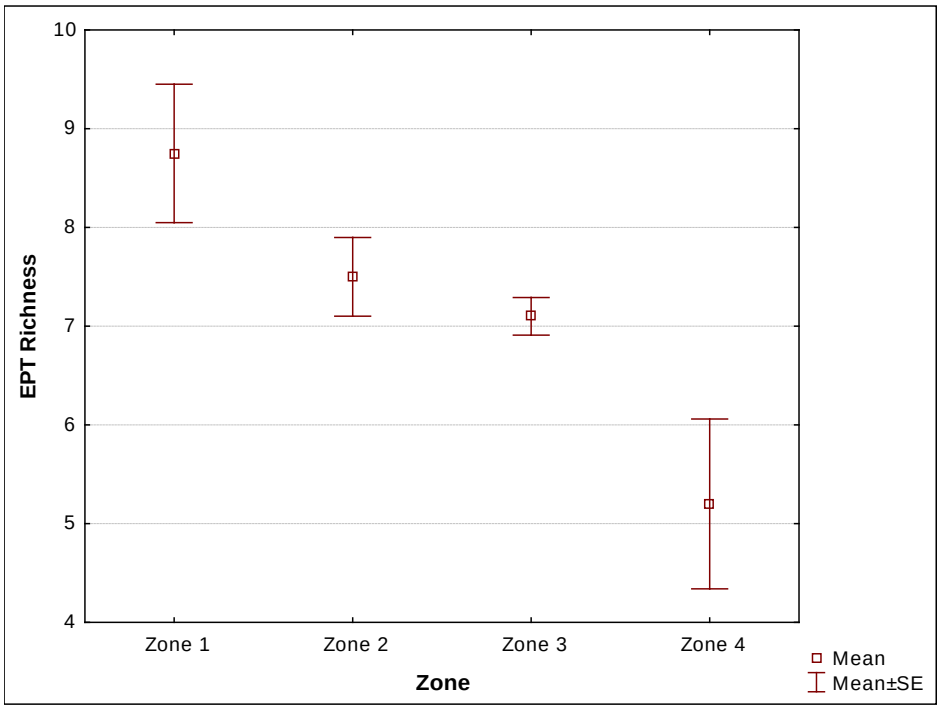


Figure 20: Means plot indicating differences in EPT richness between Zones

The proportion of sensitive (EPT) taxa to overall taxa is displayed for riffle and edge samples in Figure 21 and Figure 22, respectively. Figure 21 indicates that, for riffle samples, the proportion of EPT taxa was fairly consistent between sites even when the magnitude of richness changed. More variation in the proportion of EPT taxa was observed for edge samples when comparing between sites. An ANOVA found that the proportion of sensitive taxa was significantly higher (p<0.05) in riffle samples compared to edge samples (Table 22). No significant difference was found in the proportion of EPT taxa between Zones.

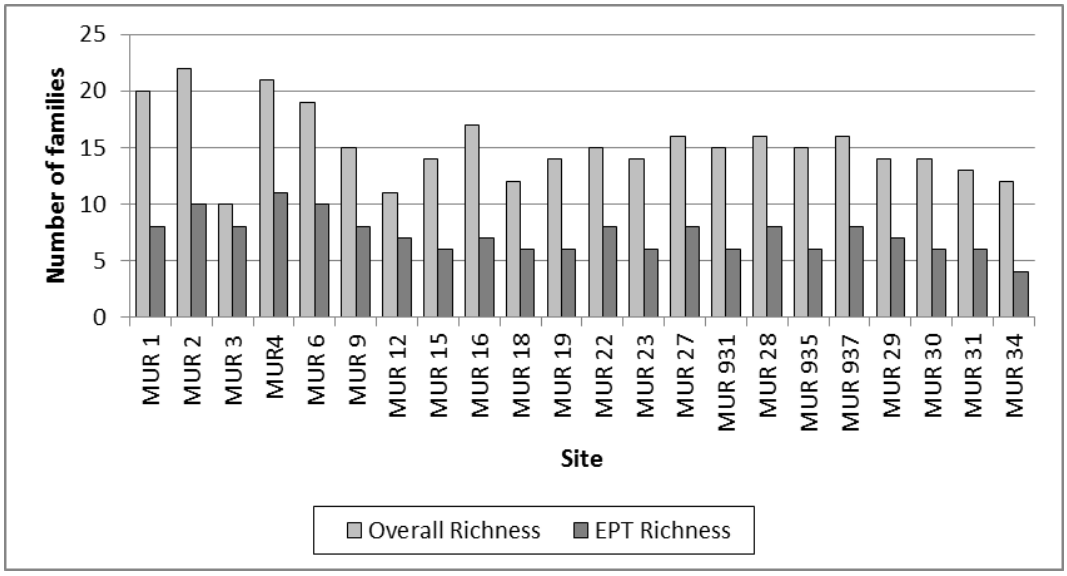


Figure 21: Relative number of families and sensitive taxa within riffle samples

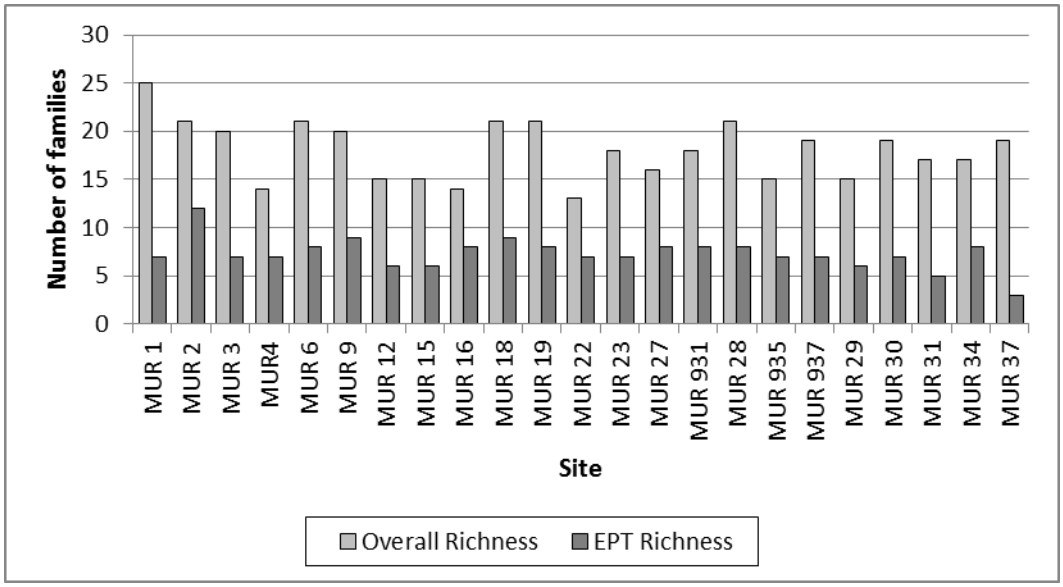


Figure 22: Relative number of families and sensitive taxa within edge samples

Table 22: ANOVA of %EPT taxa between Zones and Habitats. Significant results highlighted in red.

Source	*df*	Sum of squares	Mean squares	F value	*p*- value
Habitat	1	531.17	531.17	6.185	0.017
Zone	3	623.23	207.74	2.419	0.081
Zone*Habitat	3	102.29	34.10	0.391	0.756
Residual	37	3177.29	85.87		

AUSRIVAS banding was either A or B for all sites except MUR 3. ANOVA was used to test for differences in O/E family score between Zones and Habitats. A significant interaction (p<0.05) was detected for O/E 50 score between Zones and Habitats (Table 23). Consequently, O/E 50 score was separated by habitat so that ANOVA could be conducted between Zones. The one-way ANOVA of O/E 50 scores for edge samples did not identify any significant differences in O/E 50 score between Zones. An ANOVA of O/E 50 scores for riffle samples identified a significant difference (p<0.05) in O/E 50 score between Zone 1 and Zone 3. Figure 23 shows that O/E 50 score was higher, on average, for riffle samples collected from Zone 3. Zone 3 samples also displayed the smallest within-zone variation in O/E 50 scores. O/E 50 score was lower, on average, within Zone 1 riffle samples.

Table 23: Results from the ANOVA model of O/E 50 scores

Source	*df*	Sum of squares	Mean squares	F value	*p*- value
Habitat	1	0.1027	0.1027	10.417	**0.002**
Zone	3	0.0421	0.0140	1.425	0.251
Zone*Habitat	3	0.0925	0.0308	3.128	**0.037**
Residual	37	0.3650	0.0098		

Table 24: Tukey's HSD post- hoc analysis of pairwise comparisons of O/E 50 scores for riffle samples between Zones. Text in red indicates significant differences (p<0.05).

Zone	1	2	3
1			
2	0.483		
3	**0.028**	0.333	
4	0.458	0.970	0.897

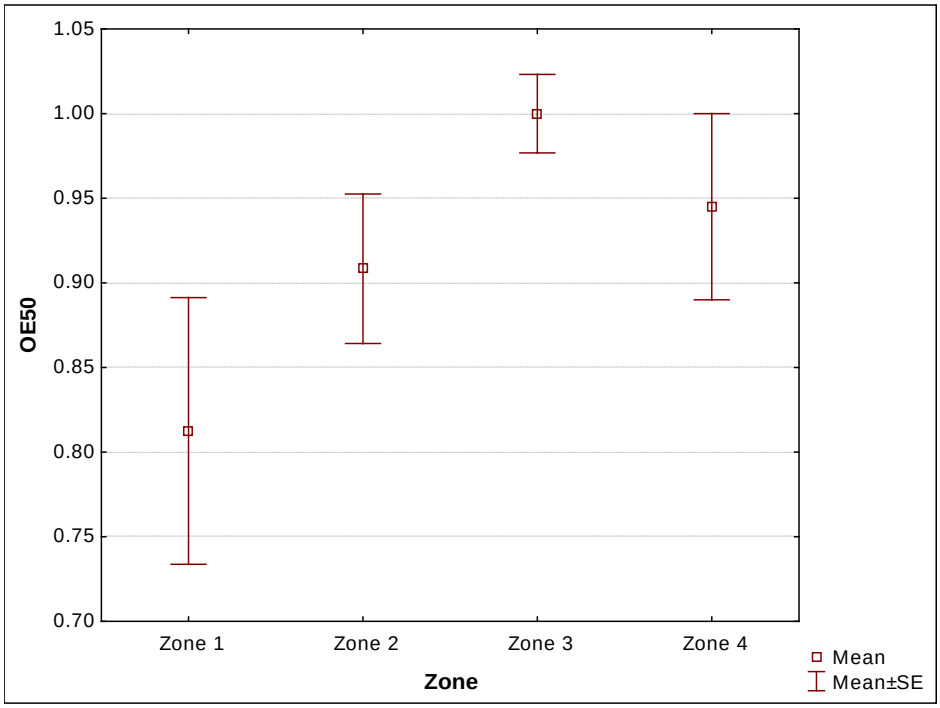


Figure 23: Means plot of O/E 50 scores for riffle samples between Zones

4 Discussion

4.1 Water Quality

Electrical Conductivity was below recommended levels at the two furthest upstream sites of Zone 1. This is consistent with results collected in autumn and spring 2010. Few guideline exceedances were observed for pH, turbidity and DO values. An increasing gradient of EC, alkalinity and water temperature was observed between upstream sites and downstream sites of Murrumbidgee River (Figures 3, 4 & 6). This pattern has been noted in previous sampling events including spring 2010. This gradient of water quality suggests localised processes within each Zone influencing the water characteristics along a broad spatial gradient, which includes the influence of major tributaries; namely: The Bredbo, Numeralla, Cotter, Molonglo and Gudgenby Rivers (Figure 1). Zone 1 generally exhibited the best water quality which is most likely a reflection of this Zone having the least agricultural land use and urbanisation compared to Zones 2, 3 and 4. Land-use in Zone 2 is largely agriculture, whilst agricultural practices are less predominant in Zone 3 and urban influences are greater. The land use in Zone 4 is almost entirely grazing. Agriculture and urbanisation have both been shown to increase nutrients and EC levels as well as decreasing DO levels (Wang *et al*., 2003). Influences can be direct, by the use of chemicals/fertilisers that are then washed into the waterways, or indirectly by the clearing of land for grazing which leads to increased run-off and sedimentation.

Although nutrient levels exceeded guideline levels at sites across all zones, the number of exceedances was much lower than was observed after the heavy rainfall in spring 2010. The elevated nutrient levels are attributed to the predominance of grazing practices throughout the region. Nutrients (particularly total nitrogen) were particularly high within Zone 4. As the confluence of Molonglo River is just upstream of MUR 31, the increased nutrient levels downstream of the confluence are most likely due to a high nutrient load in the Molonglo River. The Molonglo River catchment features a wastewater treatment facility that discharges treated effluent into the river so elevated nutrients at MUR31 could well be related to the increased levels at MUR 31. Levels of alkalinity, electrical conductivity and temperature were also notable higher downstream of the confluence with Molonglo River. This is consistent with patterns observed as part of the LMWQCC monitoring study carried out by ALS on behalf of ACTEW. Elevated EC downstream of the LMWQCC treatment plant has been found to relate mainly to elevated calcium and nutrients in the effluent released rather than to elevated sodium chloride concentrations. Temperature increases of several degrees have also been noted previously downstream of the LMWQCC release point. Treated effluent is often several degrees warmer than ambient temperatures during autumn in temperate regions of Australia.

Particularly high total suspended solids were observed at MUR 22 around Tharwa Bridge. This is likely related to the ongoing Tharwa Bridge upgrade and the largely unstable substrate at this site, which is predominantly sand and small gravel. Interestingly, turbidity was only slightly elevated at this site. This could indicate that suspended particulate matter at this site was of an origin other than sediment mobilisation and was perhaps related to either floc associated with metal compounds or to phytoplankton. Total suspended solids were particularly low between MUR 1 and MUR 9. In fact, a distinct difference is temperature, alkalinity, EC and total phosphorus was also observed between MUR 1 and MUR 9. This suggests that Bredbo township may be contributing to degraded water quality downstream of MUR 9.

The values of continuously monitored DO, EC, pH, turbidity and temperature at Angle Crossing, Lobb's Hole and Hall's Crossing were within guideline limits for across most of autumn 2011. There were some peaks and troughs in pH and EC that were evident, particularly at Angle Crossing and Lobb's Hole stations. These patterns can be matched to rainfall events in most cases.

Multivariate analysis of physico-chemical data mirrored the gradient of increasing water temperature, alkalinity, EC and turbidity from the upstream Murrumbidgee River sites towards the furthest downstream Murrumbidgee sites that was evident in the univariate graphs. The spatial gradient in decreasing water quality is most likely the result of increased intensity of agricultural land use between Zone 1 and Zone 4 as well as the inputs from the major tributaries along the length of our sampling program.

4.2 Patterns in macroinvertebrate communities

Macroinvertebrate samples collected from Riffle habitat were less variable than those collected from Edge habitat. Most sites shared at least 60% of the same taxa for riffle samples while edge samples were at least 40% similar. Similarity was particularly low for riffle samples between Zone 1 and Zone 4 sites. This is logical as they are the most spatially separated of the Zones. By the same reasoning it was not surprising to discover that the highest similarity in multivariate community composition was between the adjacent Zones 2 and 3. These Zones also exhibited very similar water quality conditions which would encourage a similar macroinvertebrate community.

The macroinvertebrate community composition of edge samples was significantly different between Zones 1, 2 and 3. The difference between these sites was mostly due to higher levels of Oligochaeta, Simuliidae, Orthocladiinae and Hydroptilidae and lower numbers of Corixidae in Zone 1 compared to Zone 2 and 3. A very similar pattern was observed for riffle samples. However, for riffle samples, Gripopterygidae was one of the main discerning taxa between the zones. Much higher numbers of Gripopterygidae were observed in Zone 1 samples compared to either Zone 2 or Zone 3 samples. In general, samples collected from Zone 1 sites had a higher abundance of moderately (Simuliidae, Orthocladiinae, Hydroptilidae) to highly (Gripopterygidae) sensitive taxa compared to Zones 2 and 3 which had higher numbers of tolerant taxa (Corixidae). This most likely reflects the improved water quality that was observed in Zone 1 compared to Zones 2 and 3. Although a higher number of Oligochaeta were also found to occur in Zone 1, the raw data showed that this was mainly due to unusually high abundance at a single site (MUR 4). Given the clear differences in geography and water quality between Zone 1 and Zone 4 it is surprising that no differences in community composition were observed between these zones.

Differences in the macroinvertebrate community between Zones 1, 2 and 3 were attributed to the relative abundance of several taxa with no clearly dominant taxa. However, the most notable difference was in the number of Oligochaeta and Simuliidae. Oligochaeta usually prefer areas of little or no flow while Simuliidae are almost solely restricted to the fast-flowing conditions of Riffle habitat. The fact that the contribution of each taxa towards the Zone differences was quite low suggests that differences in the community between zones is due to small-scale changes in habitat, flow and water quality rather than larger-scale differences at the Zone level. The pattern in macroinvertebrate assemblage was most strongly related to changes in temperature, pH (both edge and riffle) and total phosphorus (edge samples only). Values of these parameters were lowest between MUR 1 and MUR 9 which could be responsible for the increased proportion of sensitive taxa at these sites.

A particularly high number of Simuliidae and Oligochaeta were observed at MUR 4. This could be related to sediment deposits (Taylor, Per. Obs., 2011) since the previous sampling run, which probably occurred after the high flow events over spring. Oligochaeta are opportunistic animals which are frequently found to occur in large numbers in the presence of high nutrient loads. The increased number of Simuliidae at Zone 1 may indicate higher flows within these sites as Simuliidae tend to prefer faster-flowing waters. However, considering that Zone 1 sites are usually characterised by lower flows, the reason for high numbers of Simuliidae at a Zone 1 site is unclear. However, again, our field observations suggested a lower level of periphyton coverage on the substrate which could promote higher densities of Simuliids given their affinity for clean substrates (Gooderham and Tsyrlin, 2005).

4.3 River Health (AUSRIVAS assessment & univariate indices)

Higher taxa richness and EPT richness was observed in edge habitat compared to riffle habitat. This is unexpected due to increased Dissolved Oxygen (and variable habitat conditions which typically increases the number of families present in riffle habitats (Brown and Brussock, 1991; Thorp and Covich, 2001). However, the proportion of sensitive taxa was higher in riffle habitats compared to edge habitats. No overall difference in taxa richness was observed between the four zones. EPT richness was significantly higher in Zone 1 sites compared to Zone 4 sites.

Average SIGNAL-2 score generally decreased between upstream sites in Zone 1and the downstream sites of Zone 4. The SIGNAL-2 score was significantly higher at Zone 1 sites than Zone 4 sites. This is in keeping with the higher numbers of EPT taxa that were observed at Zone 1 sites. The increase in sensitive taxa at Zone 1 sites is probably a result of the improved water quality and lower levels of disturbance from surrounding land-use within this zone. The declining numbers of sensitive taxa corresponds to the declining gradient of water quality between MUR 1 and MUR 37.

AUSRIVAS results were consistent between zones. Only one site (MUR 3) was given a grade of “severely impaired” with most sites being labelled as “similar to reference” or “significantly impaired”. The AUSRIVAS health score for riffle samples was significantly higher for Zone 3 sites compared to Zone 1 sites. No significant difference was detected in the AUSRIVAS score of edge samples between Zones. The decreased AUSRIVAS score for Zone 1 sites (compared to Zone 3 sites) is interesting as it seems to contradict the increased number of sensitive taxa that were observed in these samples. However, it must be remembered that the AUSRIVAS method relies on the ratio of observed taxa to expected taxa and as such is governed by which taxa are expected under certain environmental conditions rather than being biased towards more sensitive taxa. On that basis, the Zone 1 assemblage was slightly lower in terms of expected taxa richness, but the taxa present were predominantly sensitive taxa based on EPT richness and SIGNAL-2 score data. This suggests that whatever the reasons for some taxa expected to occur in that zone being absent from autumn 2011 samples, the contributing factors are unlikely to be water quality related.

5 Conclusions

Water quality improved for the autumn 2011 sampling event compared to that observed in spring 2010. The spring 2010 sampling event was complicated by high rainfall events across the three month-period which led to a high number of exceedances in water quality variables. Few exceedances were observed in autumn 2011 apart from nutrients. Levels of total nitrogen were higher than recommended at almost all sites. Total phosphorus was also higher than recommended at several sites in Zones, 2, 3 and 4. Consistently high levels of nutrients were observed at Zone 4 sites. This is attributed to the influence of the Molonglo River.

Electrical conductivity, alkalinity, TSS and temperature followed a decreasing gradient through the Murrumbidgee River between the upstream sites of Zone 1 and the downstream sites of Zone 4. This is assumed to be due to changes in land-use throughout the region and, in particular, the increased intensity of agricultural practices in Zones 2 to 3. A very similar pattern has been observed over the last few sampling events. Differences in water quality downstream of the Cotter River and Molonglo River confluences indicate that these rivers have poorer water quality than that seen in the upper sections of Murrumbidgee River.

The macroinvertebrate community collected within edge and riffle habitats were different in Zone 1 compared to Zone 2 and Zone 3. The differences were attributed to the relatively large numbers of moderately sensitive taxa in Zone 1 compared to less sensitive taxa in Zones 2 and 3. These results are attributed to the improved water quality within Zone 1. While, AUSRIVAS grade was higher, on average, in Zone 3 than in Zone 1, the EPT and SIGNAL 2 results, combined with water quality data, would suggest that the lower AUSRIVAS grade for zone 1 sites was unlikely to be related to pollution. Overall, AUSRIVAS scores indicated fairly good ecological health for most Murrumbidgee sites.

During the autumn 2011 sampling event, differences in water quality and the macroinvertebrate community appear to be strongly linked to changes in land-use and the influence of inflows from Molonglo River. The drivers of the changes in the macroinvertebrate communities were varying levels of temperature, pH and total phosphorus. There is little evidence of any major influence of fluctuating flow conditions on the macroinvertebrate community within this sampling event. Unlike, the spring 2010 sampling event, there was minimal disturbance to the environment from heavy rainfall. Regardless, this data should provide a reliable baseline for when changes are made to the flow regime in the future.

6 References

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

Allan, J.D. & Castillo, M.M. (2008) Stream Ecology: Structure and Function of Running Waters., Springer., The Netherlands.

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

Bray, J.R., Curtis, J.T. (1957) An ordination of the upland forest communities of Southern Wisconsin. *Ecol. Monogr*. 27: 325-349.

Brown, A. V. & Brussock, 1991, Comparisons of benthic invertebrates between riffles and pools. *Hydrobiologia*, 220: 99-108.

Chessman, B.C. (2003) SIGNAL 2 – A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers. Monitoring River Heath Initiative Technical Report no 31, Commonwealth of Australia, Canberra.

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

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

Clifford, H.T. & Stephenson, W. (1975) An Introduction to Numerical Classification. Academic Press, New York.

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

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

Del Rosario, R.B., Betts, E.A. & Resh, V.H. (2002) Cow Manure in Headwater Streams: Tracing Aquatic Insect Responses to Organic Enrichment. Journal of the North American Benthological Society, 21, 278-289.

Ecowise Environmental. (2009) Murrumbidgee Ecological Monitoring Program. Part 1: Angle Crossing. Proposal to ACTEW Corporation.

Frissell, C.A., Liss, W.J., Warren, C.E. & Hurley, M.D. (1986) A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management*, 10, 199-214.

Gooderham, J. & Tsyrlin, E. (2005) The Waterbug Book: A guide to the freshwater macroinvertebrates in temperate Australia, CSIRO Publishing, Victoria.

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

Keen, G. (2001) Australia - Wide Assessment of River Health: Australian Capital Territory Bioassessment Report (ACT Interim Final Report), Monitoring River Health Initiative Technical Report no 3, Commonwealth of Australia and Environment ACT.

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

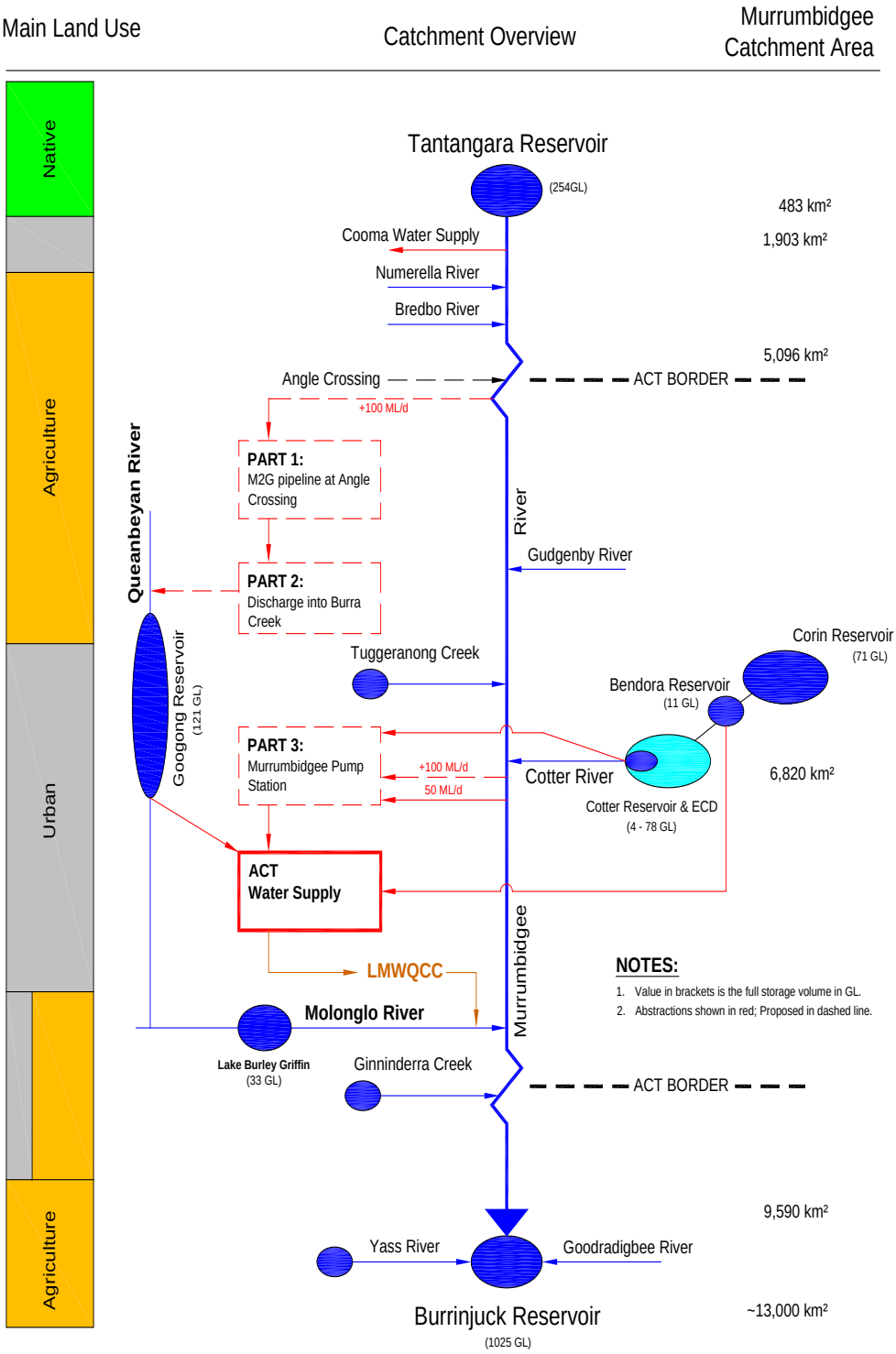
Marchant, R. (1989) A subsampler for samples of benthic invertebrates. *Bulletin of the Australian Society of Limnology*, 12, 49-52.

Quinn, G.P. & Keough, M.J. (2002) *Experimental Design and Data Analysis for Biologists*.

Thorp, J.H. & Covich, A.P. (ed) (2001). *Ecology and Classification of North American Freshwater Invertebrates,* Academic Press, California.

Wang, H., Hondzo, M., Xu, C., Poole, V. and Spacie, A. (2003) Dissolved oxygen dynamics of streams draining an urbanized and an agricultural catchment. *Ecological Modelling*, 160, 145-161.

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


Main Land Use
Catchment Overview
Murrumbidgee Catchment Area
Native
Agriculture
Urban
Agriculture
Tantangara Reservoir
(254GL)
483 km²
Cooma Water Supply
1,903 km²
Numerella River
Bredbo River
5,096 km²
Angle Crossing
ACT BORDER
+100 ML/d
PART 1:
M2G pipeline at Angle Crossing
PART 2:
Discharge into Burra Creek
Queanbeyan River
Googong Reservoir
(121 GL)
River
Gudgenby River
Tuggeranong Creek
Corin Reservoir
(71 GL)
Bendora Reservoir
(11 GL)
PART 3:
Murrumbidgee Pump Station
+100 ML/d
50 ML/d
Cotter River
6,820 km²
Cotter Reservoir & ECD
(4 - 78 GL)
ACT
Water Supply
LMWQCC
Molonglo River
Murrumbidgee
NOTES:
1. Value in brackets is the full storage volume in GL.
2. Abstractions shown in red; Proposed in dashed line.
Lake Burley Griffin
(33 GL)
Ginninderra Creek
ACT BORDER
9,590 km²
Yass River
Goodradigbee River
Burrinjuck Reservoir
(1025 GL)
~13,000 km²

Appendix B - Principal Components Analysis of water quality variables

PCA

Principal Component Analysis

Data worksheet

Name: Data5
Data type: Environmental
Sample selection: All
Variable selection: All

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	6.96	58.0	58.0
2	1.71	14.2	72.2
3	1.14	9.5	81.7
4	0.923	7.7	89.4
5	0.529	4.4	93.8

Eigenvectors

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

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	-0.346	0.017	-0.164	0.023	0.275
EC	-0.360	-0.190	-0.018	-0.117	-0.056
pH	-0.357	0.062	-0.085	0.177	0.211
D.O (% Sat.)	-0.300	-0.052	-0.235	0.296	0.350
Turbidity	-0.336	0.243	0.211	-0.002	-0.086
Alkalinity	-0.359	0.092	-0.166	-0.002	0.064
Total Nox	-0.240	-0.537	0.174	-0.226	-0.196
Ammonia	-0.062	0.359	-0.283	-0.826	-0.013
TP	-0.059	0.228	0.831	-0.115	0.357
TN	-0.274	-0.476	0.168	-0.207	-0.172
TSS	-0.232	0.345	0.086	0.276	-0.740
TKN	-0.311	0.273	0.044	-0.038	-0.011

Appendix C -
BEST analysis – output

BEST
Biota and/or Environment matching

Data worksheet
Name: Env data_edge
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
1 Water temp.
2 EC
3 pH
4 D.O (% Sat.)
5 Turbidity
6 Alkalinity
7 Total Nox
8 Ammonia
9 TP
10 TN
11 TSS
12 TKN

Best results

No.Vars	Corr.	Selections
3	0.598	1,3,9
3	0.598	1,6,9
4	0.584	1,3,6,9
2	0.582	1,9
4	0.576	1,5,6,9
2	0.574	6,9
4	0.570	1,3,5,9
5	0.569	1,3,5,6,9
2	0.565	3,9
3	0.565	3,6,9

BEST
Biota and/or Environment matching

Data worksheet
Name: Env data_riffle
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Resem2
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
1 Water temp.
2 EC
3 pH
4 D.O (% Sat.)
5 Turbidity
6 Alkalinity
7 Total Nox
8 Ammonia
9 TP
10 TN
11 TSS
12 TKN

Best results

No.Vars	Corr.	Selections
2	0.604	3,6
1	0.603	6
3	0.592	3,5,6
1	0.589	3
3	0.582	2,3,6
4	0.580	2,3,5,6
3	0.575	3,6,12
4	0.573	3,5,6,12
2	0.571	5,6
2	0.568	2,6

Appendix D - Raw taxa counts for macroinvertebrates collected in riffle and edge habitats: autumn 2011

Appendix E. Taxonomic inventory of the macroinvertebrate taxa collected in autumn 2011. Taxa from sub- sorted samples have been multiplied to 100%.

	Unique QSN	MEMP07/01	MEMP07/02	MEMP07/03	MEMP07/04	MEMP07/05	MEMP07/06	MEMP07/07	MEMP07/08	MEMP07/09	MEMP07/10
	Site Code	MUR1	MUR1	MUR2	MUR2	MUR3	MUR3	MUR4	MUR4	MUR6	MUR6
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	9/5/2011	9/5/2011
Acarina	sp.	8		40				20	20	11	
Amphipoda	Eusiridae								20		
Bivalvia	Corbiculidae										
Bivalvia	Sphaeriidae						7				
Coleoptera	Dytiscidae						5				
Coleoptera	Elmidae	100	4	140			4	140		11	
Coleoptera	Gyrinidae										
Coleoptera	Hydraenidae		4								
Coleoptera	Hydrophilidae										
Coleoptera	Psephenidae			80	13						
Coleoptera	Scirtidae		29	40				20			4
Crustacea	Cladocera										
Crustacea	Copepoda		18				2				13
Crustacea	Ostracoda		11		13						
Decapoda	Atyidae						2				4
Decapoda	Palaemonidae										4
Decapoda	Parastacidae										
Diptera	Ceratopogonidae	17	4								
Diptera	Culicidae										
Diptera	Empididae	25	4	40					80	11	4
Diptera	Muscidae										
Diptera	Psychodidae										
Diptera	s-f Aphroteniinae			40							
Diptera	s-f Chironominae	67	71	300	38		96	180	240	11	35
Diptera	s-f Orthocladiinae	258	61	500	538	13	9	480	420	378	96
Diptera	s-f Tanypodinae	8	25	780	125		144	40			9
Diptera	Simuliidae	708	68		13	20		720	1780	11	
Diptera	Tabanidae										
Diptera	Tipulidae		46	20				20		89	9
Ephemeroptera	Baetidae			180	488	607	9	520	60	278	4
Ephemeroptera	Caenidae		4	420	88	13		240	120	244	170

	Unique QSN	MEMP07/01	MEMP07/02	MEMP07/03	MEMP07/04	MEMP07/05	MEMP07/06	MEMP07/07	MEMP07/08	MEMP07/09	MEMP07/10
	Site Code	MUR1	MUR1	MUR2	MUR2	MUR3	MUR3	MUR4	MUR4	MUR6	MUR6
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	11/5/2011	9/5/2011	9/5/2011
Ephemeroptera	Coloburiscidae	17		300	13	120		260			
Ephemeroptera	Leptophlebiidae	17	39	580	288	547	7	100		167	13
Ephemeroptera	sp.		4						140	89	9
Gastropoda	Ancylidae										4
Gastropoda	Lymnaeidae		18		25						
Gastropoda	Physidae						16				
Gastropoda	Physidae/Planorbidae imm.		4								
Gastropoda	Planorbidae	8	29		25						
Hemiptera	Corixidae		11		50		20				9
Hemiptera	Gerridae										
Hemiptera	Mesoveliidae										
Hemiptera	Notonectidae						2				
Isopoda	Phreatoicidae	25	4								
Lepidoptera	Crambidae										
Megaloptera	Corydalidae			540							
Odonata	Coenagrionidae						5				
Odonata	Epiproctophora	8						20			
Odonata	Gomphidae			60				20			
Odonata	Lestidae						15				
Odonata	Telephlebiidae							20			
Odonata	Zygoptera										
Oligochaeta	Oligochaeta	183	57						1660	622	61
Plecoptera	Gripopterygidae	258	39	1360	338	73		540	140	56	17
Plecoptera	sp.										
Trichoptera	Atriplectididae				25						
Trichoptera	Calamoceratidae				13		2				
Trichoptera	Conoesucidae	158	50	60	150			40	40	11	
Trichoptera	Ecnomidae	17	11	100	13	7	2	40		11	30
Trichoptera	Hydrobiosidae	33			100	13		40	60	22	
Trichoptera	Hydropsychidae			800		193	2	920	740	633	52
Trichoptera	Hydroptilidae	42	68		175		22	20	440	56	339
Trichoptera	Leptoceridae	25	129	60	113		5			11	22
Trichoptera	Philopotamidae			80				160			
Turbellaria	Dugesiidae	8	4							11	4

	Unique QSN	MEMP07/11	MEMP07/12	MEMP07/13	MEMP07/14	MEMP07/15	MEMP07/16	MEMP07/17	MEMP07/18	MEMP07/19	MEMP07/20
	Site Code	MUR9	MUR9	MUR12	MUR12	MUR22	MUR22	MUR27	MUR27	MUR30	MUR30
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	9/5/2011	9/5/2011	6/5/2011	6/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011
Acarina	sp.	7	16		55			20	33	33	24
Amphipoda	Eusiridae										
Bivalvia	Corbiculidae	7	11			14					
Bivalvia	Sphaeriidae		5							11	
Coleoptera	Dytiscidae										
Coleoptera	Elmidae	14				86		33		33	10
Coleoptera	Gyrinidae										
Coleoptera	Hydraenidae				9						
Coleoptera	Hydrophilidae										
Coleoptera	Psephenidae										
Coleoptera	Scirtidae		5								
Crustacea	Cladocera										
Crustacea	Copepoda		11		27						
Crustacea	Ostracoda										
Decapoda	Atyidae										
Decapoda	Palaemonidae		11						13		
Decapoda	Parastacidae										
Diptera	Ceratopogonidae										
Diptera	Culicidae										
Diptera	Empididae	7	5			100	6	33	13		
Diptera	Muscidae										
Diptera	Psychodidae										
Diptera	s-f Aphroteniinae										
Diptera	s-f Chironominae		21	300	9	614	41	207	413	89	62
Diptera	s-f Orthocladiinae	143	79	620	18	214	200	293	140	178	33
Diptera	s-f Tanypodinae										5
Diptera	Simuliidae			2000	9	43		40	7	511	29
Diptera	Tabanidae										
Diptera	Tipulidae	7						53	13	11	5
Ephemeroptera	Baetidae	86	5	1320		243	41	147	180	789	276
Ephemeroptera	Caenidae	343	411	1460	136	100		73	53	111	105

	Unique QSN	MEMP07/11	MEMP07/12	MEMP07/13	MEMP07/14	MEMP07/15	MEMP07/16	MEMP07/17	MEMP07/18	MEMP07/19	MEMP07/20
	Site Code	MUR9	MUR9	MUR12	MUR12	MUR22	MUR22	MUR27	MUR27	MUR30	MUR30
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	9/5/2011	9/5/2011	6/5/2011	6/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011	10/5/2011
Ephemeroptera	Coloburiscidae										
Ephemeroptera	Leptophlebiidae	214	42	280	9	29	12	80	7	56	24
Ephemeroptera	sp.	14				157					
Gastropoda	Ancylidae										5
Gastropoda	Lymnaeidae				9						
Gastropoda	Physidae						6				10
Gastropoda	Physidae/Planorbidae imm.										
Gastropoda	Planorbidae										
Hemiptera	Corixidae		21		1800		676				14
Hemiptera	Gerridae										
Hemiptera	Mesoveliidae										5
Hemiptera	Notonectidae										
Isopoda	Phreatoicidae										
Lepidoptera	Crambidae										
Megaloptera	Corydalidae										
Odonata	Coenagrionidae										
Odonata	Epiproctophora										
Odonata	Gomphidae										
Odonata	Lestidae										
Odonata	Telephlebiidae										
Odonata	Zygoptera										
Oligochaeta	Oligochaeta	457	268	8220	73	1029	182	40	1200	11	210
Plecoptera	Gripopterygidae	100	74	60		29	24		20		
Plecoptera	sp.										
Trichoptera	Atriplectididae										
Trichoptera	Calamoceratidae										
Trichoptera	Conoesucidae										
Trichoptera	Ecnomidae	64	105	20	82	43	47	20	7		5
Trichoptera	Hydrobiosidae	14	5	40		114		13	27	33	5
Trichoptera	Hydropsychidae	50	32	3620	9	686	12	553	27	367	
Trichoptera	Hydroptilidae	93	42		18	100	6	7	20	22	233
Trichoptera	Leptoceridae		26		27		6				38
Trichoptera	Philopotamidae							7			
Turbellaria	Dugesiidae										

	Unique QSN	MEMP07/21	MEMP07/22	MEMP07/23	MEMP07/24	MEMP07/25	MEMP07/26	MEMP07/28	MEMP07/30	MEMP07/32
	Site Code	MUR31	MUR31	MUR34	MUR34	MUR37	MUR15	MUR15	MUR16	MUR16
	Habitat	Riffle	Edge	Riffle	Edge	Edge	Riffle	Edge	Riffle	edge
	Date Collected	4/5/2011	4/5/2011	4/5/2011	4/5/2011	4/5/2011	6/5/2011	6/5/2011	9/5/2011	9/5/2011
Acarina	sp.	75		50	5	4	20		25	
Amphipoda	Eusiridae									
Bivalvia	Corbiculidae						160	1	13	
Bivalvia	Sphaeriidae				5					
Coleoptera	Dytiscidae		6							
Coleoptera	Elmidae	75	6	25						
Coleoptera	Gyrinidae									
Coleoptera	Hydraenidae					2				
Coleoptera	Hydrophilidae					4				
Coleoptera	Psephenidae									
Coleoptera	Scirtidae								13	
Crustacea	Cladocera					2				
Crustacea	Copepoda					4				
Crustacea	Ostracoda									
Decapoda	Atyidae					31		1		16
Decapoda	Palaemonidae			25		8	20	3		
Decapoda	Parastacidae					2				
Diptera	Ceratopogonidae									
Diptera	Culicidae		6							
Diptera	Empididae			50					13	4
Diptera	Muscidae				5					
Diptera	Psychodidae									
Diptera	s-f Aphroteniinae									
Diptera	s-f Chironominae	550	71	175	140	31	100	13	150	124
Diptera	s-f Orthocladiinae	1400	47	600	35	4	140	1	13	16
Diptera	s-f Tanypodinae					2		1	13	
Diptera	Simuliidae	1875		2325	15	4	420	3	13	16
Diptera	Tabanidae									
Diptera	Tipulidae	475	6		5	2			50	
Ephemeroptera	Baetidae	2825	6	1325	170		580	3	500	40
Ephemeroptera	Caenidae	725	65	50	45	8	800	6	225	68

	Unique QSN	MEMP07/21	MEMP07/22	MEMP07/23	MEMP07/24	MEMP07/25	MEMP07/26	MEMP07/28	MEMP07/30	MEMP07/32
	Site Code	MUR31	MUR31	MUR34	MUR34	MUR37	MUR15	MUR15	MUR16	MUR16
	Habitat	Riffle	Edge	Riffle	Edge	Edge	Riffle	Edge	Riffle	edge
	Date Collected	4/5/2011	4/5/2011	4/5/2011	4/5/2011	4/5/2011	6/5/2011	6/5/2011	9/5/2011	9/5/2011
Ephemeroptera	Coloburiscidae									
Ephemeroptera	Leptophlebiidae	100	53		45	6	580	8	600	16
Ephemeroptera	sp.			300						
Gastropoda	Ancylidae									
Gastropoda	Lymnaeidae									
Gastropoda	Physidae		76			2				
Gastropoda	Physidae/Planorbidae imm.									
Gastropoda	Planorbidae									
Hemiptera	Corixidae		735		200	267		10		
Hemiptera	Gerridae									
Hemiptera	Mesoveliidae									
Hemiptera	Notonectidae									
Isopoda	Phreatoicidae									
Lepidoptera	Crambidae		6							
Megaloptera	Corydalidae									
Odonata	Coenagrionidae		18							
Odonata	Epiproctophora									
Odonata	Gomphidae		6							
Odonata	Lestidae									
Odonata	Telephlebiidae									
Odonata	Zygoptera									
Oligochaeta	Oligochaeta	50	106	125	235	13	1080	25	163	132
Plecoptera	Gripopterygidae						20			12
Plecoptera	sp.									
Trichoptera	Atriplectididae									
Trichoptera	Calamoceratidae									
Trichoptera	Conoesucidae									
Trichoptera	Ecnomidae	175	6		5		40	7	138	4
Trichoptera	Hydrobiosidae			225	10				13	12
Trichoptera	Hydropsychidae	675		425	60		580	2	1050	52
Trichoptera	Hydroptilidae	150			10				100	276
Trichoptera	Leptoceridae		112		50	21		7		
Trichoptera	Philopotamidae									
Turbellaria	Dugesiidae						20			

	Unique QSN	MEMP07/33	MEMP07/35	MEMP07/37	MEMP07/39	MEMP07/41	MEMP07/43	MEMP07/49	MEMP07/51
	Site Code	MUR18	MUR18	MUR19	MUR19	MUR23	MUR23	MUR28	MUR28
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	6/5/2011	6/5/2011	6/5/2011	6/5/2011	10/5/2011	10/5/2011	5/5/2011	5/5/2011
Acarina	sp.	50	1			117	2	20	
Amphipoda	Eusiridae								
Bivalvia	Corbiculidae			25	3		2		1
Bivalvia	Sphaeriidae								
Coleoptera	Dytiscidae								
Coleoptera	Elmidae			75		33		7	4
Coleoptera	Gyrinidae		1		3				1
Coleoptera	Hydraenidae				3				1
Coleoptera	Hydrophilidae								
Coleoptera	Psephenidae								
Coleoptera	Scirtidae		1						1
Crustacea	Cladocera								
Crustacea	Copepoda								
Crustacea	Ostracoda								
Decapoda	Atyidae				8		2		6
Decapoda	Palaemonidae								
Decapoda	Parastacidae								
Diptera	Ceratopogonidae		1			17			
Diptera	Culicidae								
Diptera	Empididae	25						40	4
Diptera	Muscidae								
Diptera	Psychodidae								
Diptera	s-f Aphroteniinae								
Diptera	s-f Chironominae	150	44	75	53	67	10	127	40
Diptera	s-f Orthocladiinae	150	11	125	23	50	16	160	18
Diptera	s-f Tanypodinae		6		3		2		
Diptera	Simuliidae	50		950	5	33	36	27	8
Diptera	Tabanidae								
Diptera	Tipulidae		3	50	5	33	2	80	
Ephemeroptera	Baetidae	1825	19	1300	28	850	128	313	16
Ephemeroptera	Caenidae	525	67	100	168	433	44	60	15

	Unique QSN	MEMP07/33	MEMP07/35	MEMP07/37	MEMP07/39	MEMP07/41	MEMP07/43	MEMP07/49	MEMP07/51
	Site Code	MUR18	MUR18	MUR19	MUR19	MUR23	MUR23	MUR28	MUR28
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	6/5/2011	6/5/2011	6/5/2011	6/5/2011	10/5/2011	10/5/2011	5/5/2011	5/5/2011
Ephemeroptera	Coloburiscidae								
Ephemeroptera	Leptophlebiidae	425	30	300	13	317	4	40	3
Ephemeroptera	sp.								
Gastropoda	Ancylidae								
Gastropoda	Lymnaeidae						2		
Gastropoda	Physidae		1		3		2		5
Gastropoda	Physidae/Planorbidae imm.								
Gastropoda	Planorbidae								
Hemiptera	Corixidae		10		5				28
Hemiptera	Gerridae								
Hemiptera	Mesoveliidae								
Hemiptera	Notonectidae								
Isopoda	Phreatoicidae								
Lepidoptera	Crambidae		1		3				
Megaloptera	Corydalidae								
Odonata	Coenagrionidae								
Odonata	Epiproctophora								
Odonata	Gomphidae								
Odonata	Lestidae								
Odonata	Telephlebiidae								
Odonata	Zygoptera								3
Oligochaeta	Oligochaeta	1250	44	2125	83	33	46	100	28
Plecoptera	Gripopterygidae		6	25			8	13	
Plecoptera	sp.	25							
Trichoptera	Atriplectididae								
Trichoptera	Calamoceratidae								
Trichoptera	Conoesucidae								
Trichoptera	Ecnomidae		4		10	117		53	16
Trichoptera	Hydrobiosidae	75	1	100	3	17	10	7	1
Trichoptera	Hydropsychidae	1150	1	775	20	1367	98	293	14
Trichoptera	Hydroptilidae	25	11		80			127	33
Trichoptera	Leptoceridae		31		18		14		15
Trichoptera	Philopotamidae								
Turbellaria	Dugesiidae			250					

	Unique QSN	MEMP07/45	MEMP07/47	MEMP07/52	MEMP07/54	MEMP07/56	MEMP07/58	MEMP07/60	MEMP07/62
	Site Code	MUR931	MUR931	MUR935	MUR935	MUR937	MUR937	MUR29	MUR29
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	5/05/2011	5/05/2011	5/05/2011	5/05/2011	5/05/2011	5/05/2011	4/05/2011	4/5/2011
Acarina	sp.	100	8	233		33	3	33	33
Amphipoda	Eusiridae								
Bivalvia	Corbiculidae		3					7	
Bivalvia	Sphaeriidae								
Coleoptera	Dytiscidae								
Coleoptera	Elmidae	60		33		33			20
Coleoptera	Gyrinidae								
Coleoptera	Hydraenidae						3		
Coleoptera	Hydrophilidae		3		13				
Coleoptera	Psephenidae								
Coleoptera	Scirtidae								
Crustacea	Cladocera								
Crustacea	Copepoda								
Crustacea	Ostracoda								
Decapoda	Atyidae				27		6		20
Decapoda	Palaemonidae								
Decapoda	Parastacidae								
Diptera	Ceratopogonidae		3						
Diptera	Culicidae								
Diptera	Empididae	20			3	33	9		
Diptera	Muscidae								
Diptera	Psychodidae						3		
Diptera	s-f Aphroteniinae								
Diptera	s-f Chironominae	1480	100	567	87	500	26	313	247
Diptera	s-f Orthocladiinae	100	10	533	37	200	9	67	13
Diptera	s-f Tanypodinae						3		7
Diptera	Simuliidae	140	8	2300		1500	11	47	13
Diptera	Tabanidae	100							
Diptera	Tipulidae			133	3	67		13	
Ephemeroptera	Baetidae	240	3	2500	60	3233	46	533	40
Ephemeroptera	Caenidae	160	75	200	23	233	57	200	67

	Unique QSN	MEMP07/45	MEMP07/47	MEMP07/52	MEMP07/54	MEMP07/56	MEMP07/58	MEMP07/60	MEMP07/62
	Site Code	MUR931	MUR931	MUR935	MUR935	MUR937	MUR937	MUR29	MUR29
	Habitat	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge
	Date Collected	5/05/2011	5/05/2011	5/05/2011	5/05/2011	5/05/2011	5/05/2011	4/05/2011	4/5/2011
Ephemeroptera	Coloburiscidae								
Ephemeroptera	Leptophlebiidae	80	3		7	100	43	100	87
Ephemeroptera	sp.								
Gastropoda	Ancylidae								
Gastropoda	Lymnaeidae								
Gastropoda	Physidae								
Gastropoda	Physidae/Planorbidae imm.								
Gastropoda	Planorbidae								
Hemiptera	Corixidae		180		167		286		607
Hemiptera	Gerridae		5						33
Hemiptera	Mesoveliidae								
Hemiptera	Notonectidae						6		
Isopoda	Phreatoicidae								
Lepidoptera	Crambidae	20		33					
Megaloptera	Corydalidae								
Odonata	Coenagrionidae								
Odonata	Epiproctophora								
Odonata	Gomphidae								
Odonata	Lestidae								
Odonata	Telephlebiidae								
Odonata	Zygoptera								
Oligochaeta	Oligochaeta	160	100	100	23	333	40	20	
Plecoptera	Gripopterygidae		3						
Plecoptera	sp.								
Trichoptera	Atriplectididae								
Trichoptera	Calamoceratidae								
Trichoptera	Conoesucidae								
Trichoptera	Ecnomidae	100	13	67	20	33	29	53	100
Trichoptera	Hydrobiosidae			133		267	3	13	
Trichoptera	Hydropsychidae	1280	18	767	17	333		60	
Trichoptera	Hydroptilidae	100	10	200	157	167	9	87	33
Trichoptera	Leptoceridae		15		7		26		53
Trichoptera	Philopotamidae					67			
Turbellaria	Dugesiidae			33					