Biological and Water Quality Monitoring

Spring 2008

prepared for City of Ryde

delivered by Analytical Services, Monitoring Services, Sydney Water

Sydney Office
51 Hermitage Road West Ryde NSW Australia 2114

PO Box 73 West Ryde NSW Australia 2114
telephone +61 2 9800 6935
facsimile +61 2 9800 6973

Commercial-in-Confidence
This report and the information, ideas, concepts, methodologies, technologies and other material it contains remain the intellectual property of Sydney Water Corporation, unless otherwise agreed.

Report Number: 2008/0018

File Reference: …\PM000094\City of Ryde\Spring 2008\Report sp08\City of Ryde Spring 2008 final.doc

January 2009

Executive Summary

This report has been developed by Sydney Water in response to engagement under of the City of Ryde Tender Number COR-EOC-05/07. This report contributes to the City of Ryde Council's implementation of its Biological and Chemical Water Quality Monitoring Strategy using macroinvertebrates and water chemistry in the main creek systems within its area. This report starts the fifth year of the strategy with collection of samples from Archers, Shrimptons, Buffalo, Porters and Terrys creeks in Spring 2008. Spring 2008 sampling was conducted on 16th and 17th of September 2008 and on the 13th and 14th of October 2008.

A total of 1,787 macroinvertebrates were collected and examined from the Spring 2008 sampling period which saw visits to Archers, Shrimptons, Buffalo, Porters and Terrys creeks, with 37 taxa recorded. A total of 74 taxa have been recorded from all creeks in the Spring 2004 to Spring 2008 period from the edge habitat.

Macroinvertebrate results of Spring 2008 indicated that Archers, Shrimptons, Buffalo, Porters and Terrys creeks have impaired macroinvertebrate communities with similar results recorded in Spring 2004 to Autumn 2008. The poorest SIGNAL-SF and AUSRIVAS OE50 result of the program was recorded for Buffalo Creek in Spring 2008. EPT taxa whilst in very low numbers were collected at all five creeks in Spring 2008, the caddisfly Hydroptilidae was the only EPT taxa collected. No AUSRIVAS EPT indicator taxa was observed in Spring 2008. Multivariate analysis of macroinvertebrate data indicated slight changes in community composition between sampled seasons for each creek with Shrimptons Creek showing the most variability in community structure over the 2005 to 2008 period. Archers Creek displays the second most variable community structure over this time period. Terrys Creek has had the most stable community.

Indicative water quality results of Spring 2008 indicate Archers, Shrimptons, Buffalo, Porters and Terrys creeks did not meet, on all or virtually all sampling occasions, ANZECC (2000) guidelines for the protection of aquatic ecosystems for Total Oxidised Nitrogen, Total Nitrogen, Dissolved Oxygen and Ammonium (NH_4) although levels varied between creeks. ANZECC (2000) recommended levels were also exceeded for Total Phosphorus in Shrimptons Creek. These water quality results of Spring 2008 suggest that whilst some similarity exists, influences on water chemistry in each creek are not the same across the City of Ryde. The impaired macroinvertebrate communities recorded in each of the five study streams reflect water quality failures highlighted in the comparison of water quality results to ANZECC (2000) guidelines and probably other unmeasured parameters.

Multivariate analysis of extrinsic water quality parameters for each creek highlighted rainfall as a contributor to influencing community structure. Multivariate analysis of extrinsic water quality parameters on all creeks highlighted surrogate measures of storm water catchment drainage, Total Length of Pipe and Ratio of Number of Outlets/Catchment Area as contributors to influencing community structure.

Contents

List of Figures

List of Tables

Appendixes

1 Introduction

Sydney Water Corporation (Sydney Water) has developed this report in response to engagement under the City of Ryde Council Tender Number COR-EOC-05/07.

This report contributes to the City of Ryde Council's implementation of its Biological and Chemical Water Quality Monitoring Strategy using macroinvertebrates and water chemistry in the main creek systems within its area. This strategy was originally planned as a seven year program of which the first two years of the program saw all five creeks monitored. The intention of the broad program for the remaining five years was to target two of the five creeks each year on a rotational basis. However, discussions arising out of presentation of the Spring 2006 report lead to inclusion of all five sites in Autumn 2007 report to better encompass natural variation from drier and wetter hydrological conditions that may prevail through the program. The Spring 2008 report ends the fifth year of the seven-year program with inclusion of all five sites for macroinvertebrates and water chemistry, which were sampled once each month in September and October 2008. Additional water quality was conducted as per variations.

Monitoring macroinvertebrates and water chemistry enables the City of Ryde Council to:

- Evaluate chemical and biological water quality monitoring both for short and long term interpretation and temporal evaluation over the duration of the strategy;
- Detail where, when and how often samples should be taken from creeks within the Ryde Local Government Area based on existing site data, catchment position, accessability and trends identified;
- Prescribe how to sample for macroinvertebrates, building on the standard protocols designed by AUSRIVAS;
- Provide for a series of options for identification of key indicator taxa to family and or morphospecies;
- Identify suitable indices such as SIGNAL SF to assess water quality, including calculation of the Observed/Expected (OE50 and OE0 SIGNAL2) ratios from the respective AUSRIVAS predictive models for autumn, spring, and combined seasons;
- Provide the basis for an appraisal of the capacity of a standard monitoring strategy to be intergrated into a community monitoring program eg. Streamwatch.
- Provide the foundation to augment the Streamwatch capacity within the City of Ryde including options for improved education awareness of water quality issues within schools and community groups.
- Provide information and direction on potential infrastructural works to complement water quality monitoring and improve overall creek health.

2 Study Area

2.1 Site locations

The five designated sites (Figure 1) of the City of Ryde Council's Biological and Chemical Water Quality Monitoring Strategy are:

- Site 1 – Terrys Creek near M2 motorway at the end of Somerset Road, North Epping
- Site 2 – Shrimptons Creek at Wilga Park
- Site 3 – Porters Creek, accessed through the Ryde City Depot, after the creek is piped under the depot
- Site 4 – Buffalo Creek, accessed through private property (52 Higginbotham Rd)
- Site 5 – Archers Creek at Maze Park

Additional water quality sites for Shrimptons, Porters and Buffalo creeks were sampled for various analytes in Spring 2008, refer to Table 8 for these locations.

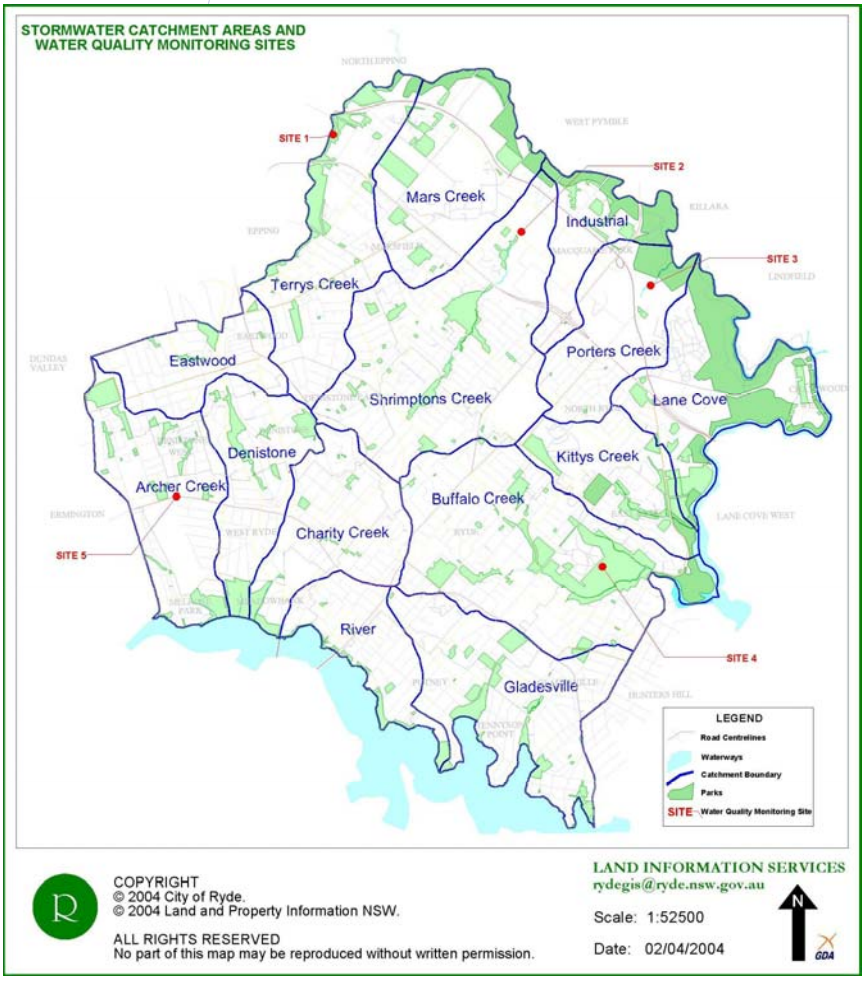


Figure 1 ***Site locations of the Biological and Chemical Water Quality Monitoring Strategy of the City of Ryde***

2.2 Spring 2008 sampling events

Two sampling events were conducted in Spring 2008 for the City of Ryde Biological and Chemical Water Quality Monitoring Strategy. Sampling was conducted at all five creeks in each of the following periods:

- 16th to 17th September 2008
- 13th to 14th October 2008

Figure 2 Archers Creek in Autumn 2008 showing completed rehabilitation work

3 Methodology

3.1 Macroinvertebrate sampling

Rapid assessment macroinvertebrate sampling was conducted in accordance with AUSRIVAS protocols for NSW (Turak et al., 2004). Sydney Water staff that conducted field sampling have met criteria of the in-house test method for macroinvertebrate identification and enumeration. Use of experienced staff addresses issues identified by Metzeling et al. (2003).

Three edge habitat samples were collected from each site within a pre-selected area in September and October within the season of Spring 2008 as specified in the City of Ryde Biological and Chemical Water Quality Monitoring tender document COR-EOC-05/07. The ‘edge’ habitat is defined as areas with little or no current. These areas were sampled with a hand-held dip net with 320 mm by 250 mm opening and 0.25 mm (250 µm) mesh that conformed to ISO 7828-1985 (E). The net was swept from open water towards the shore, working over a bank length of about 10 m moving in an upstream direction. In the process, deposits of silt and detritus on the stream bottom were stirred up so that benthic animals were suspended and then caught in the net.

The net contents were then emptied into a large white sorting tray with a small amount of water to allow live macroinvertebrate specimens to be picked out with fine forceps and pipettes for a period of 40 minutes. If new taxa are collected between 30 and 40 minutes, sorting will continue for a further 10 minutes. If no new taxa are found after 10 minutes the picking ceases. If new taxa are found, the 10 minute processing cycle is continued up to a maximum total sorting time of 1 hour. There is no set minimum number of animals collected using the NSW protocols (Turak, et al., 2004).

All specimens collected will be preserved in small glass specimen jars containing 70% ethanol with a clear label indicating site code, creek name, date, habitat and name of Sydney Water staff sampler. Sampling equipment will be washed thoroughly between samples to prevent the cross contamination of animals.

3.2 Macroinvertebrate sample processing

Macroinvertebrates were identified and enumerated to the family taxonomic level, except for: non-biting midges (Chironomids) to sub-family; aquatic worms to Class Oligochaeta; and aquatic mites to Order Acarina. The method used, SSWI433 *In-house test method macroinvertebrate cataloguing, identification and counting,* is in compliance with the requirements of AS ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories* under technical accreditation number 610 issued by National Association of Testing Authorities (NATA) and has been employed since 1997. In particular, macroinvertebrate identification was performed using appropriate published keys listed in Hawking (2000), internal keys to the Sydney Water macroinvertebrate reference collection, unpublished descriptions and voucher specimens.

Quality assurance was conducted as per *SSWI434 In-house test method quality control of macroinvertebrate identification, counting and archiving of collections* in compliance with the requirements of AS ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories under technical accreditation number 610. Quality assurance was conducted on 5% of samples collected for this study. Quality assurance is further described in Appendix A.

3.3 Water quality sampling

Water chemistry was sampled once each month within Spring 2008 (September and October) at the time of macroinvertebrate sampling.

Samples were taken by filling the sample bottles directly from the surface of the stream. Temperature, pH and dissolved oxygen were measured on site as per methods summarised in Table 1.

Table 1 Water chemistry parameters, method of analysis in field

ANALYTE	METHOD
pH, Dissolved Oxygen	WTW meter
Temperature	Thermometer

Samples for the analysis of turbidity, conductivity, total dissolved solids (TDS), faecal coliforms, total phosphorus, total nitrogen (as a measure of total oxidised nitrogen and total Kjeldahl nitrogen), total alkalinity and ammonia were returned to the laboratory and analysed by the methods summarised in Table 2 within 12 hrs of sampling.

Table 2 Water chemistry parameters, method of analysis in laboratory

ANALYTE	DETECTION LIMIT	METHOD
Turbidity	0.10 NTU	APHA 2130B
Total Dissolved Solids	10 mg/L	APHA 2450 C
Faecal Coliforms	1 cfu/100mL	APHA 9222-D
Total Phosphorus	0.002 mg/L	APHA4500P- H
Alkalinity ($CaCO_3$/L)	0.5 mg/L	APHA 2320 B
Oxidised Nitrogen	0.01 mg/L	APHA 4500-NO3 I
Total Kjeldahl Nitrogen	0.1 mg/L	Calculation
Ammoniacal Nitrogen	0.01 mg/L	APHA 4500-NH3 H
Conductivity	0.1 mS/m	APHA 2510 B

Additional water quality sample collection and measurements in Autumn on Archers, Shrimptons, Buffalo and Porters creeks and in Spring 2008 on Shrimptons, Buffalo and Porters creeks allowed spatial comparisons of collected variables on each creek in an attempt to investigate potential dry weather point sources.

While not to the sampling frequency suggested by ANZECC (2000), the water quality results did allow characterisation of each study creek against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary).

3.4 Rainfall Data

Daily rainfall data from the Marsfield Bureau of Meteorology Station number 066156 are presented where records were recorded. For the few missing records from station 066156, data were substituted from Sydney Water Meteorology Station number 566040 at West Epping. At the time of reporting rainfall data was only available until end of September 2008.

3.5 Comparison with historical data

The City of Ryde Council Tender Number COR-EOC-05/07 requested compilation and analysis of all historic raw data (where comparable) back to 2004 and, where data was available back to 2001, for assessment with Spring 2008 study data to provide a temporal evaluation of ecological health of the five creeks under study. Ecowise supplied raw macroinvertebrate and water chemistry data (Spring 2004 to Autumn 2006) and together with Spring 2006, Autumn 2007, Spring 2007, Autumn 2008 and Spring 2008 data allowed the compilation of data points as summarised in Table 3. Previous data were unavailable in a suitable format for this purpose or had comparability issues such as the location sampled on Porters and Buffalo creeks in Spring 2004.

Table 3 Summary of when, each variable was sampled, between Spring 2004 and Spring 2008

	Sampling period																																												
	Spring 2004					Autumn 2005					Spring 2005					Autumn 2006					Spring 2006					Autumn 2007					Spring 2007					Autumn 2008					Spring 2008				
	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck
Macroinvertebrates	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Alkalinity (Total)	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Ammonia NH3-N						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Conductivity (mS/m)						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
DO (mg/L)	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Faecal Coliform	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Oxidised Nitrogen NOx-N						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
pH	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Temp	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
TN						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Total Dissolved Solids	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Total Kjeldahl Nitrogen						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Total Phosphorus	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Turbidity	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

3.6 Data analyses

After identification and enumeration of macroinvertebrates the data were analysed with univariate and multivariate analysis techniques.

Univariate methods

Data analyses were performed using a number of biological indices and predictive models. These included:

- Diversity index EPT (mayfly, stonefly, caddis fly) richness
- Biotic index SIGNAL-SF
- Output from AUSRIVAS predictive models (Eastern Edge Autumn; Eastern Edge Spring; Combined Edge)
    - AUSRIVAS OE50
    - AUSRIVAS OE0 SIGNAL2

The range of each measure has been plotted in this report with +/-1 standard deviation of the mean for basing ecological decisions (ANZECC, 2000). Presenting data in this way attempts to take account of variation at study sites and provide a basis in future years to enable management tracking and or as a basis for making management decisions.

EPT richness

The biotic index EPT (Ephemeroptera - mayfly, Plecoptera - stonefly and Trichoptera - caddisfly families) richness is based upon the sensitivity of these taxa to respond to changes in water quality condition (Lenat 1988). Generally the number of these taxa found at a site can be used as an indicator of stream biological health, although some EPT taxa are more tolerant.

Some caution must be given when interpreting patterns based on EPT taxa as many of these macroinvertebrates are also sensitive to natural changes in streams, such as altitude. In general, EPT taxa favour higher altitude streams to low altitude streams. However Sydney Water has observed a diverse range of these taxa at altitudes as low as 10 metres in undisturbed waterways in the greater Sydney region and in the Clyde River. The absence of these taxa in streams may be attributable to human disturbances within urban catchments and or decline in flow over recent years from lack of rainfall.

SIGNAL-SF

The original version of the Stream Invertebrate Grade Number Average Level (SIGNAL) biotic index (Chessman, 1995-Sydney Water data) has been refined by testing that included the response of SIGNAL to natural and human influenced (anthropogenic) environmental factors (Growns *et al*. 1995), variations in sampling and sample processing methods (Growns *et al*. 1997; Metzeling *et al*. 2003) and setting sensitivity grades of the taxa objectively (Chessman *et al*. 1997; Chessman *et al*. 2002). "F" indicates taxonomy is at the family level and "S" indicates Sydney region version. SIGNAL-SF has been derived from macroinvertebrate data of the greater Sydney region (Chessman et al., 2007). Water quality status of clean water has been established in the index using data from near pristine reference sites in the bushland fringes of Sydney by using the 10th percentile of the average score of these reference sites. SIGNAL-SF allows a direct measure of test site condition and incorporates abundance information from the rapid assessment sampling.

The first step in calculating a SIGNAL-SF score is applying predetermined sensitivity grade numbers (from 1, tolerant to 10, highly sensitive) to family counts that occur within a location habitat sample. Then multiply the square root transformed count of each family by the sensitivity grade number for that family, summing the products, and dividing by the total square root transformed number of individuals in all graded families. Families that were present in the samples but with no grade numbers available (relatively few, only 4 with infrequent occurrence) were removed from the calculation of the SIGNAL-SF score for the sample. This procedure was repeated for each sample. Calculation then occurs of a location specific average and a measure of variation (plus and minus one standard deviation of the average score) through time as recommended by Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000) was made to allow stream health comparisons between sampling occasions for each creek and between creeks. Comparisons in this manner allow ranking of stream health as a guide to management decisions.

As aquatic mites (Order Acarina) and aquatic worms (Class Oligochaeta) are left at higher taxonomic levels in the AUSRIVAS protocol, the respective SIGNAL-SF grades of the families of aquatic mites and worms were averaged and used in the calculation of SIGNAL-SF scores for this report.

Arbitrary pollution categories can be assigned (Table 4). Sydney Water has successfully demonstrated the application of this index in stream monitoring of management changes to the sewerage system and subsequent organic pollution responses in creeks from these decisions (Besley & Chessman, 2008).

Table 4 Interpretation of SIGNAL-SF scores (Chessman et al., 2007)

SIGNAL-F score	Water quality status
> 6.5	Clean water
5.2-6.5	Possible mild organic pollution
3.8-5.2	Probable moderate organic pollution
< 3.8	Probable severe organic pollution

AUSRIVAS predictive models OE50 output

AUSRIVAS (AUStralian RIVers Assessment System) predictive model is based on the British bioassessment system RIVPACS (River Invertebrate Prediction and Classification System; Wright 1995). The RIVPACS model was modified to suit the environmental conditions present only in Australia (Turak et al*.* 2004). The AUSRIVAS model is an interactive software package, which uses the macroinvertebrate and environmental data collected from numerous reference river sites across the state of NSW. It is a tool that can quickly assess the ecological health of any river or creek site. Collected macroinvertebrate data are transformed into presence absence (1 or 0) form, which is also referred to as binary data. The predictor environmental variables required to run for each model vary as outlined in Tables 5 and 6 but generally include altitude, location (latitude and longitude), stream size characteristics, substratum composition, river alkalinity and rainfall (Turak 2001). These environmental variables allow the software to compare test sites, in this case City of Ryde creek samples, to comparable reference site groups with similar environmental characteristics.

AUSRIVAS models can incorporate data taken from pool edge or riffle habitats. The paucity of riffle habitats at the sites under study by the City of Ryde in sampling conducted for the program to date preclude use of the riffle models. Ecowise collected only four riffle samples between Spring 2004 and Autumn 2006. Hence in comparison of Spring 2008 data with historical data the respective edge models have been employed.

The applicable AUSRIVAS models for comparison of the City of Ryde test creek sites are: the eastern edge Autumn model; eastern edge Spring model; and Combined Season eastern edge model. However, Ecowise (Spring 2005) suggested the later model does not allow changes in condition between seasonal sampling events for the City of Ryde strategy. The later model has been included here for completeness as Ransom et al. (2004) describes this model as preferable as it maximizes the family list for the test site being examined.

The respective model uses the test site information and comparable reference site group information to calculate a score called the “OE50 ratio” (observed/expected number of macroinvertebrate families with greater than 50% probability of occurring at a test site) (Coysh et al., 2000). The OE50 ratio provides a measure of impairment at a test site (Ransom et al., 2004). The OE50 ratio of each test site sample also corresponds to a band that assists in interpretation and aids management decisions (Coysh et al., 2000). That is, the band helps to categorise each test site showing how it compares with reference sites from rivers of the same type. Interpretation of the five possible bands of river condition is detailed in Table 5 (Coysh et al., 2000). Thresholds that correspond to these bands of each respective model are detailed in Table 6.

Table 5 Interpretation of bands associated with AUSRIVAS OE50 model output (Coysh et al., 2000)

Band	Description	O/E taxa	O/E taxa interpretations
X	More biologically diverse than reference	▪ O/E greater than 90th percentile of reference sites used to create the model	▪ More families found than expected ▪ Potential biodiversity ‘hot spot’ or mild organic enrichment ▪ Continuous irrigation flow in a normally intermittent stream
A	Similar to reference	▪ O/E within range of central 80% of reference sites used to create the model	▪ Expected number of families within the range found at 80% of the reference sites
B	Significantly impaired	▪ O/E below 10th percentile of reference sites used to create the model. ▪ Same width as band A	▪ Fewer families than expected ▪ Potential impact either on water and/or habitat quality resulting in a loss of families
C	Severely impaired	▪ O/E below band B ▪ Same width as band A	▪ Many fewer families than expected ▪ Loss of families from substantial impairment of expected biota caused by water and/or habitat quality
D	Extremely impaired	▪ O/E below band C down to zero	▪ Few of the expected families and only the hardy, pollution tolerant families remain ▪ Severe impairment

Table 6 Upper thresholds for bands of impairment (OE50 taxa) for AUSRIVAS models developed for NSW (Turak and Waddell, 2001)

Model	Threshold			
	A	B	C	D
Combined edge (East)	1.17	0.82	0.48	0.14
Autumn edge	1.17	0.81	0.46	0.11
Spring edge	1.16	0.83	0.51	0.19

Indicator taxa from the AUSRIVAS predictive models output

AUSRIVAS output identifies taxa that were expected from the respective reference site group to which a test site is being compared. As part of this output missing taxa are listed with greater than 50% probability of occurrence. To provide consistency in this report the definition used by Ecowise (2004, 2005a, 2005b, 2006) has been used in this report. That is, indicator taxa are defined as taxa within the EPT (Ephemeroptera - mayfly, Plecoptera - stonefly and Trichoptera – caddisfly) orders with SIGNAL2 scores of greater than 6.

AUSRIVAS predictive models OE0 SIGNAL-2 output

Together with OE50 output each AUSRIVAS model also generates AUSRIVAS OE50-SIGNAL2 values and AUSRIVAS OE0-SIGNAL2 values. This output incorporates SIGNAL2 (Chessman 2003a) tolerance grades derived from reference sites across NSW sampled to create the AUSRIVAS models in NSW. Please note SIGNAL2 tolerance grades are different to the greater Sydney region tolerance grades of SIGNAL-SF as the later has been derived from sites of the Sydney region and not from broadly across NSW.

An example calculation of AUSRIVAS OE50-SIGNAL2 values is provided in previous Ecowise reports, which sourced this example from Chessman (2003a). In the Spring 2006 report AUSRIVAS OE50 SIGNAL2 values were found to be quite variable and for this reason were not recommended for use in future temporal comparisons. That is, the large variation recorded in this measure provided little ability to detect future changes in community structure from future management decisions.

In contrast AUSRIVAS OE0-SIGNAL2 values were found to have less variance and were recommended to be calculated in Autumn 2007 and beyond. The lesser variation of AUSRIVAS OE0-SIGNAL2 is attributed to the inclusion of taxa with 50% probability of occurrence or more used to calculate AUSRIVAS OE50-SIGNAL2 and additional taxa with less than 50% probability of occurrence.

No bands have been developed for SIGNAL2 (Coysh et al*.* 2000), however, values of around 1 would be similar to reference condition (Chessman pers comm.). Using AUSRIVAS calculated values are recommended by Chessman (2003a) as a way to overcome natural variation, which is an issue for calculation of SIGNAL2 as described in Chessman (2003b).

Multivariate methods

Data analyses were performed using the PRIMER software package (Clark and Warwick 2001). Analysis techniques included:

- Classification and ordination, SIMPROF test
- SIMPER
- BIOENV

These analysis techniques complement univariate analyses by exploring patterns of macroinvertebrate community structure. Macroinvertebrate community structure at a site can also be referred to as the biological signature. Prior to analysis the data from the field survey was square root transformed and rare taxa observed in only one sample were removed.

Spring 2008 macroinvertebrate samples were compared in an ordination with 2005, 2006, 2007 and Autumn 2008 data for all creeks of the monitoring program to look at context of community composition. Please note Spring 2004 data were not included in these comparisons as comparable sites in Buffalo and Porters creeks were not sampled in Spring 2004 and also not sampled in Spring 2004 were all water quality variables at Archers, Shrimptons and Terrys creeks (Table 3).

Macroinvertebrate data of each creek were also explored by a comparison of data from the seasons, Autumn 2005, Spring 2005, Autumn 2006, Spring 2006, Autumn 2007, Spring 2007, Autumn 2008 and Spring 2008.

Classification, Ordination and SIMPROF test

The group average classification technique was used to place the sampling sites into groups, each of which had a characteristic macroinvertebrate community based on relative similarity of their attributes. Similarities (distances) between the fauna of each pair of sites were calculated using the Bray-Curtis measure, which is not sensitive to rough approximations in the estimation of taxa abundances (Faith et al. 1987), as is the case with rapid assessment sampling. The group average classification technique initially forms pairs of samples with the most similar taxa and gradually fuses the pairs into larger and larger groups (clusters) with increasing internal variability.

Classification techniques will form groups even if the data set actually forms a continuum. The SIMPROF test provides a way to view community structure differences and similarities between samples and overcome the limitation of classification analysis. SIMPROF results have been overlaid onto classification result output (dendrogram) with red lines indicating no difference between samples and the black line indicating a difference in community structure. SIMPROF test groups can be checked against ordination results. Samples were ordinated using the non-metric multidimensional scaling (MDS) technique. Ordination produces a plot of sites on two or three axes such that sites with a similar taxa lie close together and sites with a differing taxon composition lie farther apart. When Ordination and SIMPROF test results produce similar overall patterns the analysis can be considered reliable.

Any ordination procedure inevitably introduces distortion when trying to simultaneously represent the similarities between large numbers of samples in only two or three dimensions. The success of the procedure is measured by a stress value, which indicates the degree of distortion imposed. In the PRIMER software package a stress value of below 0.2 indicates an acceptable representation of the original data although lower values are desirable.

To achieve suitable mutlivariate representations of data in 2 or 3 dimensions with greater data collection, an analysis strategy to minimize stress (and achieve a better measure of fit) is to pool up macroinvertebrate data of the same season for each creek to produce one data point per season per creek as demonstrated in the Spring 2007 report for all five creeks. This analysis strategy has been adopted for the ordination plot of all creeks in this report.

SIMPER

The SIMPER routine was employed to investigate community structure between and within groups of sites as detailed above. This routine employs Bray Curtis similarities to examine the contribution of individual taxa to the average similarity between groups and also within groups.

BIOENV

The extrinsic physical and chemical characteristics of the creeks were compared with the intrinsic macroinvertebrate community structure using the BIOENV routine. The underlying similarity matrix was constructed with the normalised Euclidean Distance association measure option. This option enabled a comparison of water quality variables without undue weight being assigned by differing unit scales. Log10 transformations were applied to: Faecal Coliforms; Ammonia; Oxidised Nitrogen; Total Phosphorus; Total Kjeldahl Nitrogen; Total Nitrogen; Turbidity; Conductivity; and Total Dissolved Solids. All other physical and chemical variables listed in Table 2 were untransformed in the BIOENV analysis.

4 Results

4.1 Water quality & site observations

The field and laboratory results for water quality parameters measured at Archers, Shrimptons, Buffalo, Porters and Terrys creeks in Spring 2008 are presented in Table 7. Whilst not to the sampling frequency suggested by ANZECC (2000), it did allow characterisation of water quality for each study creek against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary).

The dissolved oxygen saturation levels from Shrimptons, Buffalo and Terrys creeks during Spring 2008 were all below the 85% recommended level within ANZECC (2000) for the protection of aquatic ecosystems. In September both Archers and Porters creeks recorded dissolved oxygen saturation levels within ANZECC (2000) recommended levels, 98% and 88.5 % respectively. In October however they both fell below these levels, Archers Creek was well below with 35% and Porters Creek recorded 74%. Porters Creek has the highest overall historical average for dissolved oxygen saturation levels (83%, Table 7) in the period Spring 2004 to Autumn 2008. In October Shrimptons Creek recorded 0% dissolved oxygen saturation and Buffalo recorded 3.3%. Shrimptons Creek has the lowest overall historical average dissolved oxygen saturation levels (41%, Table 7). When water quality samples were collected from Shrimptons Creek in October (both at the core site and additional Kent Rd site) tadpoles were observed actively coming to the water-surface to get oxygen from the air.

Bacteriological results were compared with ANZECC (2000) recommended levels for secondary contact (recreation). Since water bodies sampled for City of Ryde were unlikely to be used for primary contact purposes such as swimming, it was considered that application of the secondary contact guidelines were appropriate. However, it must be noted that comparisons with these guidelines do not infer a measure of compliance with the guidelines, as samples have not been collected under an appropriate regime for compliance monitoring (five samples in a 30 day period). The comparisons are indicative only to provide a degree of context to bacteriological results obtained. All samples taken from the five core sites during Spring 2008 were below the ANZECC (2000) limit of 1000 CFU/100mL indicating all creeks were within safe levels for secondary contact at the time of sampling.

Turbidity levels were within the ANZECC (2000) recommended levels for all core site samples taken from Terrys, Shrimptons, Porters, Buffalo and Archers creeks in Spring 2008. Historical averages for all five creeks are well below ANZECC (2000) recommended levels. Recent turbidity levels for the Buffalo Creek core site have not exceeded ANZECC (2000) recommended levels. The additional site samples in Autumn 2008 did produce some recordings that exceeded the recommended levels, these were at the upstream and downstream Burrows Park sites. Additionally very turbid stream conditions were observed in Buffalo Creek when taking photos in late April for the Autumn 2008 report (refer to Figure 3) at both the core site and the two additional Burrows Park sites. At the core site in Spring 2008 it was noted that the streambed had a drape of sediment of greater thickness than previously observed.

Total Oxidised Nitrogen as a measure of nutrient levels were elevated above ANZECC (2000) recommended levels of 40 µg/L in September for Shrimptons Creek and for all samples at Terrys, Porters, Buffalo and Archers creeks in Spring 2008. Total Oxidised Nitrogen levels for Shrimptons Creek in October were within ANZECC (2000) recommended levels. Total Oxidised Nitrogen levels in Shrimptons Creek from the previous two sampling seasons (Spring 2007 and Autumn 2008) had not exceeded ANZECC (2000) recommended levels for Total Oxidised Nitrogen. Porters Creek considerably exceeded ANZECC (2000) recommended levels for Total Oxidised Nitrogen in Spring 2008 with 1660 µg/L in September and 1870 µg/L in October and was above the historical average of 911 µg/L.

Total Nitrogen levels for all five creeks exceeded the ANZECC (2000) recommended levels of 500 µg/L, except Terrys Creek in September, which recorded 490 µg/L. Porters Creek considerably exceeded ANZECC (2000) recommended levels for Total Nitrogen in Spring 2008 with 6180 µg/L in September and 3280 µg/L in October and was above the historical average of 2153 µg/L.

Ammonia levels greatly exceeded ANZECC (2000) recommended levels of 20 µg/L at Porters Creeks on both sampling occasions in Spring 2008, recording 4000 and 980 µg/L respectively. Ammonia results for Archers, Shrimptons, Buffalo and Terrys creeks were within ANZECC (2000) recommended levels in September but exceeded levels in October. Historical averages show that all five creeks average above the ANZECC (2000) recommended levels.

Shrimptons Creek exceeded ANZECC (2000) recommended levels for Total Phosphorus (50 µg/L) on both sampling occasions in Spring 2008, 54 µg/L in September and 197 µg/L in October. Terrys Creek narrowly exceeded the level in October with 52 µg/L, but was within the levels in September. Archers, Buffalo and Porters creeks were within levels for total phosphorus on both sampling occasions in Spring 2008.

Conductivity (as a measure of salinity) was outside ANZECC (2000) recommended range for all samples at all five creeks in Spring 2008. All results were below the lower limit of 125 µS/cm. Historically Porters Creek is the only creek to average outside the range for conductivity recommended levels ANZECC (2000), it's historical average however is 2746 µS/cm, which is above the upper limit.

The pH was within the recommended levels (ANZECC, 2000) for all samples at all creeks for Spring 2008, as are the historical averages.

Alkalinity recordings for Spring 2008 were similar across all five creeks and were reflective of historical averages except for Porters Creek which had 130 mg $CaC0_3$/L in September and 92 mg $CaC0_3$/L in October, both above the historical average of 63 mg $CaC0_3$/L. Total Dissolved Solids were similar across all five creeks in Spring 2008. Porters Creek recorded levels well below its historical average.

Additional water quality sample collection and measurements on Shrimptons, Buffalo and Porters creeks allowed spatial comparisons of collected variables on each creek in an attempt to investigate potential dry weather point sources.

All samples taken from Shrimptons Creek for Dissolved Oxygen were below the ANZECC (2000) recommended levels except in September at the downstream Santa Rosa Park site. October saw very low recordings of Dissolved Oxygen at the additional sites with 0% saturation at Kent Road and upstream Santa Rosa Park and 22.6% saturation at downstream Santa Rosa Park. The only additional Buffalo Creek sample to be within ANZECC (2000) recommended levels was the u/s Burrows Park sample in September. Three of the Porters Creeks samples were within ANZECC (2000) recommended levels and of the other three two only just failed. The October sample from the Porters Creek Main Branch Channel site was significantly higher than the upper limit of 110% saturation at 147.4%.

Spring 2008 recorded two elevated non-compliant levels of faecal coliforms at additional sites compared to ANZECC (2000) recommended levels. These were in September at Shrimptons Creek at Kent Road (1100 CFU/100mL) and at Buffalo Creek d/s Burrows Park (1200 CFU/100mL). These samples however are not appreciably above the ANZECC (2000) recommended levels. All other additional samples conformed to ANZECC (2000) recommended levels of 1000 CFU/100mL.

Turbidity levels at the additional upstream sites during Spring 2008 were all within ANZECC (2000) recommended levels except for the October recording of 59.8 NTU at Porters Creek Main Branch at Wicks Rd. The next highest recording at the additional sites was 30.4 NTU at Porters Creek d/s Burrows Park in September, which is still less than the ANZECC (2000) recommended limit of 50 NTU.

Total Oxidised Nitrogen levels exceeded ANZECC (2000) recommended levels, 40 µg/L, for all additional sites at Buffalo and Porters creeks, with significantly high levels in September at both the upstream (1610 µg/L) and downstream (1790 µg/L) Burrows Park Buffalo Creek sites. Shrimptons Creek additional site samples exceeded ANZECC (2000) recommended levels for Total Oxidised Nitrogen except for the October recordings at Kent Rd and d/s Santa Rosa Park at Bridge St. Total Nitrogen levels exceeded ANZECC (2000) recommended levels for all creeks except in October at Shrimptons Creek d/s Santa Rosa Park at Bridge St. This site was also the only site not to exceed ANZECC (2000) recommended levels for Ammonia, all other sites exceeded levels. Shrimptons Creek at Kent Road and the October sample for Shrimptons Creek u/s Santa Rosa Park at Quarry Rd exceeded Total Phosphorus ANZECC (2000) recommended levels, the other Shrimptons Creek samples were within limits. The September sample for Buffalo Creek upstream Burrows Park was within Total Phosphorus ANZECC (2000) recommended levels, all other Buffalo Creek samples exceeded levels. The October sample at Porters Creek Main Branch at Wicks Road was the only Porters Creek sample to exceed ANZECC (2000) recommended levels.

All samples for all creeks were within ANZECC (2000) recommended levels for pH. Shrimptons Creek upstream Santa Rosa Park at Quarry Rd was the only Shrimptons Creek samples to be within ANZECC (2000) recommended range for Conductivity, the rest were below the lower limit (125 µS/cm). The September Buffalo Creek upstream Burrows Park sample was the only Buffalo Creek sample to be outside of ANZECC (2000) recommended range for Conductivity. All Porters Creek samples were below the lower limit (125 µS/cm) for Conductivity.

Table 7 ***Water quality results for Spring 2008 in relation to the ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary)***

Parameter *Units*		Faecal Coliform CFU/100mL	NH^{4+} µg/L	NOx µg/L	TP µg/L	TKN µg/L	TN µg/L	Alkilinity mg $CaCO_3$/L	Turb NTU	Cond-uctivity µS/cm	*TDS* mg/L	pH	DO % Sat	Temp-erature ^0C
ANZECC (2000)	Aquatic Ecosystems	-	*20*	*40*	*50*	N/A	*500*	*N/A*	*50*	*125-2200*	*N/A*	*6.8-8.0*	*85-110*	-
	Secondary Contact	*1000*	-	-	-	-	-	-	-	-	-	-	-	-
ARCHERS CK	September	270	10	**670**	19	350	**1020**	83	2.7	**56**	311	7.7	98.0	13.7
	October	220	**50**	**380**	33	370	**750**	86	2.7	**50**	279	7.3	35.0	16.5
	Historical*	719	**38**	**136**	**51**	340	475	72	5.0	426	250	7.1	**58.0**	17.7
SHRIMPTONS CK	September	240	20	**250**	**54**	440	**690**	51	8.9	**28**	155	7.1	38.1	16.1
	October	420	**120**	30	**197**	900	**930**	67	3.9	**30**	171	7.1	0	16.8
	Historical*	663	**38**	**172**	**60**	482	632	64	10.0	356	213	6.9	41.0	16.8
BUFFALO CK	September	820	10	**450**	42	400	**850**	80	10.8	**52**	293	7.3	70.3	14.9
	October	84	**130**	**90**	41	540	**630**	97	13.2	**101**	573	7.2	3.3	17.1
	Historical*	766	**72**	**284**	40	347	**598**	80	10.0	669	383	7.3	61.0	17.2
PORTERS CK	September	260	**4000**	**1660**	24	4520	**6180**	130	5.5	**61**	336	7.7	88.5	14.7
	October	48	**980**	**1870**	26	1410	**3280**	92	4.9	**46**	251	7.4	74.0	16.3
	Historical*	**2845**	**610**	**911**	27	1067	**2153**	63	5.0	**2746**	1710	7.5	83.0	18.5
TERRYS CK	September	820	10	**120**	35	370	490	42	11.5	**25**	149	7.2	76.0	14.6
	October	80	**20**	**140**	**52**	440	**580**	74	3.0	**51**	281	7.1	34.5	14.1
	Historical*	348	**100**	**142**	41	378	**520**	57	5.0	366	215	7.1	61.0	15.7

Historical* = Average of historical water quality data for samples taken from Spring 2004 – Autumn 2008.

Table 8 ***Water quality results at additional COR sites for Spring 2008 in relation to the ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary)***

Parameter Units		Faecal Col CFU/ 100mL	NH^{4+} µg/L	NOx µg/L	TP µg/L	TKN µg/L	TN µg/L	Alkilinity mg $CaCO_3$/L	Turb NTU	Cond-uctivity µS/cm	TDS mg/L	pH	DO % Sat	Temp-erature ^0C
ANZECC (2000)	Aquatic Ecosystem	-	20	40	50	N/A	500	N/A	50	125-2200	N/A	6.8-8.0	85-110	-
	Secondary Contact	1000	-	-	-	-	-	-	-	-	-	-	-	-
Shrimptons Creek	Historical*	663	38	172	60	482	632	64	10.0	356	213	6.9	41.0	16.8
Shrimptons Ck Kent Rd	September	1100	40	210	59	410	620	41	10.1	29	157	7.3	59.5	14.4
	October	220	120	20	101	690	710	64	4.4	37	208	6.9	0	17
Shrimptons Ck Bridge St (d/s Santa Rosa Pk)	September	110	30	170	26	370	540	71	4.6	58	336	6.9	97.7	17.7
	October	110	20	10	24	350	360	94	5.3	61	345	7.0	22.6	18.2
Shrimptons Ck Quarry Rd (u/s Santa Rosa Pk)	September	100	180	510	35	530	1040	76	5.7	90	517	7.1	60.7	17.7
	October	25	270	440	165	1120	1560	112	12.4	145	826	6.9	0	17.6
Buffalo Creek	Historical*	766	72	284	40	347	598	80	10.0	669	383	7.3	61.0	17.2
Buffalo Ck d/s Burrows Pk	September	1200	40	1790	51	530	2320	87	30.4	124	696	7.2	76.2	15.7
	October	760	50	60	63	670	730	116	17.0	182	1034	6.9	81.5	17.2
Buffalo Ck u/s Burrows Pk	September	410	50	1610	31	380	1990	88	11.4	107	602	7.8	95.3	14
	October	410	100	680	106	780	1460	124	9.7	151	840	7.3	30.2	17.2
Porters Creek	Historical*	2845	610	911	27	1067	2153	63	5.0	2746	1710	7.5	83.0	18.5
Porters Ck Spur Branch	September	~94	60	310	35	380	690	73	3.6	34	139	7.7	106.3	15
	October	380	40	180	42	340	520	64	2.2	31	191	7.7	90.5	17.2
Porters Ck Main Branch Channel (COR staff site)	September	46	250	350	41	920	1270	240	12.7	61	350	7.0	68	13.8
	October	~4	60	170	24	750	920	414	3.1	97	569	7.4	147.4	17.6
Porters Ck Main Branch Wicks Rd	September	510	80	1040	19	300	1340	82	8.6	51	591	7.7	105.2	14
	October	730	100	900	116	660	1560	97	59.8	53	318	7.5	73.1	16.3

Historical = Average of historical water quality data for Core Site samples taken from Spring 2004 – Autumn 2008.*

Figure 3 Buffalo's Creek d/s Burrows Park in Autumn 2008

4.2 Rainfall Data

Daily rainfall data from the Marsfield Bureau of Meteorology Station number 066156 presented below displays the Spring 2008 sampling period and preceding five months. In the five months preceding the September 2008 sampling event 375 mm of rainfall occurred within a range of approximately 10 – 150 mm per month. The annual rainfall for 2007 was 1430 mm. This is the first year since 2003 with 1262 mm to record above average results (Table 9).

Table 9 Total rainfall by year

Year	Rainfall (mm)
2003	1262
2004	905
2005	788
2006	730
2007	1430
2008 to date	890

The rainfall in early to mid 2007 was characterised by infrequent, short but heavy rainfall periods between relatively longer dry periods with the exception of June 2007 (Appendix 3). This pattern changed in late 2007 to early 2008 to longer, lighter rain periods in between shorter dry periods. During mid 2008 the lighter rain periods continued but fell between longer dryer periods (Figure 4).

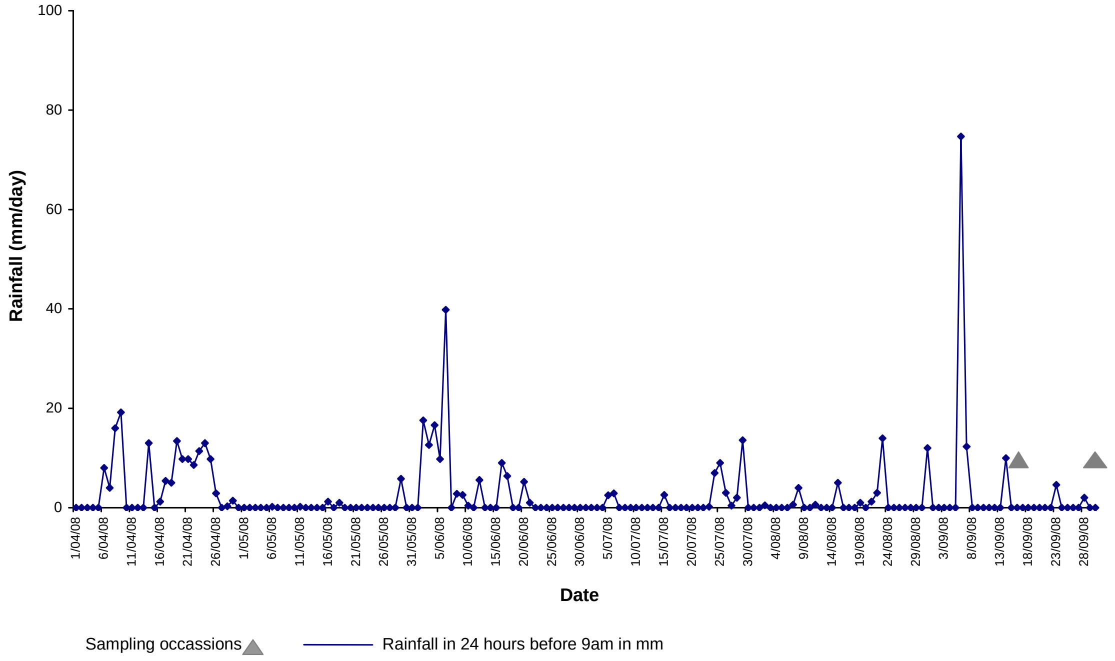


Figure 4 Daily rainfall data 1st April 2008 to 30th September 2008 with sampling occasions indicated

4.3 Macroinvertebrate Results

General Characteristics of Aquatic Macroinvertebrate Assemblages

A total of 1787 macroinvertebrates were collected and examined from the five core sites in the Spring 2008 sampling period with 37 taxa recorded. A total of 74 taxa have been recorded from all creeks in the Spring 2004 to Spring 2008 period from the edge habitat. This compares with 157 taxa of the SIGNAL-SF index of the greater Sydney region, although that total not only includes taxa from the pool edge habitat but other stream habitats.

Comparison of taxa collected in each creek between varying sampling periods such as Spring 2004 to Autumn 2008 and Spring 2004 to Spring 2008 indicates additional taxa have been collected in Spring 2008 for Buffalo, Porters and Terrys creeks (Table 10). With additional seasonal sampling planned under the strategy it is likely further additional taxa will be recorded, particularly if average or above average rainfall continues.

Table 10 Number of taxa recorded in each creek in below specified sample periods

Sampling Seasons	Archers	Shrimptons	Buffalo	Porters	Terrys
Spring 04 - Autumn 08	50	46	47	48	53
Spring 04 - Spring 08	50	46	48	49	55

The Spring 2008 samples from Shrimptons Ck produced two animals of interest to the Aquatic Ecology Laboratory, a species of mite (Hydrachnidae *Hydrachna bilobata*) and a genus of dragonfly (Libellulidae *Trapezostigma loewii*) not previously collected/identified by our Laboratory.

Neither larvae of the Sydney Hawk Dragonfly *Austrocordulia leonardi* (listed as endangered under the *FM Act*) or the Adams Emerald Dragonfly *Archaeophya adamsi* (listed as vulnerable under the *FM Act 1994*) were observed in Spring 2008 samples and are not listed in historical data supplied.

Macroinvertebrate results for comparable samples (Table 3) are consolidated in Appendix 4.

EPT richness

The average EPT taxa richness for each sampled creek was summarized for all sampled seasons in Figure 5. This summary indicated that EPT taxa are rarely collected from the five sampled creeks. Buffalo and Porters creeks have the highest average, yet neither of these two creeks averaged a single EPT taxa per sampling period (Figure 6). Spring 2008 saw EPT taxa return to Shrimptons and Terrys creeks after Autumn 2008 recorded no EPT taxa, albeit very low occurrences. Similarly Buffalo and Porters creeks had very low occurrences of EPT taxa, Archers Ck had the highest during Spring 2008 averaging a single EPT taxa (Figure 6).

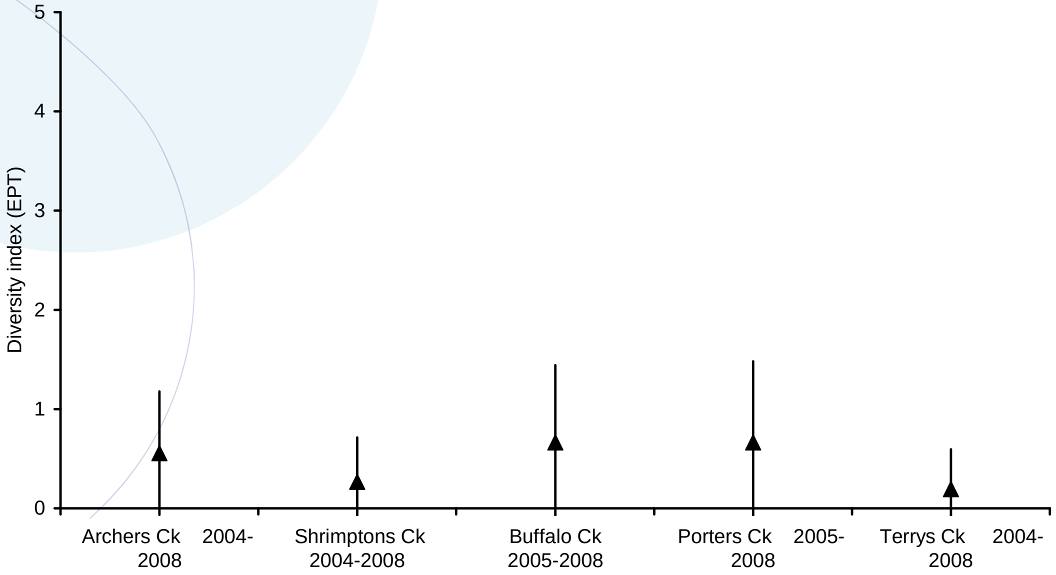


Figure 5 EPT richness of all creeks of monitoring program

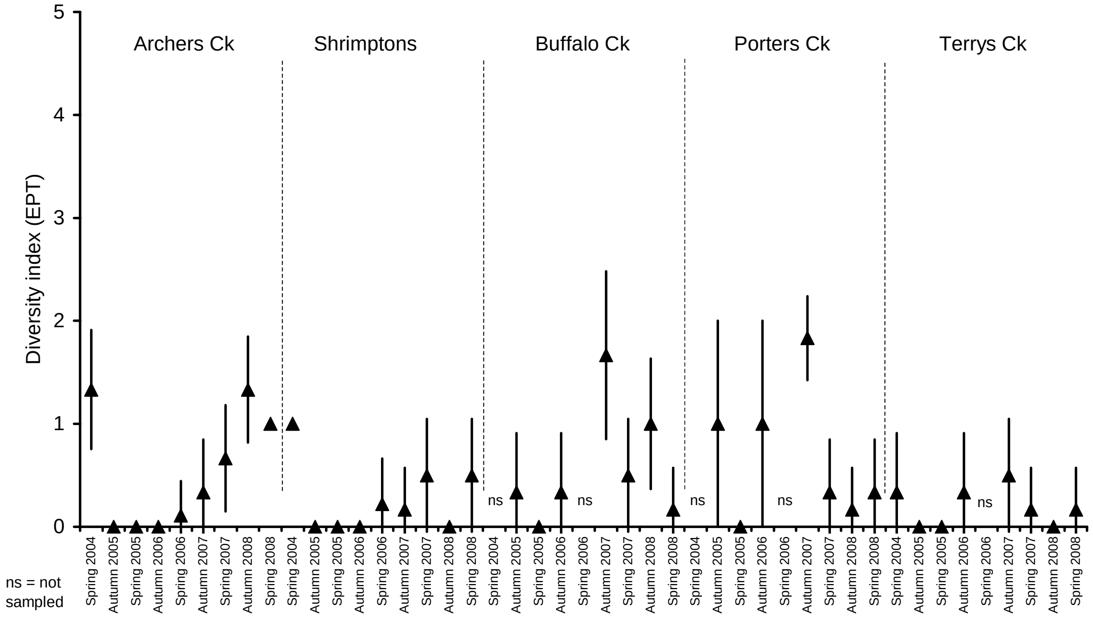


Figure 6 EPT richness by season

SIGNAL-SF

Stream health as described by the SIGNAL-SF biotic index results indicated impaired macroinvertebrate communities, this is most likely due to polluted water quality inputs via efficient stormwater delivery systems and other urban disturbances within catchments of all study creeks (Figure 7 and Figure 8).

Average stream health slightly decreased in Spring 2008 for Archers, Porters and Terrys creeks compared to Autumn 2008, average stream health for Shrimptons Creek slightly increased. Buffalo Ck had a large drop in average stream health compared to Autumn 2008 and all other sampling occasions for the creek since Autumn 2005 (Figure 7).

Average scores, of these five creeks for all seasons combined (Spring 2004 to Autumn 2008), occur in the probable moderate organic pollution category (Figure 8, Table 4). Shrimptons Creek in Autumn/Spring 2005, Autumn 2008 and Buffalo Creek in Spring 2008 are the only data points to occur in the probable severe organic pollution category (Figure 8, Table 4).

Shrimpton’s Creek stream health had been steadily improving each sampling period since Autumn 2005, however stream health dropped in Spring 2007 and again in Autumn 2008 when it returned to probable severe organic pollution. The slight increase in Spring 2008 was only small but did place it in the probable moderate organic pollution, however only just (0.02 above) (Figure 8, Table 4).

Archers Creek continued its trend of average stream health being higher in autumn seasons and lower in spring seasons. Spring 2008 dropped in stream health compared to Autumn 2008, which saw it record it’s highest average score since sampling began in Spring 2004 (Figure 7).

Buffalo Creeks stream health dropped in Spring 2008 to the lowest it has been since first sampled in Autumn 2005, placing it in the probable severe organic pollution category. The drop in stream health from Autumn to Spring 2008 has only occurred on this magnitude once since the sampling program began in Spring 2004, that was for Shrimptons Ck Autumn to Spring 2007 (Figure 8, Table 4). Before the Spring 2008 data point Buffalo Creek had shown to have a narrow range of stream health (Figure 7 & 8).

The range of stream health for Porters and Terrys creeks are relatively narrow and Spring 2008 falls within the range previously recorded (Figure 7 & 8). Porters Creek has in the last two years indicated that it may have a seasonal trend like that of Archers Creek, but with missing data points further data collection is required to establish this trend (Figure 7).

Archers Creek narrowly had the highest average stream health when assessed with SIGNAL-SF from macroinvertebrate sampling between 2004 and 2008 (Figure 8). Although when all five creeks are compared in terms of ANZECC (2000) guidelines (+/-1 standard deviation of the average), the overlapping ranges of stream health, indicate no difference was exhibited between the creeks (Figure 8). The larger range recorded for Shrimptons Creek reflects the temporal change in stream health recorded from 2004 to 2008 in Figure 7.

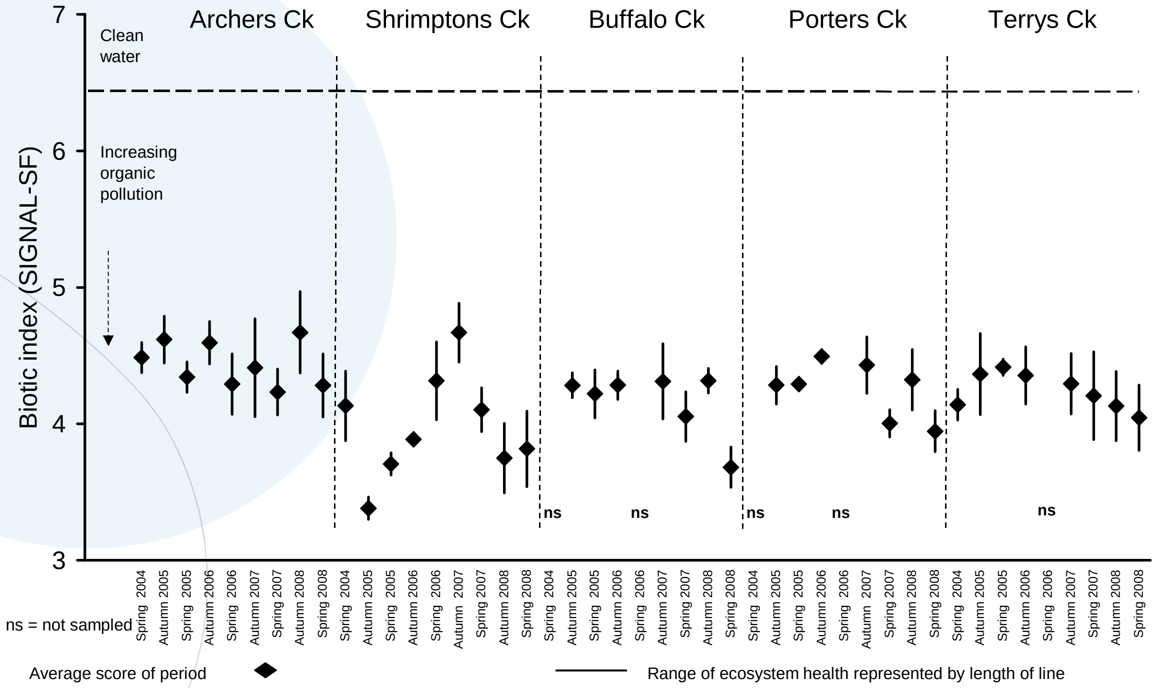


Figure 7. SIGNAL-SF by season

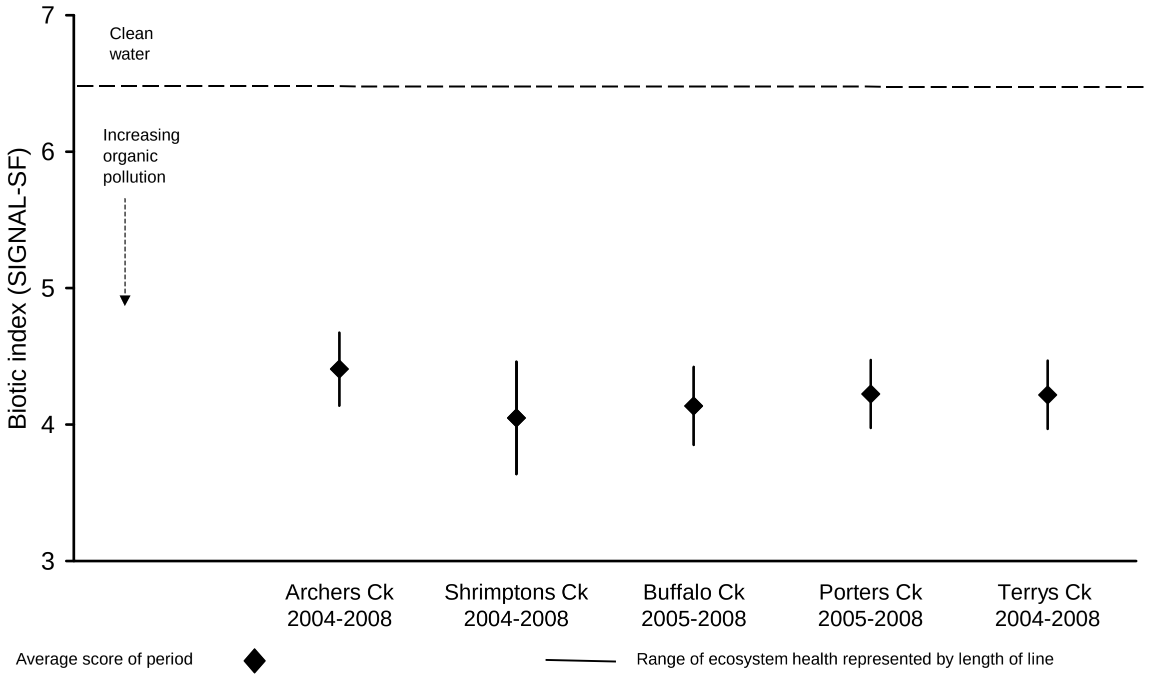


Figure 8. SIGNAL-SF of all creeks of monitoring program

AUSRIVAS OE50

The addition of Spring 2008 data to the Spring edge AUSRIVAS OE50 model was all that changed for this section of the report. The Autumn 2009 sampling will allow the Combined season edge model to be updated in the next report as this is done on a financial year basis.

The Spring 2008 average scores for Spring edge AUSRIVAS OE50 all fell within the range of stream health previously recorded for all five creeks sampled. The stream health in Spring 2008 for Archers, Porters and Terrys creeks was placed in the severely impaired band, the same as Spring 2007. The stream health in Shrimptons and Buffalo creeks fell from the severely impaired band in Spring 2007 to the extremely impaired band in Spring 2008. The actual drop in stream health for Shrimptons Creek however was quite minimal, and the Spring 2008 plot was placed close to the threshold between the two bands, and was similar to the previous Spring data points (Figure 9, Table 5 & Table 6). Buffalo Creeks drop in stream health was larger and indicates a trend of declining stream health, however the range of health for Spring 2008 still fell within the range of that in Spring 2007 (Figure 9).

The Spring edge AUSRIVAS OE50 model output suggested that the stream health across all five creeks are similar, with Archers Creek appearing slightly healthier than the other four creeks (Figure 12). Shrimptons and Porters Creeks have the least range of variability over time. Terry's Creek also shows little variation over time except for the Spring 2005 data point that is notably higher (Spring 2005 is placed in the significantly impaired band) (Figure 9, Table 5 & Table 6).

The output for all creeks of the Spring 2008 edge AUSRIVAS OE50 model was lower than the output of the Autumn 2008 edge AUSRIVAS OE50 model (except Archers Creek, refer to Autumn 2008 report). This is a trend that has generally occurred for all creeks and seasons. Archers, Porters and Terrys creeks are a band lower in Spring compared to Autumn in Figure 12 & Figure 13.

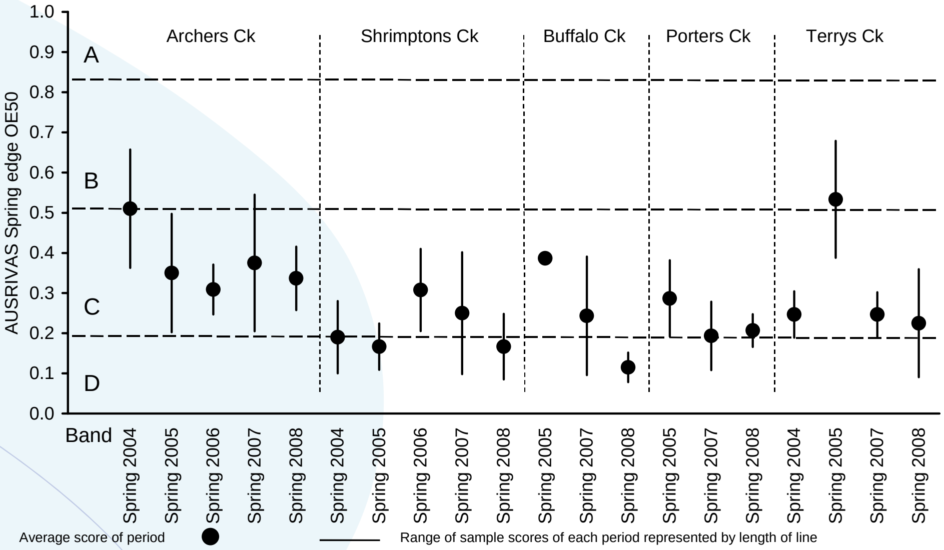


Figure 9. AUSRIVAS OE50 of all creeks from Spring edge model

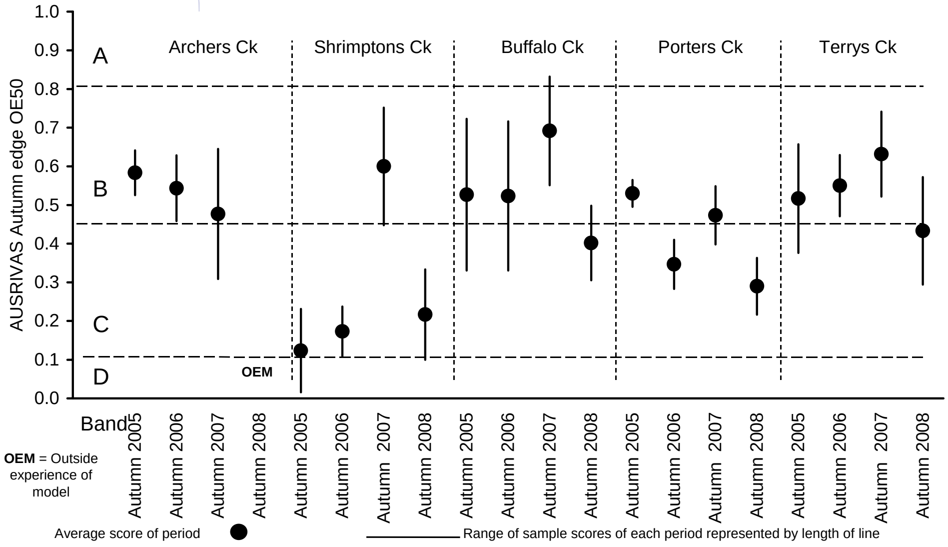


Figure 10. AUSRIVAS OE50 of all creeks from Autumn edge model

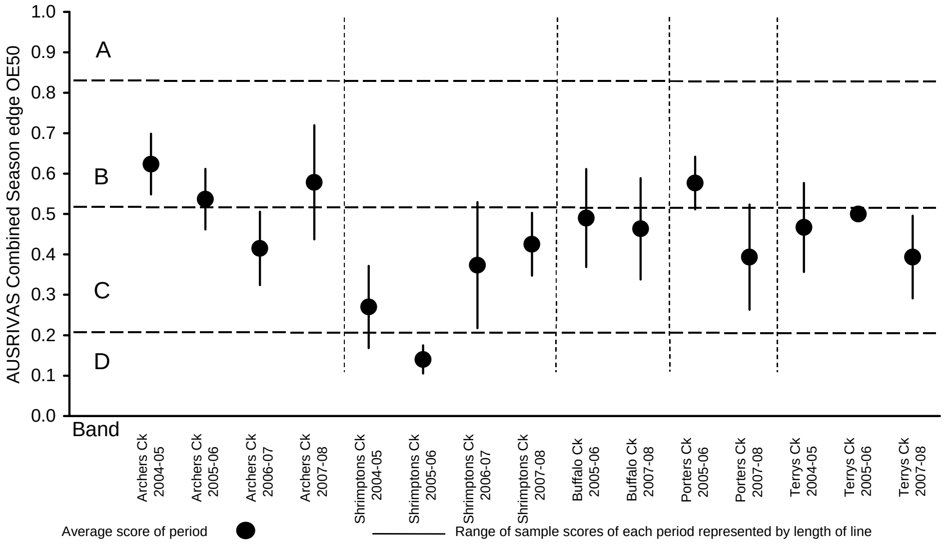


Figure 11. ***AUSRIVAS OE50 of all creeks from combined season edge model (with financial year data combined)***

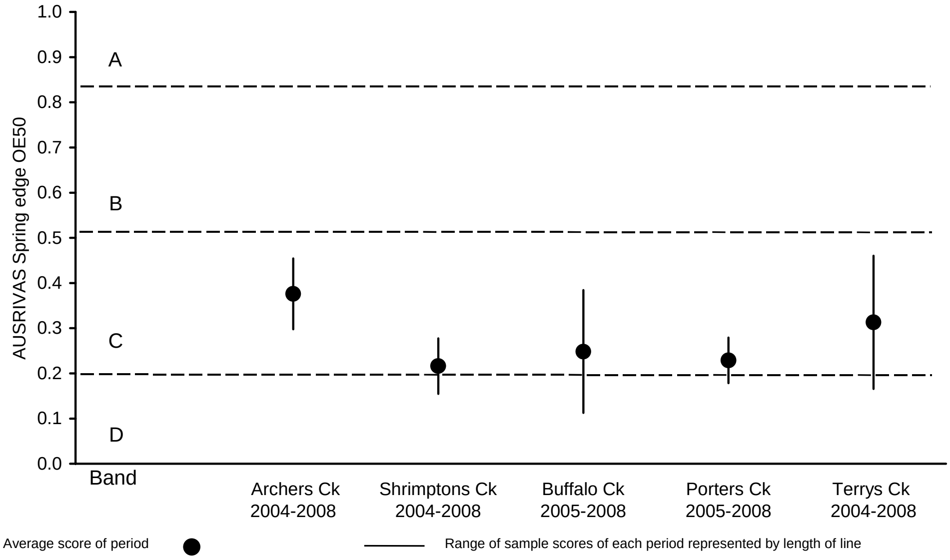


Figure 12. ***AUSRIVAS OE50 summary of all creeks from Spring edge model***

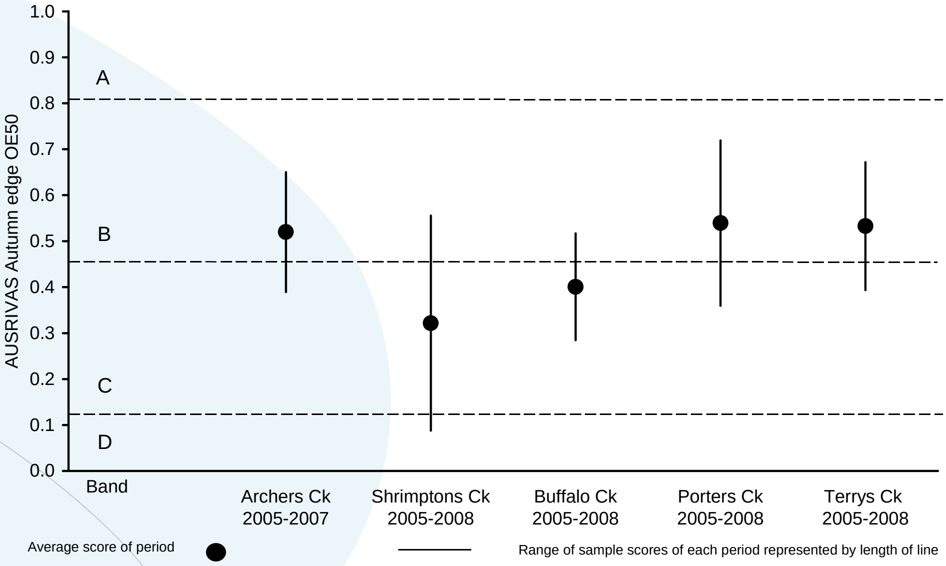


Figure 13. **AUSRIVAS OE50 summary of all creeks from Autumn edge model**

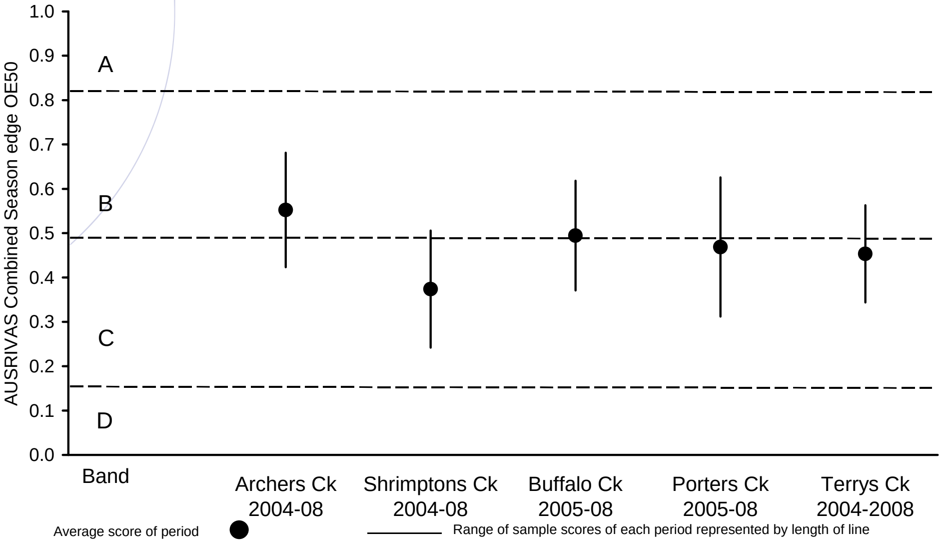


Figure 14 **AUSRIVAS OE50 summary of all creeks from combined season edge model (with financial year data combined)**

EPT Indicator taxa from AUSRIVAS predictive model output

AUSRIVAS output identifies taxa that were expected from the respective reference site group to which a test site was compared. As part of this output missing taxa are listed with greater than 50% probability of occurrence. To provide consistency in this report the definition used by Ecowise (2004, 2005a, 2005b, 2006) has been used in this report. That is, indicator taxa are defined as taxa within the EPT (Ephemeroptera - mayfly, Plecoptera - stonefly and Trichoptera – caddisfly) orders with SIGNAL2 scores of greater than 6.

Across the five creeks of the monitoring program missing EPT indicator taxa identified by AUSRIVAS Spring edge model output listed 15 taxa as missing with two mayfly larvae (Ephemeroptera), two stonefly larvae (Plecoptera) and 11 caddisfly larvae (Trichoptera).

There was no AUSRIVAS predicted EPT indicator taxa with a SIGNAL2 score of greater than 6 recorded in Spring 2008. The only EPT taxa sampled in Spring 2008 was the Hydroptilidae, a caddisfly larvae (Trichoptera) but this animal has a SIGNAL2 score of 4.

AUSRIVAS OE0 SIGNAL2

The addition of Spring 2008 data to the Spring edge AUSRIVAS OE0 SIGNAL2 model was all that changed for this section of the report. The Autumn 2009 sampling will allow the Combined season edge model to be updated in the next report as this is done on a financial year basis.

The AUSRIVAS OE0 SIGNAL2 Spring 2008 data points all fall within the previous range of stream health indicated for each creek. Although all of the Spring 2008 data points for the five creeks are lower than that of Spring 2007, the range of stream health overlaps, hence no significant change is observed (Figure 15).

All five creeks showed little variation in stream health over time, with Archers and Shrimptons creeks exhibiting the most variability, however they have the most amount of sampled seasons in which the data is pooled from. There is little variation in stream health when comparing the five creeks to one another. The average stream health of Terrys Creek is slightly healthier than the other creeks (Figure 18).

The Spring edge AUSRIVAS OE0 SIGNAL2 model output is similar through time and with seasons pooled compared to the Autumn edge AUSRIVAS OE0 SIGNAL2 model output (Figure 15, Figure 16, Figure 18 & Figure 19). This is in contrast to the AUSRIVAS OE50 model outputs which has Autumn generally healthier than Spring (Figure 9, Figure 10, Figure 12 & Figure 13).

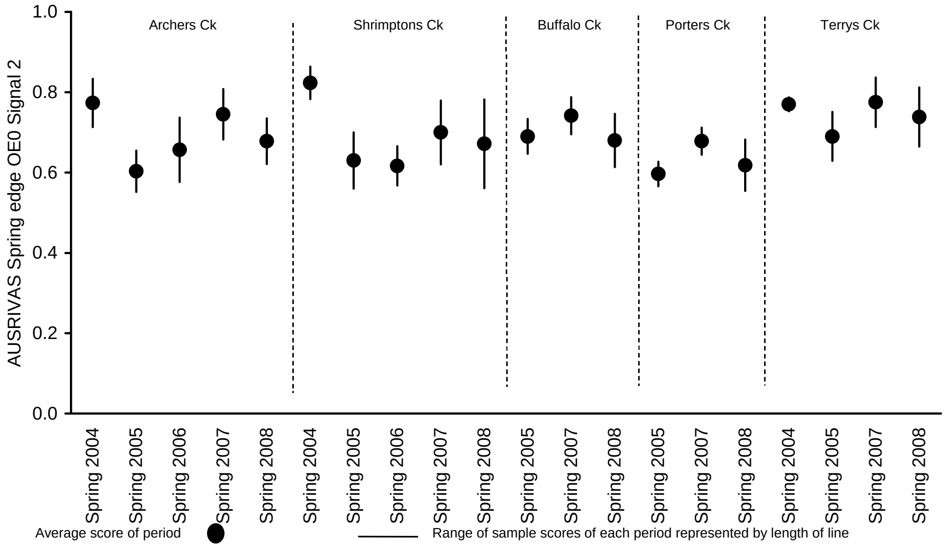


Figure 15 ***AUSRIVAS OE0 SIGNAL2 of all creeks from Spring edge model***

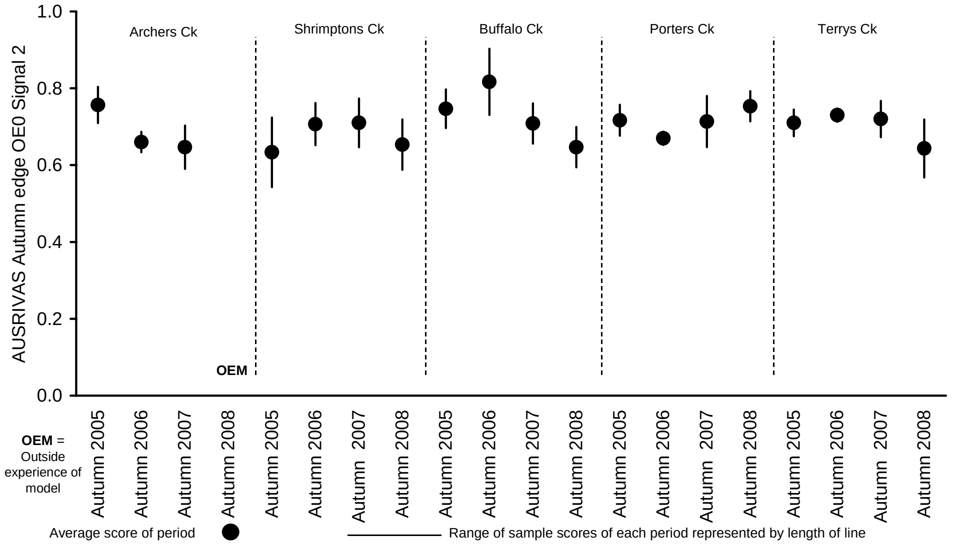


Figure 16 ***AUSRIVAS OE0 SIGNAL2 of all creeks from Autumn edge model***

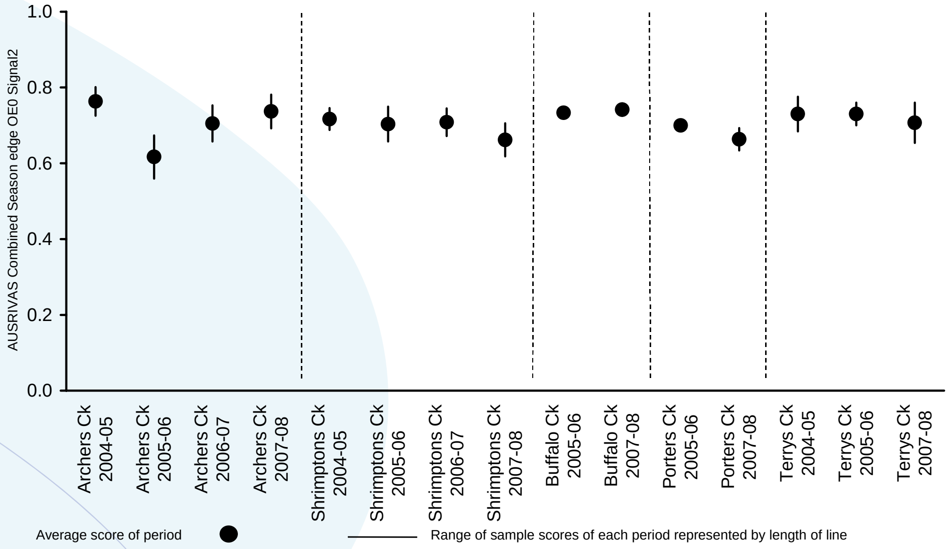


Figure 17 ***AUSRIVAS OE0 SIGNAL2 of all creeks from combined season edge model (with financial year data combined)***

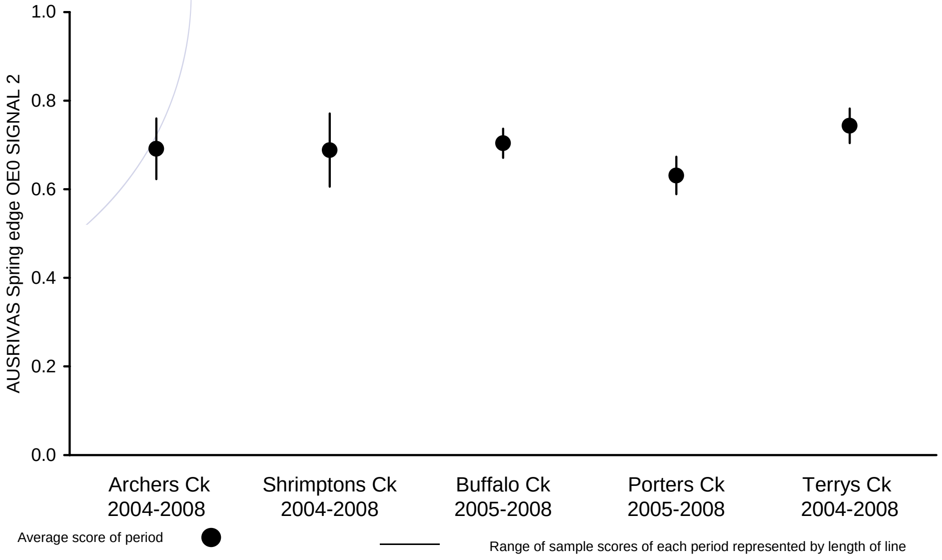


Figure 18 ***AUSRIVAS OE0 SIGNAL2 summary of all creeks from Spring edge model***

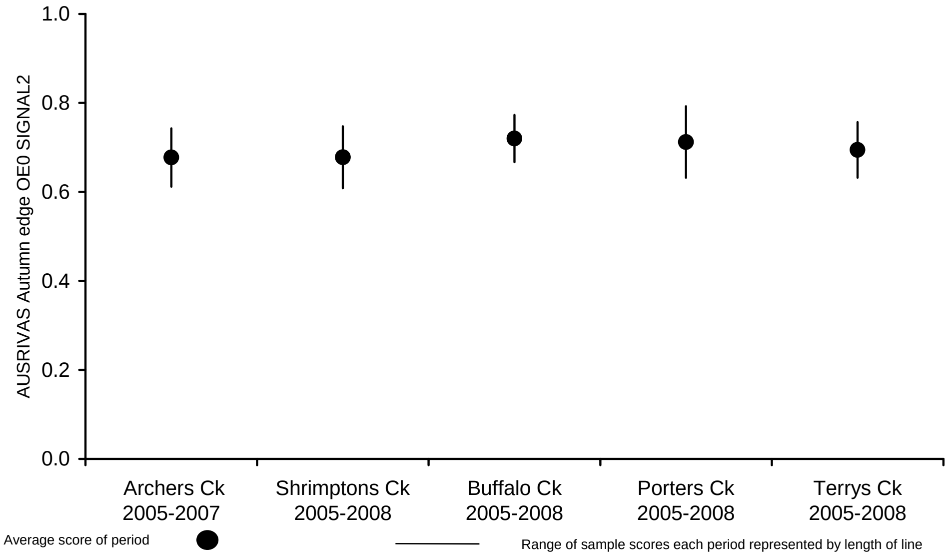


Figure 19 ***AUSRIVAS OE0 SIGNAL2 summary of all creeks from Autumn edge model***

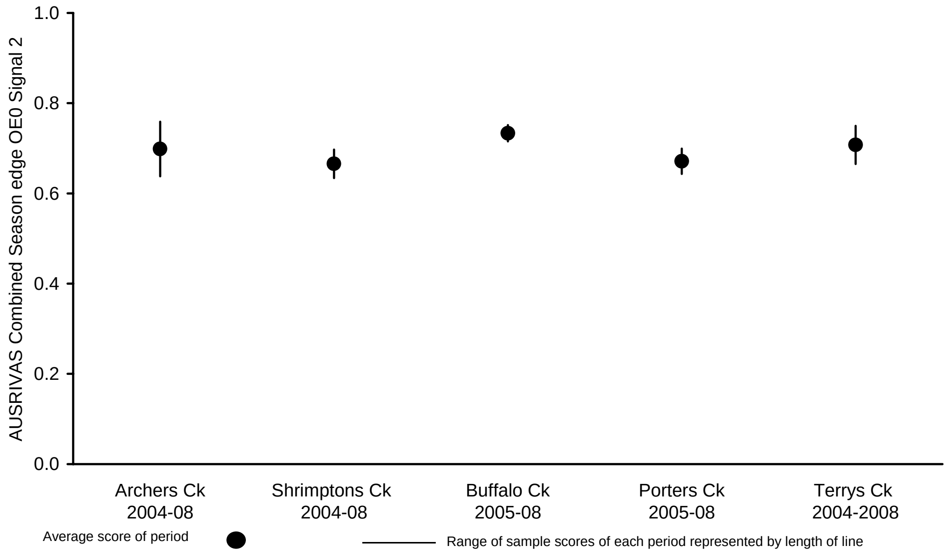


Figure 20 ***AUSRIVAS OE0 SIGNAL2 summary of all creeks from combined season edge model (with financial year data combined)***

Multivariate Analyses

Ordination and SIMPROF test

In order to achieve suitable multivariate representations of data in 2 or 3 dimensions a strategy of pooling up replicates from the same season for each creek is used. This is due to the continuing addition of data from seasonal sampling to the historical base data. This produces one data point per season per creek, it minimizes stress and gives a better measure of fit. It was implemented for the first time in the Spring 2007 report. This analysis strategy has been adopted for the ordination plot of all creeks (Figure 21). This summary can be thought of as reducing noise of the replicate data from the somewhat patchy occurrence of macroinvertebrates at a stream site. The addition of Spring 2008 data has required the MDS ordination plot to be presented in three dimensions. The two dimension plot is not presented as it had a higher stress (0.2) compared to the three dimension plot (0.14). The lower stress of the three dimension MDS ordination plot provides a better representation of community structure differences between the creeks.

The SIMPROF test provides another way to view community structure differences and similarities between samples. SIMPROF results have been overlaid onto classification result output (dendrogram) with red lines indicating no difference between samples and the black line indicating a difference in community structure. Two notable SIMPROF test groups consisted of a number of samples from the same creek, Archers and Shrimptons creeks respectively (Figure 22). Other groups are a mixture of samples from various creeks that have at least 60% similarity in composition of community structure of each sample.

The between season variability in community structure of Shrimptons Creek is displayed in Figure 21 and Figure 22. The latest sampling period of Spring 2008 has a similar community structure to the previous sampling period Autumn 2008, as well as Spring 2005, Autumn 2005 and Autumn 2006. It showed a distinct change to Spring 2006 and Spring 2007.

The addition of Spring 2008 data for Buffalo and Porters creeks have indicated that both creeks have a more variable community structure than has previously been observed. This has resulted in them being now more similar in variability to that of Archers Creek, the community structure of Spring 2008 for Archers Creek fits in with what has previously been observed (Figure 21 and Figure 22).

Terrys Creek has continued to show the least variability in community structure through time, Figure 22 shows that all except one season are in the last two groups of samples to be separated by SIMPROF.

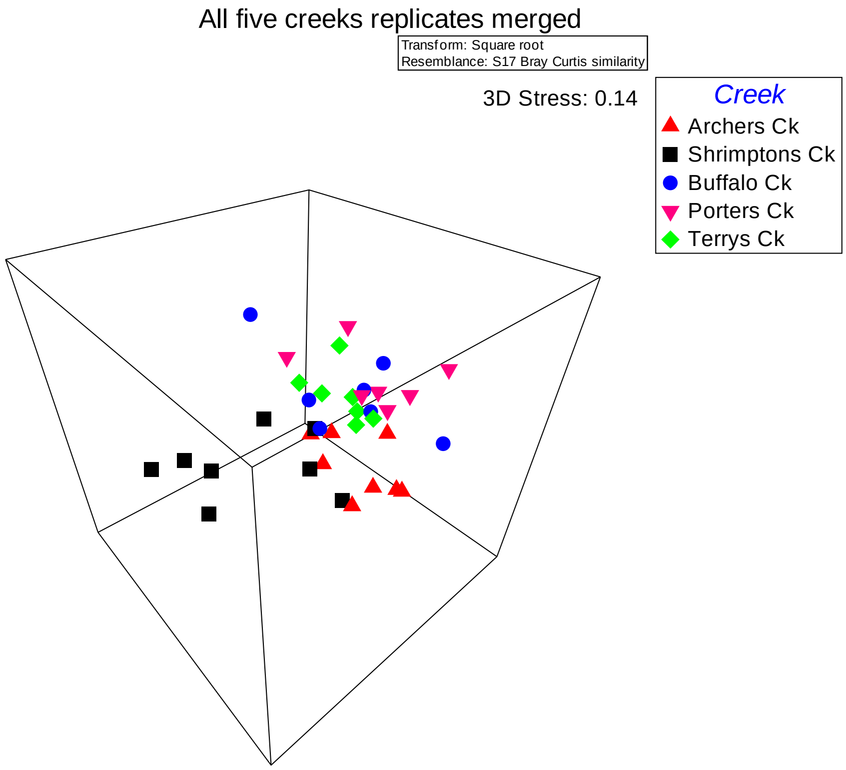


Figure 21 ***Plot of non-metric multidimensional scaling ordination results of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of all creeks with each point of the same creek representing a different season***

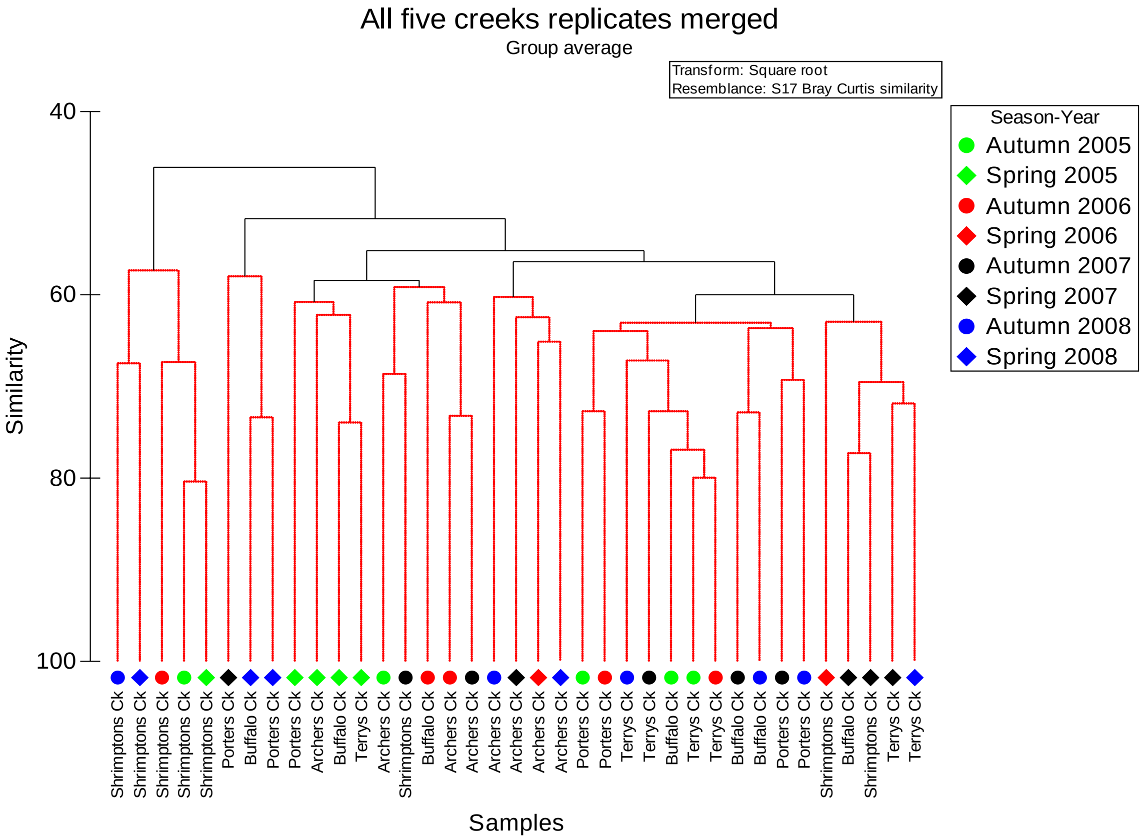


Figure 22 ***Dendrogram of all five creeks with SIMPROF test sample groups***

Exploration of the similarity of Archers Creek macroinvertebrate community structure for 2005, 2006, 2007 and 2008 showed that samples from the same season are relatively similar (Figure 23).

The SIMPROF test results indicated a general separation of autumn and spring samples, a few samples were more taxonomically different (Figure 24).

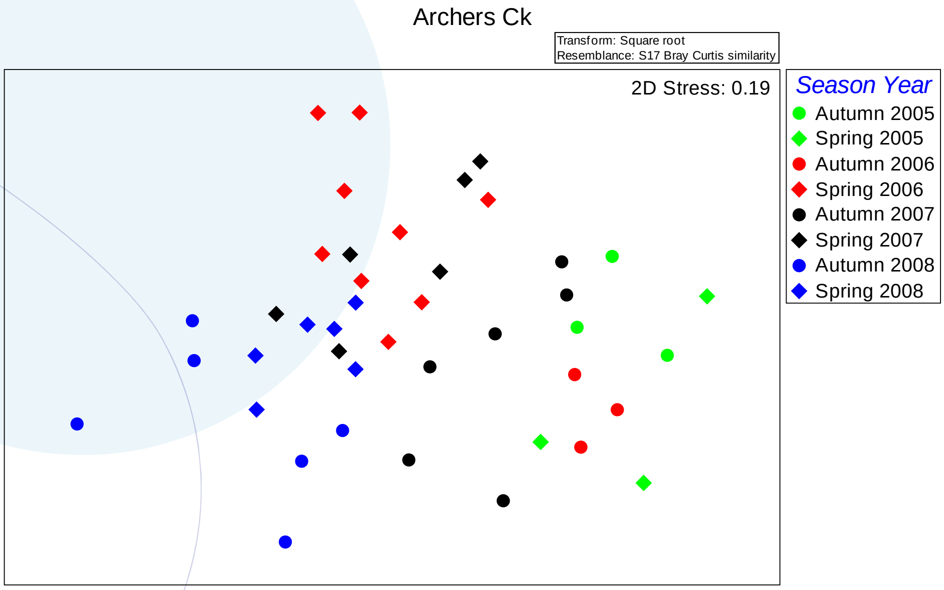


Figure 23 ***Plot of non-metric Multidimensional Scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of Archers Creek***

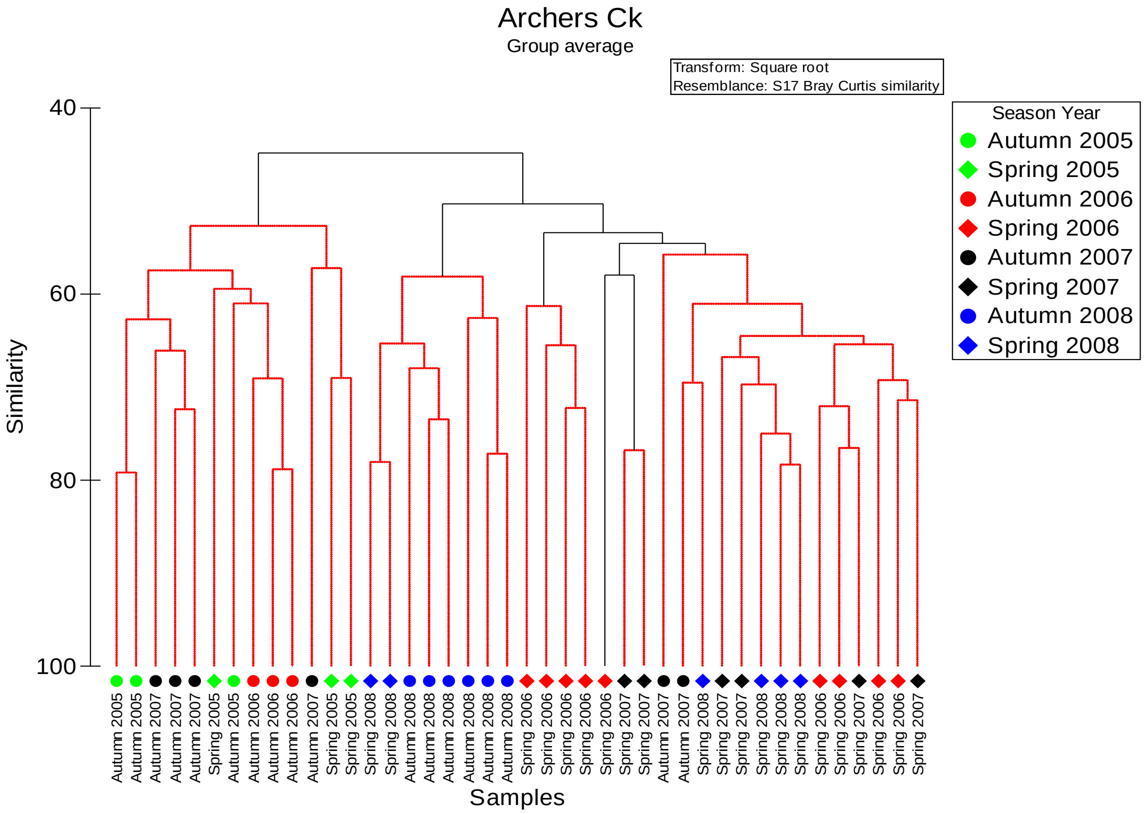


Figure 24 ***Dendrogram of Archers Creek with SIMPROF test sample groups***

The SIMPROF test results for Shrimptons Creek indicated that samples from Spring 2006, Autumn 2007 and Spring 2007 are most taxonomically similar. Samples from other seasons form more distinct groups (Figure 26) and these groups are evident on the ordination plot (Figure 25). A single outlying sample from Autumn 2008 was also highlighted by the SIMPROF test.

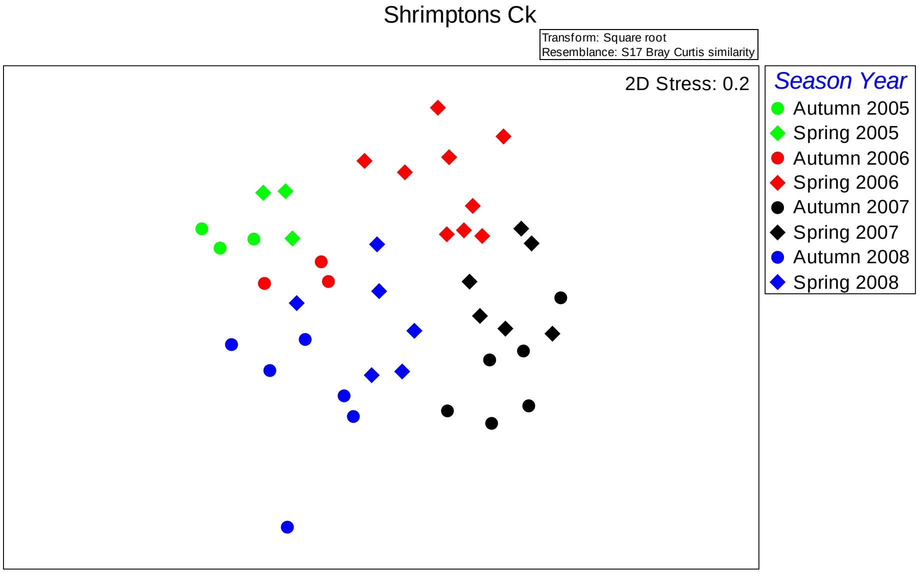


Figure 25 ***Plot of non-metric Multidimensional Scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of Shrimptons Creek***

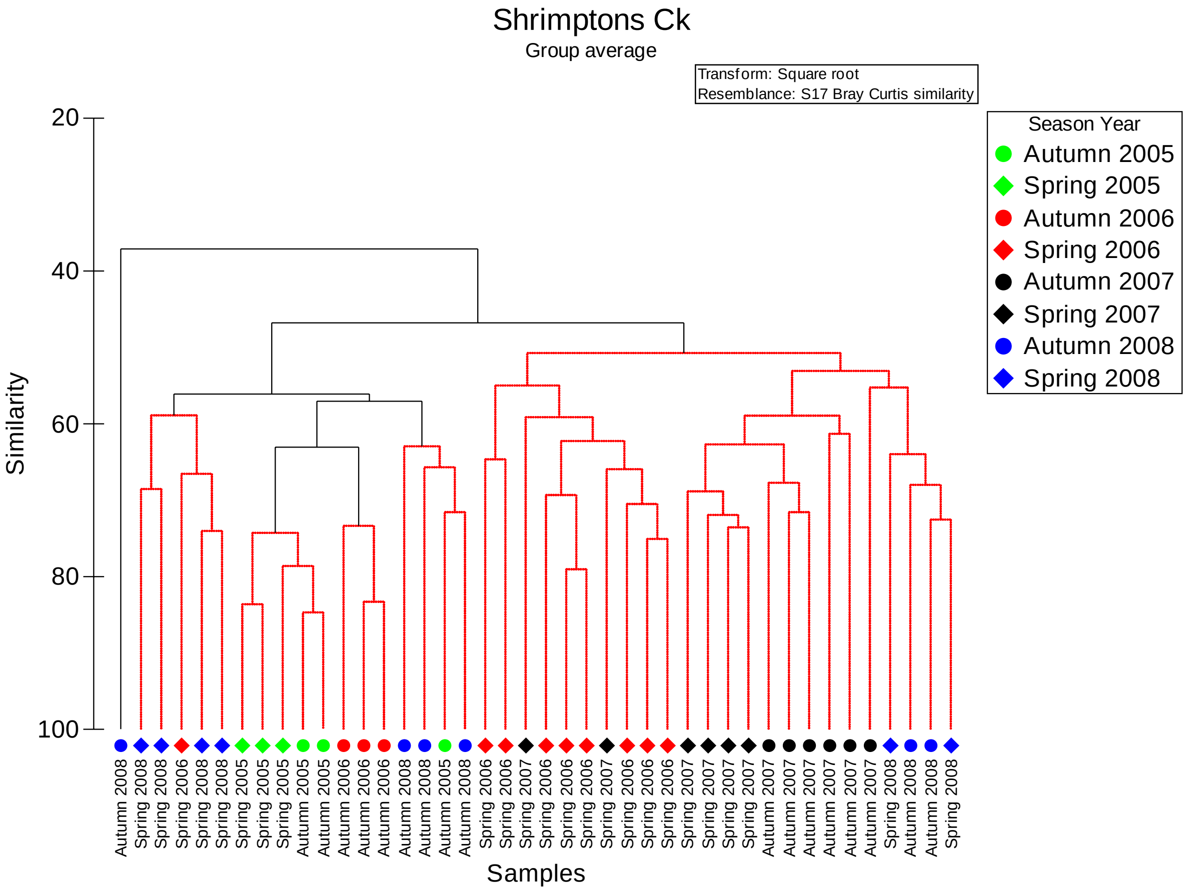


Figure 26 Dendrogram of Shrimptons Creek with SIMPROF test sample groups.

The SIMPROF test results for Buffalo Creek indicated three groups of samples and a single Autumn 2008 sample. The largest group of samples contains Spring 2007, Spring 2008 and two Autumn 2005 samples. The next largest group of samples contained Autumn 2007 and Autumn 2008 samples (Figure 28) these groups are evident on the ordination plot (Figure 28).

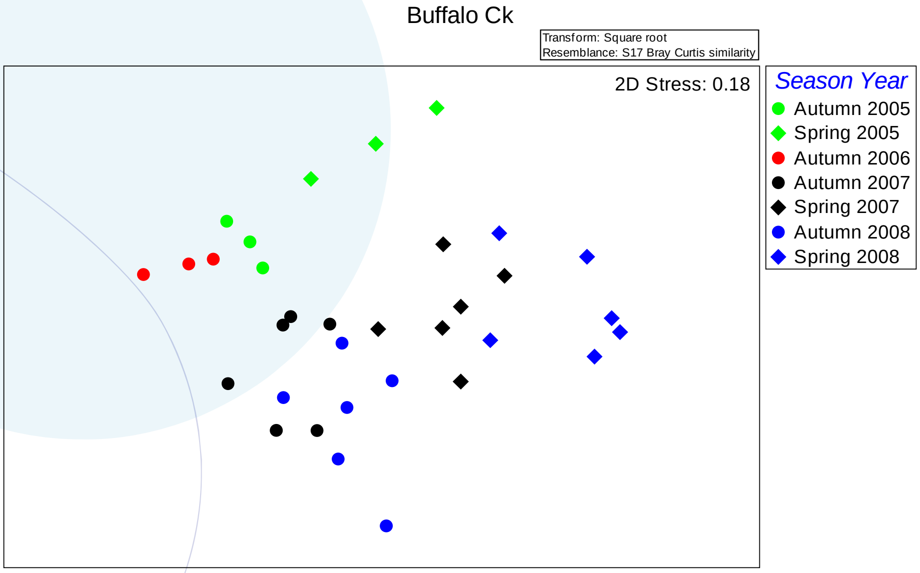


Figure 27 Plot of non-metric Multidimensional Scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of Buffalo Creek

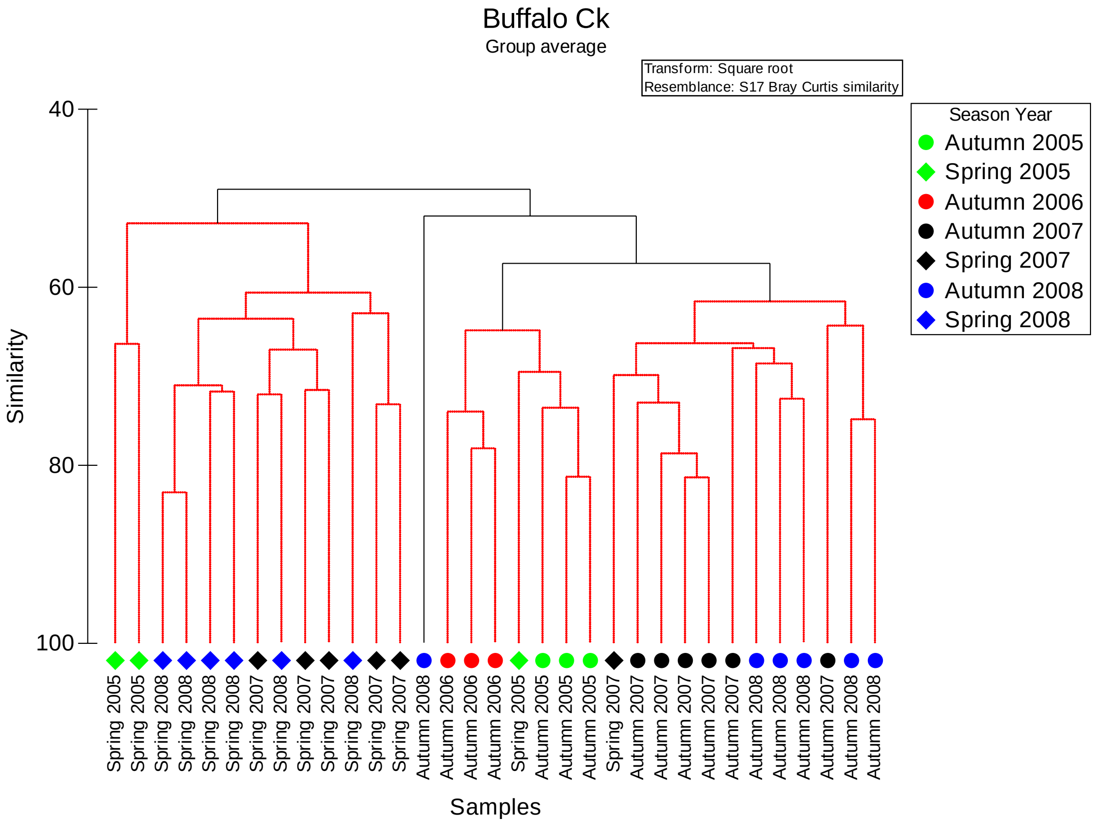


Figure 28 Dendrogram of Buffalo Creek with SIMPROF test sample groups

The SIMPROF test results for Porters Creek indicated two groups containing all but three samples. These three samples were a single sample from Spring 2005 and two samples from Spring 2008. The largest group of samples contained Autumn and Spring of 2008 and Spring 2007. The remaining samples formed the other group of samples (Figure 30) these groups are evident on the ordination plot (Figure 29).

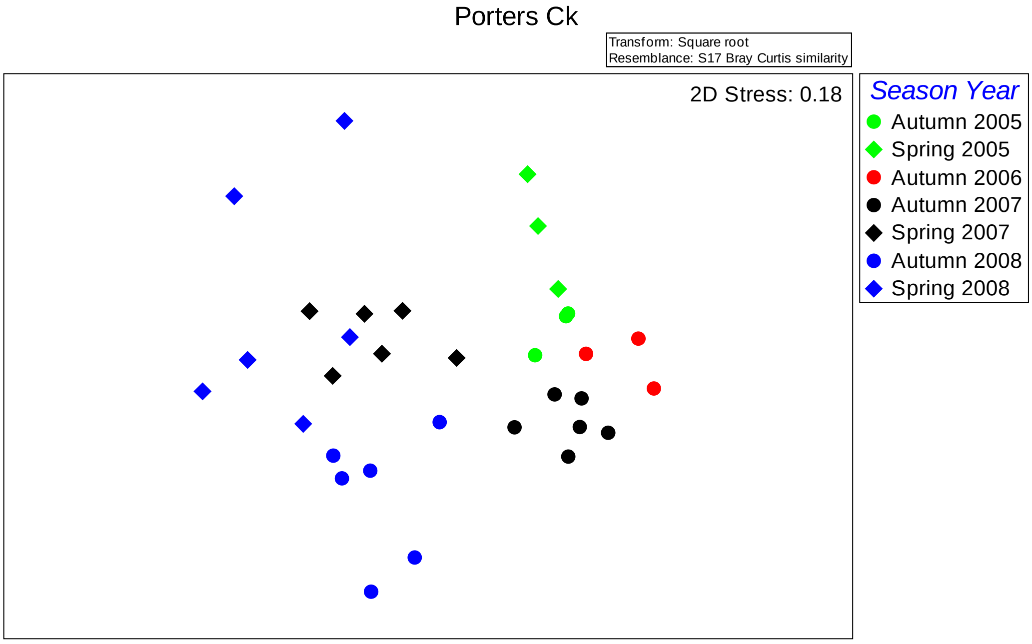


Figure 29 ***Plot of non-metric Multidimensional Scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of Porters Creek***

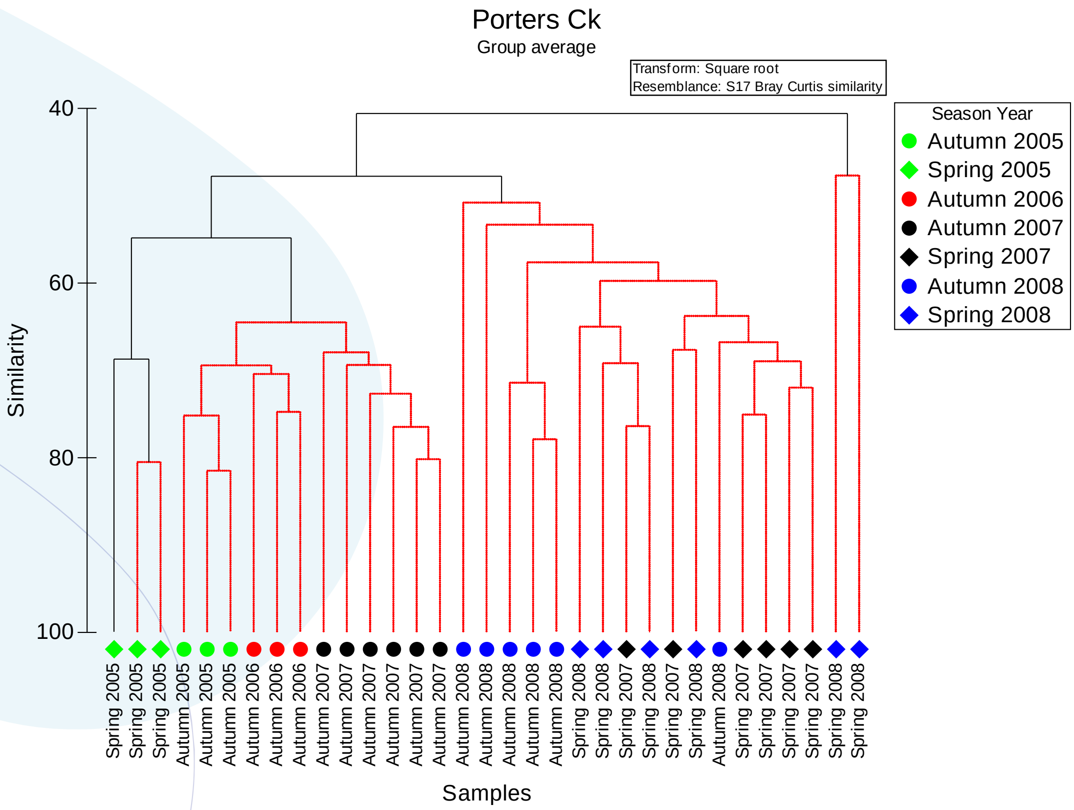


Figure 30 Dendrogram of Porters Creek with SIMPROF test sample groups

The SIMPROF test results for Terrys Creek indicated two groups contained all but two samples, which were from Spring 2007 and Spring 2008. The largest group contained samples from Autumn and Spring of 2008, Spring 2007 and half of the samples from Autumn 2007. The remaining samples formed the other group of samples (Figure 32) these groups are evident on the ordination plot (Figure 29). One sample from Spring 2008 was separated in the first SIMPROF division followed by one sample from Spring 2007 (Figure 31).

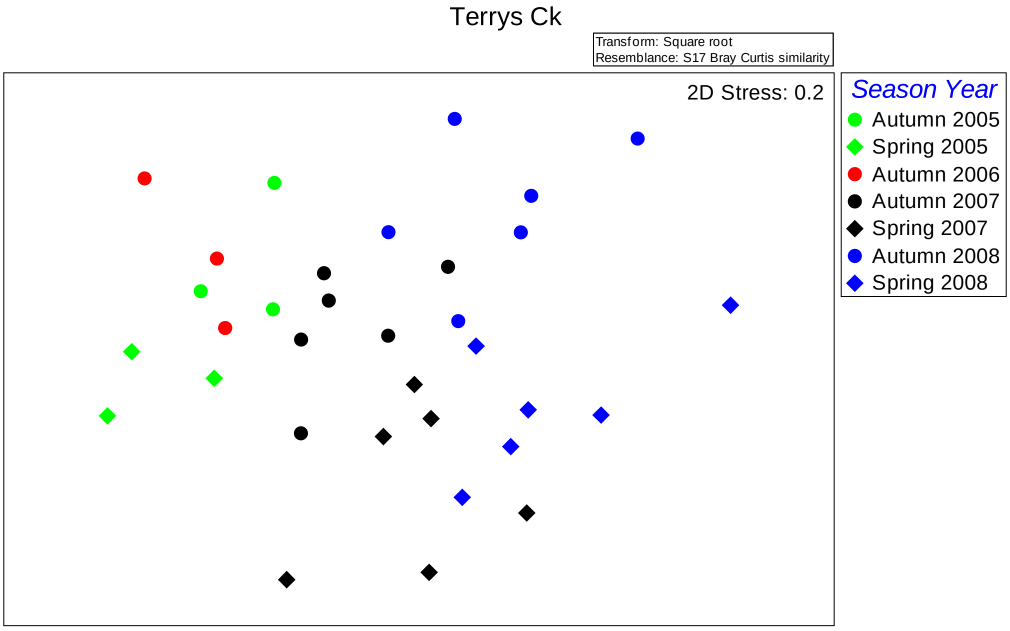


Figure 31 Plot of non-metric Multidimensional Scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005, 2006, 2007 and 2008 macroinvertebrate data of Terrys Creek

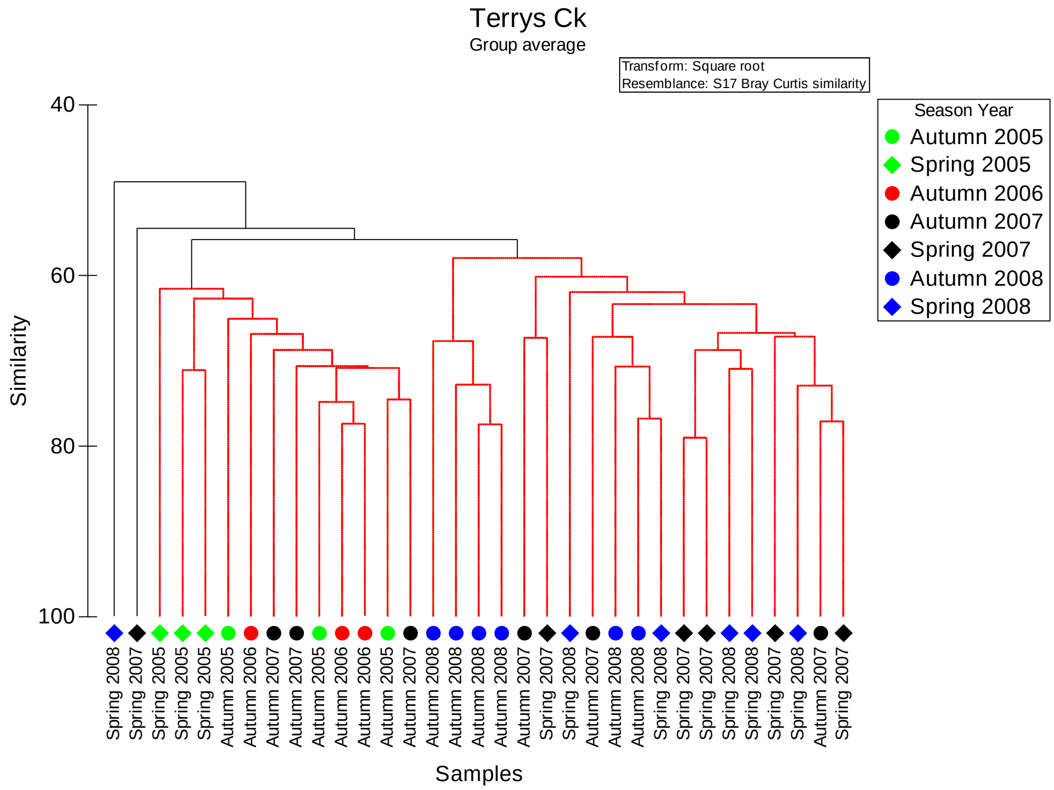


Figure 32 Dendrogram of Terrys Creek with SIMPROF test sample groups

SIMPER

SIMPER when performed on all five creeks was based on merged replicates from the same season for each creek as per the combined creek ordination (Figure 21) and classification analysis. SIMPER results indicated Archers Creek had the lowest overall (2005 to 2008) average similarity (56%). Shrimptons and Buffalo creeks was slightly higher (57%), Porters Creek slightly higher again (58%) and finally Terrys Creek had the highest similarity (68%) (Appendix 5).

Comparison of macroinvertebrate samples from each creek with each other creek was also provided by SIMPER output by average dissimilarity. These values are presented in Table 11 and indicated samples from Buffalo, Porters and Terrys creeks are more similar and reflect the closer yet separate position in the five creeks MDS plot (Figure 21).

Table 11 Average dissimilarity between samples of creek comparisons

	Archers %	Shrimptons %	Buffalo %	Porters %
Shrimptons	50			
Buffalo	47	50		
Porters	47	52	42	
Terrys	44	47	39	41

SIMPER was then performed on each creek for samples shown in the MDS plots in the Classification and Ordination section of this report. Average similarity ranged from 57% to 77% (Table 12, Appendix 5).

From the SIMPER analysis a change in community composition was evident for Shrimptons Creek from the beginning of sampling in Autumn 2005 to the previous season sampled Autumn 2008. This trend does not appear to be influenced by season. Community structure in Shrimptons Creek has gone from being dominated by tolerant non-insects to being dominated by tolerant insects, then in Autumn 2008 dominated by tolerant non-insects again. In the Autumn/Spring 2005, Autumn 2006 and Autumn 2008 seasons tolerant non-insects dominated, with 5-6 taxa contributing roughly 90% of the community structure. This was compared with Autumn and Spring 2007 where 10 taxa contributed 90% of the community structure. Spring 2008 however does not fit in with this trend as although dominated by tolerant non-insects (60%) some tolerant insects have returned.

Common non-insect community members included the introduced snail *Physa acuta* (Physidae), flatworms (Dugesiidae) and worms (Oligochaeta). The tolerant insects that were found were native non-biting midges (Chironominae), dragonflies (Megapodagrionidae, Coenagrionidae, Isostictidae, Hemicorduliidae) and back swimmers (Notonectidae).

Archers Creek in Spring 2006, 2007 and most recently 2008, the contribution of tolerant insects has been below 50% while in Spring 2005 this contribution was closer to 60%. Community structure in Archers Creek for each Autumn season has been dominated by tolerant insects with greater than 60% contribution.

During Spring seasons for Buffalo, Porters and Terrys creeks the list of taxa that contributed to community structure is reduced and higher contributions from non-insects occur. Buffalo Creek in Spring 2008 this was particularly evident with an 80% contribution of community structure from just three taxon. In Autumn each creek generally has more consistent members of the respective communities through time but with abundance differences evident between seasons of Autumn 2005 to Autumn 2008. The percentage contribution to community structure of insects was generally greater than 60% in each of these creeks. The exception being Autumn 2008 for Terrys Creek that had less dominant taxa, six compared with 13 to 14 for previous Autumn seasons (Appendix 5).

Table 12 Average similarity of the same season samples for each creek

	Archers %	Shrimptons %	Buffalo %	Porters %	Terrys %
Autumn 2005	68	76	76	77	70
Spring 2005	59	77	67	73	65
Autumn 2006	72	77	75	72	73
Spring 2006	60	62	ns	ns	ns
Autumn 2007	57	60	70	71	66
Spring 2007	61	63	65	68	65
Autumn 2008	61	58	64	60	67
Spring 2008	70	63	66	52	62

ns = not sampled

BIOENV

The output of BIOENV routine is presented in Appendix 6. The correlation of extrinsic water quality and physical variables including catchment storm water delivery characteristics (Table 13) with intrinsic macroinvertebrate sample data of all five creeks for 2005 to 2008 was moderate to weak at 0.33. This was down on Autumn 2008 that had a correlation of 0.39 but still stronger than Spring 2007 BIOENV that had a low correlation of 0.16, Spring 2007 however didn’t include catchment details. Investigation into the extrinsic variables identified in the best result correlation included Total Phosphorus, pH, Cobble, Total Length of Pipe and Ratio of Number of Outlets/Catchment Area. Total Length of Pipe was the only variable that was found in all of the 10 best correlations in the BIOENV output, Cobble was in 8 of the correlations. Rainfall was an influential variable in the Autumn 2008 BIOENV output yet the current Spring 2008 BIOENV indicated that it only occurred in four lesser variable combinations.

BIOENV analysis of each individual creek for 2005, 2006, 2007 and 2008 produced moderate to weak correlations of 0.38, 0.36, 0.41, 0.51 and 0.28 for Archers, Shrimptons, Buffalo, Porters and Terrys creeks respectively. The combination of variables varied for all creeks but rainfall was consistently highlighted by BIOENV analysis in the best result. The exception was Shrimptons Creek that was the only creek that did not have Rainfall as a variable in its best correlation. Rather Total Dissolved Solids provided the best correlation as occurred in Autumn 2008 from BIOENV analysis (Appendix 6). However, rainfall was highlighted in all or virtually all-top ten BIOENV results for each of the five creeks (Appendix 6).

The correlations for Spring 2008 BIOENV output were all weaker for each respective creek compared to the Autumn 2008 BIOENV. Terrys Creeks highest correlation occurred in Autumn 2007 and became weaker dropping from the mild (0.48) to the weak (0.28), the variables of Alkalinity and Rainfall remained (Appendix 6).

As the correlations of these extrinsic variables are weak to moderate, this suggests that the respective macroinvertebrate community structures of each creek are not predominantly influenced by these water quality variables. This suggests physico-chemical measurements collected to date under the strategy do not appear to be all of the drivers for the shifts recorded in macroinvertebrate community structure. As such efforts to improve water quality should not be solely concentrated on variables measured to date.

Table 13 Catchment storm water delivery characteristics for each creek

Creek	Total Length of Pipe (TLP) (m)	Total Number of pipe Outlets (NO)	Catchment Area (CA) **(hectares)**	Ratio TLP/CA	Ratio NO/CA
Archers	19,310	65	286	67.5	22.7
Shrimptons	41,797	74	555	75.3	13.3
Buffalo	33,336	62	546	61.1	11.3
Porters	15,797	16	225	70.2	7.1
Terrys	17,158	28	1012	16.9	2.8

5 Discussion

5.1 Water quality

Water quality results, while not to the sampling frequency suggested by ANZECC (2000), did allow for characterisation of water quality at each study creek against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary). The results of the Spring 2008 water quality sampling regime for Shrimptons, Porters, Buffalo, Terrys and Archers creeks of the Biological and Chemical Water Quality Monitoring Strategy of the City of Ryde indicated that urban pollution transport is having a moderate impact on instream water quality. This impact is notable by records of low levels of dissolved oxygen and the high levels of nutrients, especially nitrogen. This trend has also been observed in previous sampling events in 2004, 2005, 2006, 2007 and 2008 (Ecowise 2004, 2005a 2005b 2006, Sydney Water 2006, 2007a, 2007b, 2008a). The additional water quality sampling did not indicate a clear point source for Shrimptons, Buffalo and Porters creeks, however they did indicate spatial trends for particular pollutants, pointing to potential point sources.

Weather conditions, in the five months preceding Spring 2008 sampling collection, were characterised by relatively few light rain periods in between long dry periods. This resulted in sampling occurring after what could be considered a dry period. This is in contrast with the previous Autumn 2008 and Spring 2007 sampling periods that saw average rainfall in the preceding months before sampling.

Dissolved oxygen concentrations are the single most important water quality indicator for the survival of aquatic organisms and the control of many important physico-chemical processes. The oxygen balance in waters is dependant upon physical, chemical and biochemical conditions in the water body. Oxygen input results from diffusion from the atmosphere and photosynthesis by algae and other aquatic plants. Dissolved oxygen removal is due to respiration by aquatic organisms, decomposition of organic matter, oxidation of chemically reduced compounds and loss to the atmosphere. The solubility of oxygen in water decreases with increasing temperature but the respiratory rate of aquatic organisms increases with temperature (Connell, 1993). Aquatic ecosystems are thus acutely sensitive to any reduction in dissolved oxygen levels.

Dissolved oxygen concentrations are often subject to large diurnal and seasonal fluctuations as a result of changes in temperature and photosynthetic rates. Therefore, a dissolved oxygen measurement taken at one time of the day may not truly represent the oxygen regime in the water body.

Nevertheless, the low dissolved oxygen levels during October and the particularly low levels for Shrimptons Creek are an area of concern. This could be largely influenced by the lack of rainfall preceding Spring sampling. Shrimptons Creek historical average is the lowest of the five creeks, and in Spring 2008 only one recording (September downstream Santa Rosa Park) was within ANZECC (2000) recommended levels. In October the core site recorded 0% saturation, as did Kent Rd and upstream Santa Rosa Park, the downstream Santa Rosa Park sample had 22.6%. These are very low levels and indicate that there are problems with urban inputs along the whole of Shrimptons Creek. These problems would be due to in-stream conditions caused by poor quality urban run-off transported through Shrimptons Creek. This problem is exasperated during times of low rainfall and if dry conditions persist stream health will probably decline to lower levels as previously recorded in Autumn 2005.

Dissolved Oxygen levels at Porters Creek at both the core site and additional sites appear to be at acceptable levels and samples that were outside ANZECC (2000) recommended levels were usually only marginal. The historical average for Porters Creek is the healthiest of the five creeks regarding dissolved oxygen, and is probably related to more efficient run-off transport during both wet and dry periods. The Main Branch Channel in October recorded 147.4% saturation for dissolved oxygen, the first time that a sample has exceeded the upper limit for Dissolved Oxygen ANZECC (2000). This would most likely be explained by the presence of filamentous algae, which was found to be growing on the concrete channel where water quality is sampled in much greater densities and coverage than previously subjectively observed.

Buffalo Creek recorded a dissolved Oxygen level of 3.3% saturation at the core site in October and 30.2% at the upstream Burrows Park site, geographically between these sites the downstream Burrows Park recorded 81.5%. This spatial comparison along with Shrimptons and Porters creeks, of dissolved oxygen with upstream sites shows no apparent decline or improvement with increasing distance upstream from the respective downstream core sites. This suggests these creeks are influenced by urban inputs along their entire lengths.

The indicator species used for faecal coliforms are naturally occurring and harmless inhabitants of the digestive tract of all warm-blooded animals (Boey, 1993). The occurrence of large numbers of these bacteria signifies the presence of faecal pollution, and therefore the possible presence of those pathogenic organisms that occur in faeces. A variety of factors can influence faecal contamination of streams including urban runoff, presence of waterfowl and other wildlife, waste depots and illegal dumping of waste.

Recorded levels of faecal coliform concentrations at the five core sites were similar in the Spring 2008 sampling period to that observed in the Autumn 2008 sampling period and were compliant with ANZECC (2000) recommended levels.

Faecal coliform concentrations at the additional sites were compliant with ANZECC (2000) recommended levels for all but two samples in September, Shrimptons Creek at Kent Road (1100 CFU/100mL) and Buffalo Creek downstream Burrows Park (1200 CFU/100mL). These were only slightly above ANZECC (2000) recommended levels and can probably be linked to faecal contamination from urban runoff in storm water. These concentrations are relatively low and most probably reflect the recent lower rainfall. Especially when compared with the wetter Autumn 2008 when both of the additional Buffalo Creek sites recorded elevated non-compliant levels of faecal coliforms compared to ANZECC (2000) guidelines (4500 and 10,000 CFU/100mL, Table 8).

The Turbidity levels for the five core sites and the additional sites were all compliant with ANZECC (2000) recommended levels except for the October sample for Porters Ck Main Branch at Wicks Rd but its non-compliance was only minor, 59.8 NTU, the ANZECC (2000) recommended level limit is 50 NTU.

Porters Creek recorded an extremely high turbidity in Autumn 2008 at the Spur Branch site of 625 NTU. This non-compliant sample was the result of a short-term dry weather pollution event due to an unknown urban input delivered efficiently via the storm water system. In Autumn 2008 the two additional Buffalo Creek sites in March recorded non-compliant levels of Turbidity of 72.2 and 87.3 NTU. A photograph of Buffalo Creek taken in late Autumn 2008 also shows high visual turbidity. Incidences of high turbidity in Buffalo Creek may be linked to urban runoff from development in the headwaters of the creek. The recent Spring 2008 compliant results reflect reduced pollution transport under the recent drier conditions. Although a thicker drape of sediment on the bed of Buffalo Creek was observed at the core site in Spring 2008. These two examples highlight the difficult task of interpreting potential water quality influences when readings are taken from a very small period of time and when peak pollution spikes may not be captured between sampling events to which aquatic life is subjected.

Nitrogen and phosphorus are essential elements for life. They are found naturally in the earth’s crusts (phosphorus) and atmosphere (nitrogen) but are not directly available to most living organisms. As a result, a lack of these elements is often the factor limiting growth of algae, bacteria and other plants. Increasing the readily available phosphorus and nitrogen loads in streams can lead to algal blooms and excessive plant growth. The elevated nitrogen levels as measured by Total Nitrogen and Total Oxidised Nitrogen found in the core and additional sites at Archers, Shrimptons, Buffalo, Porters and Terrys creeks during Spring 2008 were most likely from urban runoff from eroded catchments, decomposing organic matter and low dissolved oxygen levels, which is known to be a significant factor in increasing the amounts of readily available nutrients from sediments via chemical synthesis.

Total Nitrogen and Total Oxidised Nitrogen levels at the additional sites upstream of Shrimptons Creek were similar to the historical average and the current Spring 2008 core site levels. This suggests no singular major point sources along Shrimptons Creek, rather there are most likely urban pollutant inputs along the whole of Shrimptons Creek.

At the additional sites upstream of Buffalo Creek Total Nitrogen and Total Oxidised Nitrogen levels were higher in Spring 2008 compared to the historical average and the current Spring 2008 core site levels. While no obvious point source is indicated it probably suggests origins are in the urbanised upper catchment.

In Porters Creek, Total Nitrogen and Total Oxidised Nitrogen levels at the additional sites had higher levels than at the core site from comparisons to the historical average and Spring 2008 levels. This suggests The City of Ryde Waste Depot provides a contribution to increased Nitrogen levels in the already nitrogen rich Porters Creek.

The Total Phosphorus samples from the core sites exceeding ANZECC (2000) recommended levels are mostly limited to Shrimptons Creek. About half of all the additional sites exceeded ANZECC (2000) recommended levels for Total Phosphorus, however none of these where as high as the Autumn 2008 April sample at Porters Creek Spur Branch which recorded 1530 µg/L. There did not appear to be any spatial trends associated with Total Phosphorus levels for the additional and core sites.

Ammoniacal nitrogen is often present in sewage effluent, because of the decomposition of nitrogen containing compounds in the treated waste. The un-dissociated form, ammonia (NH3) is far more toxic to aquatic life than the ionic form, ammonium (NH4+). During low pH and temperature NH3 dissociates to the less toxic form NH4+. This is then reversed during periods of high pH and temperature.

Laboratory methods for ammonia record the nitrogen content from the ammonium (associated ionic form) ions NH4+. This ion forms compounds with other particles dissolved within the water column. It is harmless to plants and animals within the specified concentration, pH and temp range. ANZECC (2000) has determined this to be 20 µg/L for the protection of aquatic life in lowland streams with a pH of 8 and temperature of 20^0C. Ammonia (NH3) is a toxic by product of NH4+ that exists as a gas of which the N content is not measured during the routine laboratory analysis. With increasing temperature and pH the % of NH3 against NH4+ increases exponentially and it is this compound that is detrimental to aquatic life. ANZECC (2000) does not measure this or provide guidelines on this form but it does determine the NH4+ concentrations that are dangerously high and most likely to produce the toxic NH3 compound and provides guidelines on this.

The 95% trigger value for freshwater according to ANZECC (2000) is 0.9 µg/L this is set as generally the worst-case benchmark. A more tailored level of 20 µg/L for Freshwater Lowland Streams in SE Australia (ANZECC 2000) is applied for the City of Ryde water quality monitoring.

On nearly all occasions in Spring 2008 for all creeks and at additional sites the ammonium levels exceeded ANZECC (2000) recommended levels although usually by less than 6 times the recommended level. In Porters Creek at the core site in September Ammonia exceeded the ANZECC (2000) recommended levels of 20 µg/L by 200 times and in October by nearly 50 times. The elevated levels of ammonium in this creek indicate under favourable conditions the ammonium (NH4+) ion will be converted to the potentially toxic ammonia (NH3) compound and compromise the health of the aquatic ecosystem. The additional upstream sites in Porters

Creek were less than 13 times the recommended level and hence suggest that The City of Ryde Waste Depot is responsible for these high ammonium levels recorded in low pollution transport conditions of Spring 2008. The core site in Porters Creek has historically had high levels of Ammonium often exceeding ANZECC (2000) recommended levels during 2005, 2006, 2007 and 2008.

Total Dissolved Solids refers to the total amount of organic and inorganic substances – including minerals, salts, metals, cations or anions that are dispersed among a volume of water. By definition the solids must be small enough to be filtered through a 2 micrometer sieve. Sources for TDS include agricultural and urban run-off, industrial wastewater, sewage and natural sources such as leaves, silt, plankton and rocks. Piping or plumbing may also release metals into the water. The US EPA recommends the threshold of acceptable criteria for human drinking of TDS concentrations to not exceed 500 mg/L (500 ppm). In some cases further testing may be warranted as water with a high TDS concentration may indicate elevated levels of ions that pose a health concern such as aluminium, arsenic, copper, lead, nitrate and others. Striped Bass fish species have shown reduced spawning in concentrations as low as 350 mg/L and concentrations below 200 mg/L promoted healthier spawning conditions (Kaisser, 1969).

Total Dissolved Solids in Buffalo Creek additional sites were above 500 mg/L during Spring 2008, they were particularly high in October when the core site was also elevated above 500 mg/L. The results for Buffalo Creek were above the historical average for TDS except for September at the core site. These elevated TDS levels that are higher at the upstream additional sites could be linked to the urban development in the headwaters of the creek. It is possible that contaminants associated with TDS may be impacting on aquatic stream life.

5.2 Macroinvertebrates

Results of the Spring 2008 macroinvertebrate sample collection of the Biological and Chemical Water Quality Monitoring Strategy of Ryde City Council Tender Number COR-EOC-05/07 indicated Archers, Shrimptons, Buffalo, Porters and Terrys creeks have impaired macroinvertebrate communities with similar results recorded in Spring 2004 to Autumn 2008.

ANZECC (2000) indicates adequate base line data is required to establish an acceptable level of change before informed management judgments can be made that take account of natural variability in an indicator. ANZECC (2000) suggests three to five years of data be gathered from control or reference locations. Natural variability of each site with comparable data is currently being gathered under the Biological and Chemical Water Quality Monitoring Strategy. To this end, for the macroinvertebrate indicator, use of the Sydney specific SIGNAL-SF index and NSW AUSRIVAS predictive models provides this data by the statistically defined 10th percentile of mean reference condition values. The range of each measure of stream health has been plotted in this report with +/-1 standard deviation of the mean for basing ecological decisions (ANZECC, 2000). Presenting data in this way attempts to take account of variation at study sites and provide a basis in future years to enable management tracking and or as a basis for making management decisions. To date there are seven seasons of comparable data for all five creeks since sampling began in Spring 2004. The inclusion of data from seasons in years with rainfall that is average or above would provide a better baseline for management decisions.

The period between Spring 2004 to Autumn 2007 has been characterised by below average rainfall. Spring 2007 saw a return to average rainfall, with consistent falls through late 2007 and early 2008 leading up to the Autumn 2008 sampling period. Leading up to the Spring 2008 period these falls became less frequent with only 375 mm falling in the five months preceding Spring 2008 sampling.

In the Spring 2008 sampling season a total of 1787 macroinverterbates were collected, which is similar to Autumn 2008 with 1811. This is a considerable drop compared to Spring 2007, which had 2490 animals, and the previous Autumn 2007, which saw 2635 animals collected. The total taxa collected for Spring 2008 was 37, this is a low count compared to Autumn 2008, Spring 2007 and Autumn 2007 when 51, 48 and 52 taxa were collected respectively. Autumn 2008's low total animal count was explained by the low abundance within taxa groups, as Spring 2008 has a similar total animal count it's low count is related to its low total taxa count. It is difficult and probably misconceived to try and link this to any water quality or other in-stream factors. The reduced numbers in 2008 may in fact reflect environmental cues that influence the development of macroinvertebrate taxa with either the aquatic life stage not being present in the water at the time of sampling or the cohort (age class) being too small to be retained by 0.25 mm mesh of the net. A 0.25 mm mesh is used to collect macroinvertebrates that are of a suitable size to allow identification with taxonomic keys as keying characters are generally written for relatively mature (late instar) specimens.

Sensitive taxa as measured by EPT richness were virtually absent in Spring 2008, the only EPT taxa collected was the Hydroptilidae (Trichoptera - caddisfly larvae). As a result no EPT indicator taxa from AUSRIVAS predicted model with a SIGNAL2 score greater than 6 was collected. The Hydroptilidae larvae were collected in all creeks during Spring 2008. These larvae were found sporadically amongst the replicate samples, except for Archers Creek were it was present in all replicates. It was also in quite high abundances averaging 11 specimens a replicate. The Hydroptilidae is considered a tolerant insect with a SIGNAL2 score of 4 from broader NSW wide sampling. However, its presence would influence the SIGNAL-SF output in which it has a score of 6 and its relative abundance adds weight to the SIGNAL-SF output, as it is considered a more sensitive taxa in the greater Sydney region.

Due to the status of EPT taxa in City of Ryde study creeks, EPT richness as a measure is limited in being able to infer information of any future negative impacts on stream health. In the Spring 2007 report it was suggested the return to average or above average rainfall conditions might influence the presence of EPT taxa. Average conditions returned for the Autumn 2008 sampling season but became drier before the Spring 2008 season, it may take a period of more prolonged rainfall to see an improvement. However EPT may be able to indicate positive community structure changes. Hence reference to EPT indicator taxa from AUSRIVAS predicted model output (as per criteria of section 3.6) status should be made in assessing positive changes in this measure, before attributing positive changes to management activities.

Direct measurement of stream health using SIGNAL-SF and measurement via AUSRIVAS predictive model OE50 and OE0 SIGNAL2 outcomes both reflected impaired stream health of Archers, Shrimptons, Buffalo, Porters and Terrys creeks. Average SIGNAL-SF scores for Archers and Porters creeks was marginally lower than the Autumn 2008 scores, as was Terrys Creek, although the score was virtually the same as Autumn 2008. The AUSRIVAS OE50 and OE0 SIGNAL2 models didn’t indicate any real change from the previous Spring 2007 samples for Archers, Porters and Terrys creeks. The AUSRIVAS OE50 output continued the trend of having lower scores in Spring and higher scores in Autumn for all creeks except Shrimptons, SIGNAL-SF indicated this same seasonal trend for Archers Creek.

The average Spring 2008 SIGNAL-SF score for Shrimptons Creek was marginally higher than Autumn 2008, which had dropped significantly in the previous two sampling seasons since Autumn 2007 when it recorded it’s highest score. The AUSRIVAS OE50 output showed a slight drop in stream health from Spring 2007 to 2008 and also mirrors the change in stream health over time indicated in SIGNAL-SF. OE0 SIGNAL2 showed no change from Spring 2007 and has not shown the change in stream health over time like that indicated by SIGNAL-SF and AUSRIVAS OE50.

The Spring 2008 SIGNAL-SF score for Buffalo Creek dropped significantly from the previous Autumn 2008 score. The AUSRIVAS OE50 output showed a decrease in health from Spring 2007 and placed Buffalo Creek in the Extremely Impaired band (Band D), recording the lowest Spring score historically of any creek. OE0 SIGNAL2 indicated a slight drop in stream health for Buffalo Creek but showed no real change in stream health over time.

The slight differences in patterns presented by SIGNAL-SF, AUSRIVAS OE50 and AUSRIVAS OE0 SIGNAL2 measures partially relate to the abundance and tolerance component involved in the calculation of SIGNAL-SF scores, versus presence absence component used in the calculation of AUSRIVAS OE50 and AUSRIVAS OE0 SIGNAL2. Another source of the slight differences between these two analysis tools may be from direct measurement and measurement via comparison to reference site groups of the AUSRIVAS predictive models. Despite these slight differences and together with the EPT richness index results from all univariate analysis tools indicate impaired stream health in the five creeks studied under the Biological and Chemical Water Quality Monitoring Strategy.

A limitation with AUSRIVAS models is the difference in band threshold values for Autumn, Spring, and combined season models. Although the threshold (10th percentile) for band A (similar to reference) is virtually the same for these three models, mixing Autumn and Spring output should not occur as Coysh et al. (2000) indicates mixing assessments based on different season models should be discouraged. Hence, Autumn, Spring and Combined Autumn Spring model results were presented separately for AUSRIVAS output. SIGNAL-SF (Chessman et al., 2007) does not have this seasonal limitation, and perhaps trends are more easily identified from this tool.

The abovementioned univariate analysis tools, EPT richness, SIGNAL-SF, AUSRIVAS OE50, AUSRIVAS OE0SIGNAL2 all indicated impaired ecosystem health. The multivariate analysis tools complement univariate analyses by exploring patterns of macroinvertebrate communities by looking at the chosen array of samples and all taxa recorded.

Multivariate analyses indicated biological signature or community (assemblage) structure of Shrimptons Creek has been more variable through time than the community structure of the other four creeks. Terrys Creek has shown the least amount of variability through time. SIMPER results showed that Terrys Creek has a 68% similarity between replicates through time. The multivariate analyses and most of the univariate analyses highlight that Terrys Creek has the most stable macroinvertebrate community structure and stream health of the five creeks investigated.

Exploration of multivariate SIMPER results has indicated that generally Buffalo, Porters and Terrys creeks have had a community structure resembling one another with mild shifts relating to seasonal change. Archers Creek has been similar in community structure to the aforementioned creeks but with obvious seasonal differences. The seasonal trend in Archers Creek is also apparent in the univariate tools SIGNA-SF and AUSRIVAS OE50 with Spring generally being poorer in stream health compared to Autumn. Whereas the community structure of Shrimptons Creek has at times been quite different often being dominated by tolerant non-insect taxa, and doesn’t appear to have seasonal differences.

The SIMPER results for Buffalo Creek in Spring 2008 indicated that the community structure was dominated by only three taxa with an 80% contribution from tolerant taxa Aquatic Snails (Physidae and Hydrobiidae) and the non- biting midge (Chironominae). Whilst the community structure of Buffalo Creek has previously shown high contributions of these taxa, there are usually high contributions from other slightly less tolerant insect fauna. The dominance of these tolerant taxa coincides with the relatively large drop in its SIGNAL-SF score, recording the lowest score to date in Buffalo Creek. AUSRIVAS OE50 output showed a moderate drop in stream health for Spring 2008, which placed it in the extremely impaired band (Band D) for the first time, while AUSRIVAS OE0 SIGNAL2 showed no real change. The most probable factor for the loss of some taxa in Buffalo Creek could be due to a smothering effect of fine sediment on in stream habitats caused by run-off from development in the upper catchment. Autumn 2008 recorded elevated levels of turbidity at the additional upstream sites, turbid conditions were also observed at all sites after the Autumn 2008 sampling season (Figure 3). Whilst water quality samples in Spring 2008 did not indicate elevated turbidity a build up of sediment was observed at the core Buffalo Creek site. This smothering effect has been linked to the loss of certain taxa in streams that has had an influx of fine sediment within forestry areas (Vuori & Joensuu, 1996; Death et al., 2003), this smothering coincided with the dominance of new taxa. Death et al. (2003) found that dominant sensitive mayfly taxa were lost and that tolerant (including Chironomidae and Hydrobiidae) taxa became dominant when elevated levels of fine sediment were introduced to streams.

The apparent loss of taxa and drop in stream health in Buffalo Creek is potentially reversible if the source of sediment can be controlled or removed. If it can be controlled or removed it should be a short-term impact on the creek. Wood & Armitage (1997) suggested that short term increases in fine sediment due to human disturbances like construction developments can lead to a rapid recovery. Further biological sampling of Buffalo Creek would then hopefully show this recovery.

Chessman et al. (2006) determined twice as many taxa appeared to favour sites in good geomorphic condition as favoured poor sites. Chessman et al. (2006) also indicated many taxa associated with sites in poor condition are introduced taxa. In The City of Ryde macroinvertebrate data the dominant aquatic snail was the introduced *Physa acuta* and aquatic worms counts had numerous specimens of the introduced *Lumbriculus variegatus*. Chessman et al. (2006) suggests rehabilitation of geomorphic condition can assist in the rehabilitation of native riverine biota. Native riverine macroinvertebrate community structure in bushland streams around Sydney, that have no urban water quality disturbances, typically have main contributions from insects such as MayFlies, Caddisflies, Beetles, and Aquatic Mites. The sensitive taxa of the Sydney region have higher SIGNAL grades as recorded in Chessman et al. (2007). The low occurrences of Mayflies and Caddisflies highlighted by the EPT data as well as beetles yet the abundance of introduced taxa in the City of Ryde Creeks suggests their poor condition.

In previous reports (SWC 2006, 2007a, 2007b) exploration of stormwater drainage connection was recommended. Due to cost, the calculation of the percentage of effective imperviousness in each of the five catchments was not made. Rather possible surrogates of this measure included: total length of pipe; total number of outlets; catchment area; ratio of total length of pipe to catchment area; and ratio of total number of pipe outlets to catchment area were calculated by the City of Ryde. Calculated values were included in the BIOENV routine for all five creeks.

The attempt to link water quality patterns with macroinvertebrate patterns using the multivariate BIOENV routine produced at best one moderate correlation, this was Porters Creek with a correlation of 0.51. The BIOENV correlations for all five creeks and when individually assessed were lower when compared to the previous Autumn 2008 results. This suggests physico-chemical measurements collected to date under the strategy do not appear to be all of the drivers for the shifts recorded in macroinvertebrate community structure. As such efforts to improve water quality should not be solely concentrated on variables measured to date. The variable rainfall was highlighted in all BIOENV results for individual creeks, and with average rainfall or better than average rainfall this trend may strengthen in all five creeks.

Rainfall was previously a variable highlighted in the combined analysis of all five creeks, however it was not included in the strongest correlations for Spring 2008. This could be due to the below average rainfall that fell between Autumn 2008 and the current sampling season. Despite this, the catchment storm water delivery characteristics Total Length of Pipe and the Ratio of Number of Outlets/ Catchment Area were highlighted. This outcome suggests catchment pollution transport to the stream is a contributing factor influencing in-stream macroinvertebrate community structure.

Conclusions of research conducted in the greater Melbourne area that looked at water quality, epilithic diatoms, benthic algae and macroinvertebrate indicators suggested minimisation of directly piped stormwater drainage connection of impervious surfaces to be beneficial in mitigation of urban impacts on receiving streams (Hatt et al., 2004; Walsh, 2004; Taylor et al. 2004; Newall & Walsh, in press). The primary degrading process to urban steams is suggested to be effective imperviousness (the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater pipes) (Walsh et al., 2005a), provided sewer overflows, sewage treatment plant discharges, or long-lived pollutants from earlier land uses are not operable as these can obscure stormwater impacts (Walsh et al., 2005b). Walsh (2004) determined community composition was strongly explained by the gradient of urban density and that most sensitive taxa were absent from urban sites with greater than 20% connection of impervious surfaces to streams by pipes. The virtual lack of recorded sensitive EPT indicator taxa in the monitoring conducted to date may suggest there is greater than 20% connection of impervious surfaces to Archers, Shrimptons, Buffalo, Porters and Terrys creeks. Inclusion of data from a number of above average rainfall periods is required before comments can be made with regard to disturbance influence of average or above average rainfall conditions.

The direct connection of impervious surfaces to a stream allows small rainfall events to produce surface runoff that cause frequent disturbance to the stream through regular delivery of water and pollutants (Walsh et al., 2005). In catchments with existing drainage networks such as those under study in this program, policies that facilitate infiltration, evaporation, transpiration or storage for later in-house use will gradually benefit stream health in the longer term based on outcomes of research conducted in Melbourne.

The introduction of surrogate measures for effective imperviousness into the BIOENV analysis routine suggests an effect on in-stream macroinvertebrate community structure from catchment pollution transport to the stream from efficient storm water delivery systems from the impervious surfaces of each catchment. These surrogates were used to minimise council expenditure on calculating effective imperviousness as defined under the abovementioned Melbourne research. Stronger correlations from the BIOENV routine may have been achieved if effective imperviousness had been calculated and was available for input into the BIOENV analysis. Expenditure on calculation of effective imperviousness is not considered warranted given results obtained from the surrogates. Thus the Melbourne work provides a solid basis for council decision making under the Biological and Chemical Water Quality Monitoring Strategy.

The impaired macroinvertebrate communities described above for Archers, Shrimptons, Buffalo, Porters and Terrys creeks in the City of Ryde appear to be due to stormwater connectivity with regular delivery of pollutants and altered geomorphic conditions due to this connectivity. Further data collection under average rainfall or better than average rainfall may strengthen the extrinsic rainfall trend defined by the BIOENV routine and assist in clarifying the broad driver of stream health being investigated in the Biological and Chemical Water Quality Monitoring Strategy.

6 Comments on progress of strategy aims

The section places the current knowledge of sampling data consolidated in this report within the context of the aims detailed in the City of Ryde's request for the engagement of consultants No COR-EOC-05/07.

- Evaluate chemical and biological water quality monitoring both for short and long term interpretation and temporal evaluation over the duration of the strategy;

  Consolidation of available comparable data was conducted in the Spring 2006 report. If further historical data become available then these will be added into future reports. Analysis in the Autumn and Spring 2007 and Autumn and Spring 2008 reports has also incorporated available comparable historical data. Additional sampling across all five streams has allowed statistical analysis to identify temporal shifts in community structure across seasons and under varying weather conditions. Investigation of the data in this way will continue in subsequent reports to provide a better understanding of variation between Autumn and Spring seasons and between weather conditions which will provide better base line data to assess changes in community structure that may result from future City of Ryde management actions.

- Detail where, when and how often samples should be taken from creeks within the Ryde Local Government Area based on existing site data, catchment position, accessibility and trends identified;

  Recommendations made in Spring 2006 report to sample all creeks in each sample session have been implemented and allow capture of variation through time and under different weather conditions that influence the five study streams. Benefits of sampling all five creeks are detailed above and in the last paragraph of this section.

- Prescribe how to sample for macroinvertebrates, building on the standard protocols designed by AUSRIVAS;

  Adoption of a standard methodology under the strategy allows for collection of comparable data and in turn statistical analysis of comparable measures, which facilitates interpretation of collected data.

- Provide for a series of options for identification of key indicator taxa to family and or morphospecies;

  This is provided by EPT indicator taxa from AUSRIVAS predicted model output. SIGNAL-SF grades could also be used to assess key indicator taxa. With currently only two EPT taxa recorded to date no advantage is afforded by SIGNAL-SF at this stage.

- Identify a standard suite of analyses to determine status and trends in water quality including calculation of the AUSRIVAS index;

  Suitable indices such as SIGNAL SF to assess water quality status, including calculation of the Observed/Expected (OE50 and OE0

SIGNAL2) ratios from the respective AUSRIVAS predictive models for autumn, spring, and combined seasons were evaluated in Spring 2006 with subsequent recommendation made and these have been implemented in Autumn and Spring 2007, and Autumn and Spring 2008 reports. Multivariate statistical analysis techniques have also been incorporated into Spring 2006 to the current Spring 2008 reports. A change was made to the routine used to assess water quality and macroinvertebrates linkages in Spring 2006 with the BIOENV routine employed instead of the BVSTEP routine which conducts a less thorough search. This change was made given the relatively small amount of water quality variables and suitable computing power was available to conduct a full search of the data with BIOENV. In the Spring 2008 the SIMPROF test has been added, due to recent advances in multivariate statistical software.

- Provide the basis for an appraisal of the capacity of a standard monitoring strategy to be integrated into a community monitoring program eg. Streamwatch.

  Suggestions were put forward in the Spring 2006 and Autumn 2007 reports for use of SIGNAL2 in a format that could be calculated by community groups without access to the AUSRIVAS predictive models. In the 2007 report, calibration was made for boundary points of water quality status so community groups could use this analysis in the City of Ryde area. Standard collection methods would need to be used and suitable quality control of data would need to be implemented to provide comparability of data through time.

- Provide the foundation to augment the Streamwatch capacity within the City of Ryde including options for improved education awareness of water quality issues within schools and community groups.

  As above.

- Provide information and direction on potential infrastructural works to complement water quality monitoring and improve overall creek health.

  The consolidation of available comparable data that has occurred and additional sampling will allow capture of variation through time and under different weather conditions in each of the five study streams. Continued average rainfall conditions or better would be advantageous to allow capture of variation in community structure and water quality under wetter conditions. Understanding variation between Autumn and Spring and under different weather conditions will provide better base line data to assess changes in community structure that may result from future City of Ryde management actions.

7 References

Allen, G.R., Allen, M. & Midgley, S.H. (2002). Field Guide to the Freshwater Fishes of Australia*.* *West Australian Museum*, Perth.

Andersen, N.M. & Weir, T.A. (2004). Australian Water Bugs : Their Biology and Identification. *CSIRO Publishing*, Australia.

Arthington, A.H. (1989). Diet of Gambusia affinis holbrooki, Xiphophorus helleri, X maculatus and Poecilia reticulata (Pisces: Poeciliidae) in streams of southeastern Queensland, Australia. *Asian fisheries science*, **2**, 193-212.

ANZECC (2000). Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters. *Australian and New Zealand Environment and Conservation Council*.

APHA (1995). Standard methods for the examination of water and wastewater. *American Public Health Association.*

Besley C.H. & Chessman B.C. (2008) Rapid biological assessment charts the recovery of stream macroinvertebrate assemblages after sewage discharges cease. *Ecological Indicators* **8**, 625-638

Beatty, S.J. (2006). The diet and trophic positions of translocated, sympatric populations of Cherax destructor and Cherax cainii in the Hutt River, West Australia: evidence of resource overlap. *Marine and Freshwater Research*, 2006-11 **57** (8), 825-835.

Biosphere Environmental Consultants (2006). Ryde Flora and Fauna Study. *Online available at* http://www.ryde.nsw.gov.au/WEB/SITE/RESOURCES/DOCUMENTS/PDF/AllCouncilMngStratPlans/ff_report_2006.pdf

Boey, A., Chessman, B., McEvoy, P. & Rae, D. (1993). Stream water quality and Biota in the Picton Region 1992. *AWT Science & Environment Report 93/2.*

Bureau of Meteorology. Australian Government. *Online available at* http://www.bom.gov.au/.

Chessman, B.C. (1995). Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family-level identification and a biotic index*.* *Australian Journal of Ecology,* **20**, 122-129.

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

Chessman, B.C. (2003b). SIGNAL2.iv – A Scoring System for Macroinvertebrates ('Water Bugs') in Australian Rivers. User Manual. *National Heritage Trust. Report No.31.*

Chessman, B.C., Fryirs, K.A. and Brierley, G.J. (2006). Linking geomorphic character, behaviour and condition to fluvial biodiversity: implications for river management. *Aquatic Conservation: Marine and Freshwater Ecosystems* ***16:*** *267-288.*

Chessman, B.C, Kotlash, A. and Growns, J. (1997) Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL-HU97B biotic index: application to the Hunter River system, New South Wales. *Marine and Freshwater Research*, **48**, 159-172.

Chessman, B.C., Trayler, K.M., and Davis, J.A. (2002) Family- and species-level biotic indices for macroinvertebrates of wetlands on the Swan Coastal Plain, Western Australia. *Marine and Freshwater Research*, 53, 919-930.

Chessman B.C., Williams S.A. & Besley C.H. (2007) Bioassessment of streams with macroinvertebrates: effect of sampled habitat and taxonomic resolution. *Journal of the North American Benthological Society.* 26 (3), (546-563).

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

Connell, D.W. (1993). Water Pollution. Causes and effects in Australia and New Zealand. *University of Queensland Press*.

Coysh, J., Nichols, S., Ransom, G., Simpson, J., Norris, R. Barmuta, L., & Chessman, B. (2000) 'AUSRIVAS Predictive Modelling Manual'. *Online available at* http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/Man/Pred/.

Death, R.G., Baillie, B. & Fransen, P. (2003). Effect of *Pinus radiata* logging on stream invertebrate communities in Hawke's Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* ***37****, 507-520.*

Ecowise Environmental (2004). Biological and Water Quality Monitoring of Five Core Sites in Spring 2004. *City of Ryde No.EP/WQM/E1/04.*

Ecowise Environmental (2005). Biological and Water Quality Monitoring of Five Core Sites in Autumn 2005. *City of Ryde No.EP/WQM/E1/04*.

Ecowise Environmental (2005). Biological and Water Quality Monitoring of Five Core Sites in Spring 2005. *City of Ryde No.EP/WQM/E1/04.*

Ecowise Environmental (2006). Biological and Water Quality Monitoring of Five Core Sites in Autumn 2006. *City of Ryde No.EP/WQM/E1/04.*

Faith, D.P., Minchin, P.R. & Belbin, L. (1987). Composition dissimilarity as a robust measure of ecological distance*. Vegetatio.* ***69****, 57-68.*

Gooderham, J. & Tsyrlin, E. (2002). The Waterbug Book : A Guide to the Freshwater Macroinvertebrates of Temperate Australia. *CSIRO Publishing*, Collingwood VIC.

Growns, J.E, Chessman, B.C., McEvoy, P.K. & Wright, I.A. (1995) Rapid assessment of rivers using macroinvertebrates: Case studies in the Nepean River and Blue Mountains, NSW. *Australian Journal of Ecology*, **20**, 130-141.

Growns, J.E., Chessman, B.C., Jackson, J.E., & Ross, D.G. (1997) Rapid assessment of Australian rivers using macroinvertebrates: cost efficiency of 6 methods of sample processing. *Journal of North American Benthological Society*, **16**, 682-693.

Hatt, B.E., Fletcher, T.D., Walsh, C.J., & Taylor, S.L. (2004) The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management,* **34**, 112-124.

Hawking, J.H. (2000). A Preliminary Guide to the Keys and Zoological Information to Identify Invertebrates from Australian Inland Waters. *Guide No. 2 Second Edition (Cooperative Research Centre for Freshwater Ecology: Albury VIC).*

Hawking, J.H. & Smith, F.J. (1997). Colour Guide to Invertebrates of Australian Inland Waters. *Guide No.8 (Cooperative Research Centre for Freshwater Ecology: Albury VIC).*

ISO 7828 –1985 (E) Water quality – Methods of biological sampling – Guidance on hand net sampling of aquatic benthic macroinvertebrates. *International Organisation for Standardization.*

Kaiser Engineers, California, *Final Report to the State of California, San Francisco Bay-Delta Water Qulaity Control Program,* State of California, Sacramento, CA (1969).

Lenat, D.R. (1998). Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. *Journal of North American Benthological Society,* ***7****, 222-223.*

McDowell, R. (1996). Freshwater Fishes of South-Eastern Australia. *Reed Books*, Sydney.

Metzeling, L., Chessman, B. Hardwick, R. & Wong, V. (2003) Rapid assessment of rivers using macroinvertebrates: the role of experience, and comparisons with quantitative methods. *Hydrobiologia*, **510**, 39-52.

Newall, P. & Walsh, C.J. (in press) Response of epilithic diatom assemblages to urbanisation influences. *Hydrobiologia.*

NSW Fisheries (2005) Threatened species in New South Wales. *Online available at*: http://www.dpi.nsw.gov.au/. *Fisheries Management Act (1994).*

Ohnesorge, F.K. and Wilhelm, M. (1991). Zinc. In *Metals and their Compounds in the Environment. Occurance, Analysis and Biological Relevance* (ed. E. Merian) pp. 1309-42. VHC, Weinheim.

Oliver, I. & Beattie, A.J. (1996). Invertebrate morpho-species as surrogates for species: a case study. *Cons.Biol.* ***10*** *99-109.*

Ranson, G., Coysh, J. & Nichols, S. (2004) 'AUSRIVAS Macroinvertebrate Bioassessment Predicitve Modelling Software V3.1.1 User Manual'. *Online available at* http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/Man/User/.

SWC (2005). Environmental Indicators Compliance Report. *Online available at* http://www.sydneywater.com.au/Publications/Reports/AnnualReport2005*.*

SWC (2006). Biological & Water Quality Monitoring Spring 2006 for City of Ryde. *Online available at http://www.ryde.nsw.gov.au/WEB/SITE/RESOURCES/DOCUMENTS/PDF/Environment/2006_final.pdf.*

SWC (2007a). Biological & Water Quality Monitoring Autumn 2007 for City of Ryde. *Online available at http://www.ryde.nsw.gov.au/WEB/SITE/RESOURCES/DOCUMENTS/PDF/Environment/2006_final.pdf.*

SWC (2007b). Biological & Water Quality Monitoring Spring 2007 for City of Ryde. *Online available at http://www.ryde.nsw.gov.au/WEB/SITE/RESOURCES/DOCUMENTS/PDF/Environment/enviro_report2008.pdf.*

Taylor, S.L, Roberts, S.C., Walsh, C.J., & Hatt, B.E. (2004) Catchment urbanisation and increased benthic algal biomass in streams: linking mechanisms to management. *Freshwater Biology,* **49**, 835-851.

Turak, E., Waddell, N. & Johnstone, G. (2004). New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual 2004. *Natural Heritage Trust.*

Turak, E. & Waddell, N. (2001) Development of AUSRIVAS Models for New South Wales. NSW Environment Protection Authority. *Online available at* http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/.

Turak, E., Waddell, N. & Johnstone, G. (2004) New South Wales (NSW) Australian Assessment System (AUSRIVAS) Sample Processing Manual. *Online available at* http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/.

US EPA, www.epa.gov

Vuori, K. & Joensuu, I. (1996). Impact of forest drainage on the macroinverterbates of small boreal headwater stream: Do buffer zones protect lotic biodiversity? *Biological Conservation*, **77**, 87-95.

Wallace, J.B. & Webster J.R. (1996). The role of macroinvertebrates in stream ecosystem function. *Annual Review of Entomology,* **41**, 115-139.

Walsh, C.J. (2004). Protection of in-stream biota from urban impacts: minimise catchment imperviousness or improve drainage design? *Marine and Freshwater Research, 2004,* **55**, 317-326.

Walsh, C.J. (2006). Biological indicators of stream health using macroinvertebrate assemblage composition: a comparison of sensitivity to an urban gradient. *Marine and Freshwater Research, 2006*, **57**, 37-47.

Walsh, C.J, Fletcher, T.D, & Ladson, A.R. (2005a) Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream. *Journal of the North American Benthological Society,* **24**, 690-705.

Walsh, C.J, Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., & Morgan, R.P. (2005b) The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society,* **24**, 706-723.

Water On The Web (2005). Online available at: http://waterontheweb.org/under/waterquality/oxygen.html.

Wood, P.J. & Armitage, P.D. (1997). Biological Effects of Fine Sediment in the Lotic Environment. *Environmental Management*, **21**, 203-217.

Wright, J.R. (1995). Development of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology,* **20**, 181-197.

Appendix 1 Quality assurance

Sydney Water Analytical Services is a quality business organisation, certified to AS/NZS ISO 9001:2000 Quality management systems - requirements certification number 2764, issued by Benchmark 31st November 2004 for the Monitoring Process Management System. All investigations performed for the production of this report, and all business operations of the organisation, have been conducted to the requirements of this standard including project management, macroinvertebrate sampling, water quality sampling and interpretive reporting.

Macroinvertebrates have been identified and enumerated to the genus or species taxonomic level, (as appropriate for the study) by the Aquatic Ecology team. The method used SSWI433 In-house test method macroinvertebrate cataloguing, identification and counting is in compliance with the requirements of AS ISO/IEC 17025:1999 General Requirements for the Competence of Testing and Calibration Laboratories was added under technical accreditation number 610 issued by National Association of Testing Authorities (NATA) in 1997. In particular macroinvertebrate identification was performed with appropriate published keys listed in Hawking (2000), internal keys to the macroinvertebrate collection, unpublished descriptions and voucher specimens. Where a specimen could not be keyed to a formally described species, a morphospecies number has been assigned as per in-house test method SSWI433. Terrestrial macroinvertebrate morphospecies have been shown to produce similar patterns to those obtained using formally described species (Oliver and Beattie, 1996).

Quality assurance was conducted as per SSWI434 In-house test method quality control of macroinvertebrate identification, counting and archiving of collections in compliance with the requirements of AS ISO/IEC 17025:1999 General Requirements for the Competence of Testing and Calibration Laboratories was added under technical accreditation number 610 in 1997. Quality assurance was conducted on at least 5% of samples collected for this study, and identification and counting errors on average are less than 10% for the study.

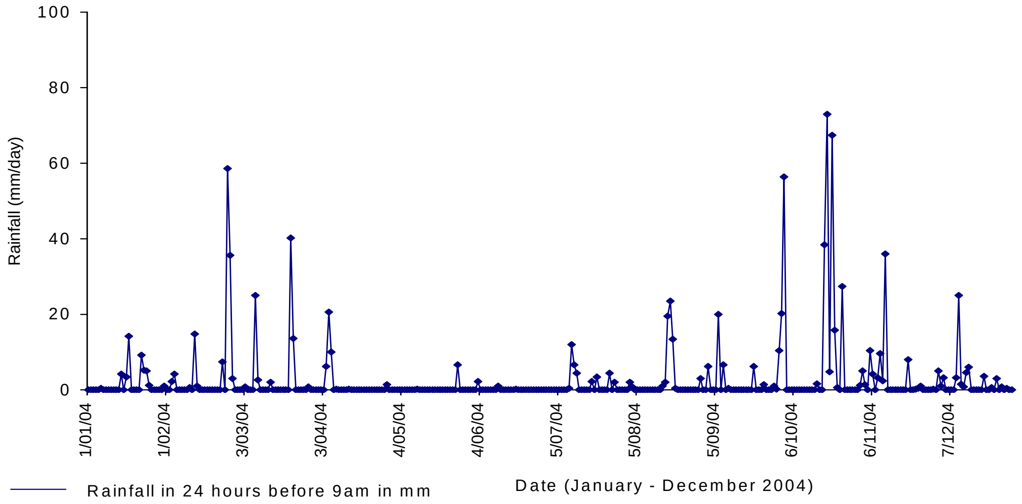
Appendix 2 Water quality results

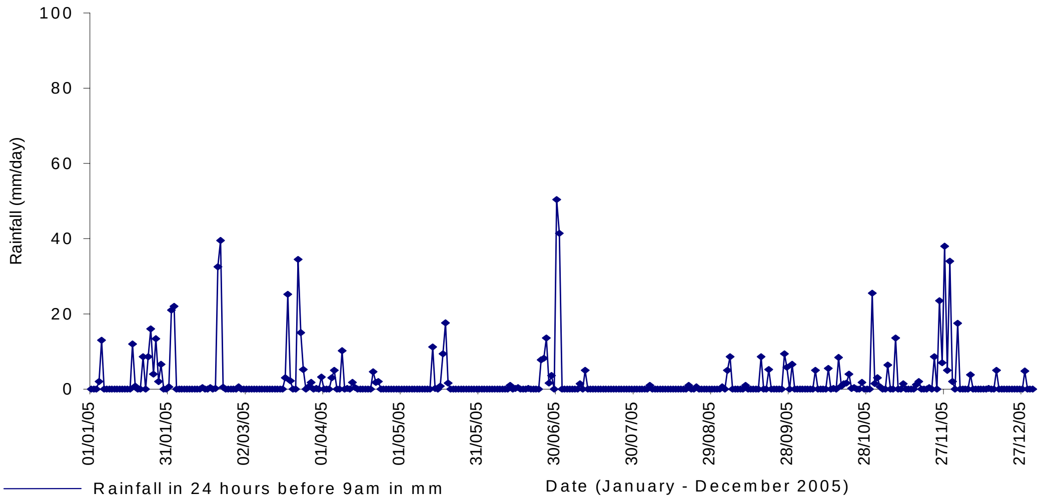
Stream	Site code	Season	Sample date	Faecal Coliforms	Ammonia	Oxidised Nitrogen NOx	Total Phosphorus TP	Total Kjeldahl Nitrogen TKN	Total Nitrogen TN	Alkalinity	Turbidity	Conductivity	Total Dissolved Solids	pH	Dissolved Oxygen DO
				CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L	mg CaCO3/L	NTU	µS/cm	mg/L		mg/L
Terrys Ck	Site 1	spring 2008	16/9/08	~820	10	120	35	370	490	41.5	11.5	25.4	149	7.2	7.75
Shrimptons Ck	Site 2	spring 2008	16/9/08	240	20	250	54	440	690	51	8.85	27.8	155	7.1	3.8
Porters Ck	Site 3	spring 2008	16/9/08	260	4000	1660	24	4520	6180	130	5.46	61.1	336	7.7	9.6
Buffalo Ck	Site 4	spring 2008	16/9/08	820	10	450	42	400	850	79.5	10.8	52.4	293	7.34	7.21
Archers Ck	Site 5	spring 2008	16/9/08	270	10	670	19	350	1020	82.5	2.71	55.5	311	7.67	10.4
Terrys Ck	Site 1	spring 2008	13/10/08	~80	20	140	52	440	580	74	3.04	50.9	281	7.13	3.64
Shrimptons Ck	Site 2	spring 2008	13/10/08	420	120	30	197	900	930	67	3.92	30.1	171	7.14	0
Porters Ck	Site 3	spring 2008	13/10/08	48	980	1870	26	1410	3280	91.5	4.88	45.6	251	7.4	7.3
Buffalo Ck	Site 4	spring 2008	13/10/08	~84	130	90	41	540	630	96.5	13.2	100.8	573	7.16	0.3
Archers Ck	Site 5	spring 2008	13/10/08	220	50	380	33	370	750	85.5	2.74	50.1	279	7.25	3.4
Terrys Ck	Site 1	autumn 2008	3/5/08	150	10	**270**	24	310	**580**	72	3.21	474	284	8.0	8.40
Shrimptons Ck	Site 2	autumn 2008	3/5/08	200	10	10	**53**	670	**680**	74	3.17	358	214	7.4	5.80
Porters Ck	Site 3	autumn 2008	3/5/08	530	**250**	**430**	38	1100	**1530**	81	15.2	650	444	7.6	6.70
Buffalo Ck	Site 4	autumn 2008	3/5/08	620	**40**	**450**	35	370	**820**	91	37.2	885	552	**8.1**	6.80
Archers Ck	Site 5	autumn 2008	3/5/08	170	**30**	**370**	20	290	**660**	78	2.18	513	310	7.3	6.50
Terrys Ck	Site 1	autumn 2008	4/3/08	250	10	**120**	25	200	320	64	3.1	351	160	7.3	8.30
Shrimptons Ck	Site 2	autumn 2008	4/3/08	700	10	10	**92**	620	**620**	73	6.17	291	130	7.2	3.80
Porters Ck	Site 3	autumn 2008	4/3/08	370	**750**	**300**	27	1100	**4100**	100	3.96	505	290	7.6	9.30
Buffalo Ck	Site 4	autumn 2008	4/3/08	120	**50**	**220**	33	260	480	77	4.69	654	389	7.3	8.00
Archers Ck	Site 5	autumn 2008	4/3/08	160	**40**	**110**	22	230	340	83	1.48	470	253	7.3	7.10

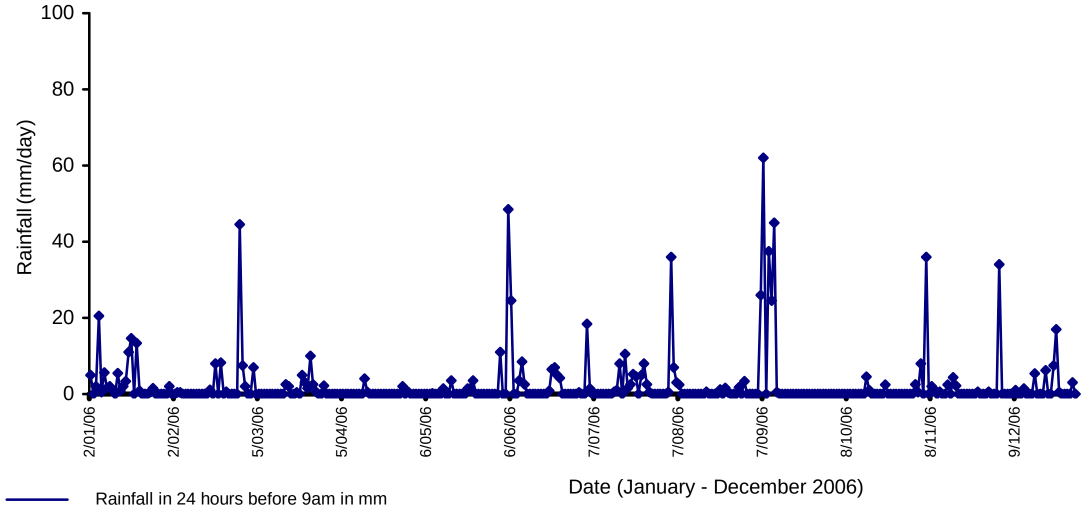
Stream	Site code	Season	Sample date	Faecal Coliforms	Ammonia	Oxidised Nitrogen NOx	Total Phosphorus TP	Total Kjeldahl Nitrogen TKN	Total Nitrogen TN	Alkalinity	Turbidity	Conductivity	Total Dissolved Solids	pH	Dissolved Oxygen DO
				CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L	mg CaCO3/L	NTU	µS/cm	mg/L		mg/L
Terrys Ck	Site 1	spring 2007	27/09/07	87	20	**190**	21	290	480	67	2	503	276	7.3	6.00
Shrimptons Ck	Site 2	spring 2007	26/09/07	300	**160**	30	**54**	650	**680**	72	2.6	403	232	7.1	2.35
Porters Ck	Site 3	spring 2007	27/09/07	**1000**	**2600**	**3200**	**60**	3110	**6310**	122	6.7	671	372	7.8	6.50
Buffalo Ck	Site 4	spring 2007	27/09/07	54	**40**	**170**	37	440	**610**	90	7.3	960	484	7.3	5.70
Archers Ck	Site 5	spring 2007	26/09/07	270	20	**480**	26	680	**1160**	59	3.2	527	304	7.5	6.30
Terrys Ck	Site 1	spring 2007	23/10/07	6	**40**	**80**	35	730	**810**	88	1.6	712	437	7.0	4.00
Shrimptons Ck	Site 2	spring 2007	22/10/07	150	<10	<10	**111**	1000	**1000**	77	11.9	519	350	**6.7**	2.90
Porters Ck	Site 3	spring 2007	23/10/07	160	**1020**	**2600**	**68**	1580	**4180**	90	8.2	505	326	7.7	7.30
Buffalo Ck	Site 4	spring 2007	23/10/07	140	**110**	**60**	**73**	790	**850**	108	7.7	1001	621	7.2	6.95
Archers Ck	Site 5	spring 2007	22/10/07	90	**150**	**50**	**57**	480	**530**	74	7.1	378	220	**6.7**	3.90
Terrys Ck	Site 1	autumn 2007	14-15/03/07	300	<10	**370**	30	280	**650**	64	1.6	472	358	7.2	5.07
Shrimptons Ck	Site 2	autumn 2007	14-15/03/07	600	<10	**550**	**58**	330	**880**	64	2.9	362	276	7.1	3.2
Porters Ck	Site 3	autumn 2007	14-15/03/07	600	**580**	**1310**	**51**	1040	**2350**	97	1.3	**3030**	2010	7.9	8.42
Buffalo Ck	Site 4	autumn 2007	14-15/03/07	68	**90**	**120**	48	440	**560**	75	2.1	646	442	7.3	5.09
Archers Ck	Site 5	autumn 2007	14-15/03/07	290	<10	**170**	**89**	270	440	64	0.9	397	300	7.2	4.60
Terrys Ck	Site 1	autumn 2007	17-18/04/07	900	**110**	**200**	**53**	530	**730**	57	2.7	438	.	7.1	5.30
Shrimptons Ck	Site 2	autumn 2007	17-18/04/07	550	**30**	**160**	45	490	**650**	81	8.4	397	.	6.9	3.75
Porters Ck	Site 3	autumn 2007	17-18/04/07	**10000**	**710**	**1590**	20	1200	**2790**	98	3.2	3130	.	7.8	7.70
Buffalo Ck	Site 4	autumn 2007	17-18/04/07	740	**130**	**120**	48	540	**660**	81	8.6	912	.	6.7	3.83
Archers Ck	Site 5	autumn 2007	17-18/04/07	210	**30**	**50**	**58**	520	**570**	70	4.2	322	.	7.2	4.10
Shrimptons Ck	Site 2	spring 2006	28/09/06	69	**130**	**140**	**64**	580	**720**	94	7.8	717	420	7.1	4.33
Archers Ck	Site 5	spring 2006	28/09/06	160	5	5	**104**	520	**520**	83	2.0	509	293	7.4	6.53
Shrimptons Ck	Site 2	spring 2006	18/10/06	560	10	20	**136**	1180	**1200**	66	6.3	481	311	**6.5**	2.21
Archers Ck	Site 5	spring 2006	18/10/06	340	5	10	**90**	500	**510**	70	2.3	448	295	6.9	3.94
Shrimptons Ck	Site 2	spring 2006	10/11/06	880	**70**	**1200**	**68**	800	**2000**	58	**96.7**	384	265	7.4	4.16
Archers Ck	Site 5	spring 2006	10/11/06	**1700**	**20**	**40**	**50**	360	400	84	1.8	502	310	7.2	7.19
Terrys Ck	Site 1	autumn 2006	9-10/03/06	160	<10	**60**	30	310	370	50	2.3	381	180	6.8	4.99
Shrimptons Ck	Site 2	autumn 2006	9-10/03/06	330	**40**	<10	**50**	380	390	85	4.6	435	230	**6.7**	2.13
Porters Ck	Site 3	autumn 2006	9-10/03/06	**9800**	**820**	**760**	20	1500	**2300**	48	1.9	**3712**	2200	7.4	7.41
Buffalo Ck	Site 4	autumn 2006	9-10/03/06	220	**130**	**470**	**70**	500	**1000**	90	8.0	738	390	7.2	4.36
Archers Ck	Site 5	autumn 2006	9-10/03/06	140	**90**	**80**	**100**	520	**600**	95	2.5	1482	830	7.0	4.09
Terrys Ck	Site 1	autumn 2006	19-20/04/06	560	**450**	**90**	**100**	1100	**1200**	45	3.2	306	180	7.0	2.40
Shrimptons Ck	Site 2	autumn 2006	19-20/04/06	860	**30**	30	**80**	480	**510**	40	5.0	281	160	**6.7**	4.61
Porters Ck	Site 3	autumn 2006	19-20/04/06	290	**350**	**630**	20	700	**1300**	45	2.3	**3792**	2100	7.6	8.30
Buffalo Ck	Site 4	autumn 2006	19-20/04/06	170	**90**	**450**	**60**	470	**920**	70	5.1	749	400	7.2	4.64
Archers Ck	Site 5	autumn 2006	19-20/04/06	240	**90**	**470**	**70**	390	**860**	45	4.1	259	150	7.1	4.38
Terrys Ck	Site 1	autumn 2006	9-10/05/06	66	**70**	**240**	**50**	380	**620**	60	2.4	358	220	7.1	3.98
Shrimptons Ck	Site 2	autumn 2006	9-10/05/06	750	20	**40**	**80**	340	380	35	7.7	264	140	6.8	5.04
Porters Ck	Site 3	autumn 2006	9-10/05/06	40	**400**	**650**	10	800	**1400**	1	1.2	**2916**	1700	7.3	8.33
Buffalo Ck	Site 4	autumn 2006	9-10/05/06	110	**60**	**480**	**60**	240	**720**	90	4.4	667	400	7.3	4.72
Archers Ck	Site 5	autumn 2006	9-10/05/06	28	**50**	**370**	40	300	**670**	55	5.1	245	120	7.2	6.31

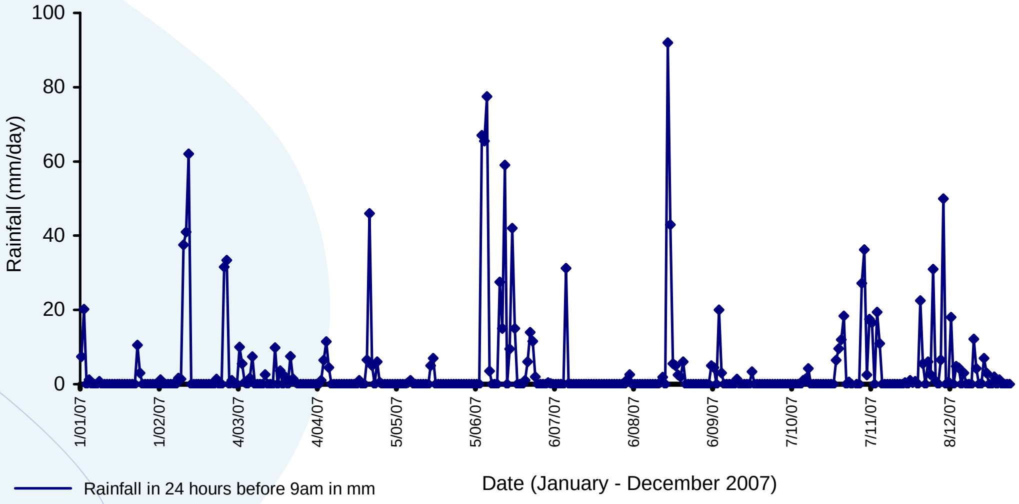
Stream	Site code	Season	Sample date	Faecal Coliforms	Ammonia	Oxidised Nitrogen NOx	Total Phosphorus TP	Total Kjeldahl Nitrogen TKN	Total Nitrogen TN	Alkalinity	Turbidity	Conductivity	Total Dissolved Solids	pH	Dissolved Oxygen DO
				CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L	mg CaCO3/L	NTU	µS/cm	mg/L		mg/L
Terrys Ck	Site 1	spring 2005	6-7/09/05	300	**59**	**48**	10	90	140	43	6.5	187	140	**6.7**	8.10
Shrimptons Ck	Site 2	spring 2005	6-7/09/05	90	5	37	4	28	65	42	7	164	140	**6.7**	4.31
Porters Ck	Site 3	spring 2005	6-7/09/05	500	**110**	**58**	2	240	300	37	3	**6141**	4000	7.0	8.72
Buffalo Ck	Site 4	spring 2005	6-7/09/05	16	10	**50**	8	27	77	79	5.5	620	380	7.0	6.19
Archers Ck	Site 5	spring 2005	6-7/09/05	**2000**	17	26	11	56	82	56	10	245	160	6.8	5.56
Terrys Ck	Site 1	spring 2005	11-12/10/05	**2000**	10	33	10	52	85	47	2.2	245	180	7.1	4.49
Shrimptons Ck	Site 2	spring 2005	11-12/10/05	**32000**	16	36	10	54	90	43	3.9	246	150	7.2	3.26
Porters Ck	Site 3	spring 2005	11-12/10/05	**16000**	**54**	**51**	5	130	180	31	4.5	**3965**	2600	7.6	8.67
Buffalo Ck	Site 4	spring 2005	11-12/10/05	**6500**	**26**	**63**	20	70	130	44	29	472	210	7.6	9.16
Archers Ck	Site 5	spring 2005	11-12/10/05	**3800**	6	**54**	10	50	100	30	5.1	206	100	7.3	4.56
Terrys Ck	Site 1	spring 2005	2/11/05	380	<1	2	4	37	39	37	1	159	110	**6.5**	5.40
Shrimptons Ck	Site 2	spring 2005	2/11/05	500	6	19	6	45	64	50	6.1	226	150	**6.6**	5.24
Porters Ck	Site 3	spring 2005	2/11/05	260	**83**	**42**	<1	210	250	30	6.4	**5633**	3500	7.1	7.89
Buffalo Ck	Site 4	spring 2005	2/11/05	**2000**	5	28	5	35	63	60	4.1	299	200	7.0	5.65
Archers Ck	Site 5	spring 2005	2/11/05	640	6	18	4	56	74	79	12.6	350	210	6.9	5.58
Terrys Ck	Site 1	autumn 2005	30-31/03/05	**60000**	**590**	**170**	**100**	800	**970**	40	42	315	130	7.2	8.44
Shrimptons Ck	Site 2	autumn 2005	30-31/03/05	**3400**	20	**240**	40	280	**520**	52	9	305	170	**6.7**	4.46
Porters Ck	Site 3	autumn 2005	30-31/03/05	**1000**	**670**	**820**	40	1100	**1900**	99	18.9	1719	1100	7.3	7.61
Buffalo Ck	Site 4	autumn 2005	30-31/03/05	36	**130**	**290**	30	370	**660**	59	17.4	241	140	7.6	8.37
Archers Ck	Site 5	autumn 2005	30-31/03/05	360	20	**50**	60	350	400	68	22.2	183	180	7.1	7.49
Terrys Ck	Site 1	autumn 2005	26-27/04/05	90	**70**	**140**	40	300	440	62	1.7	264	180	**6.6**	6.60
Shrimptons Ck	Site 2	autumn 2005	26-27/04/05	940	**40**	**100**	30	270	370	65	3.2	236	160	**6.4**	5.73
Porters Ck	Site 3	autumn 2005	26-27/04/05	220	**400**	**590**	20	1100	**1700**	35	3.6	**2520**	1800	7.2	8.77
Buffalo Ck	Site 4	autumn 2005	26-27/04/05	520	**80**	**940**	40	.	**770**	95	7.6	548	390	**6.7**	5.4
Archers Ck	Site 5	autumn 2005	26-27/04/05	300	**40**	20	10	240	260	78	1.4	261	160	6.8	5.80
Terrys Ck	Site 1	autumn 2005	26-27/05/05	130	**40**	**110**	30	260	370	61	1.8	325	180	7.3	8.34
Shrimptons Ck	Site 2	autumn 2005	26-27/05/05	400	**40**	**290**	30	.	**560**	65	4.9	333	180	7.2	5.65
Porters Ck	Site 3	autumn 2005	26-27/05/05	59	**350**	**640**	20	1100	**1700**	30	1.5	**2305**	1500	7.8	10.02
Buffalo Ck	Site 4	autumn 2005	26-27/05/05	170	**90**	**350**	40	300	**650**	92	7.1	641	360	7.5	7.39
Archers Ck	Site 5	autumn 2005	26-27/05/05	360	**60**	**70**	20	310	380	99	3.3	376	200	7.4	8.14
Terrys Ck	Site 1	spring 2004	14-15/09/04	80	.	.	**110**	.	.	50	2.4	.	150	6.8	5.08
Shrimptons Ck	Site 2	spring 2004	14-15/09/04	880	.	.	**90**	.	.	58	3.1	.	140	6.8	2.20
Archers Ck	Site 5	spring 2004	14-15/09/04	650	.	.	**150**	.	.	70	0.6	.	110	7.0	6.53
Terrys Ck	Site 1	spring 2004	11-12/10/04	44	.	.	30	.	.	64	0.3	.	310	7.6	5.01
Shrimptons Ck	Site 2	spring 2004	11-12/10/04	110	.	.	**60**	.	.	76	0.5	.	260	7.4	5.69
Archers Ck	Site 5	spring 2004	11-12/10/04	**1500**	.	.	**50**	.	.	82	0.8	.	230	7.5	4.27
Terrys Ck	Site 1	spring 2004	23-24/11/04	150	.	.	40	.	.	56	2.6	.	180	**6.7**	6.90
Shrimptons Ck	Site 2	spring 2004	23-24/11/04	**1000**	.	.	**90**	.	.	75	11.5	.	190	**6.4**	2.93
Archers Ck	Site 5	spring 2004	23-24/11/04	**1700**	.	.	40	.	.	84	4.7	.	270	**6.6**	8.02

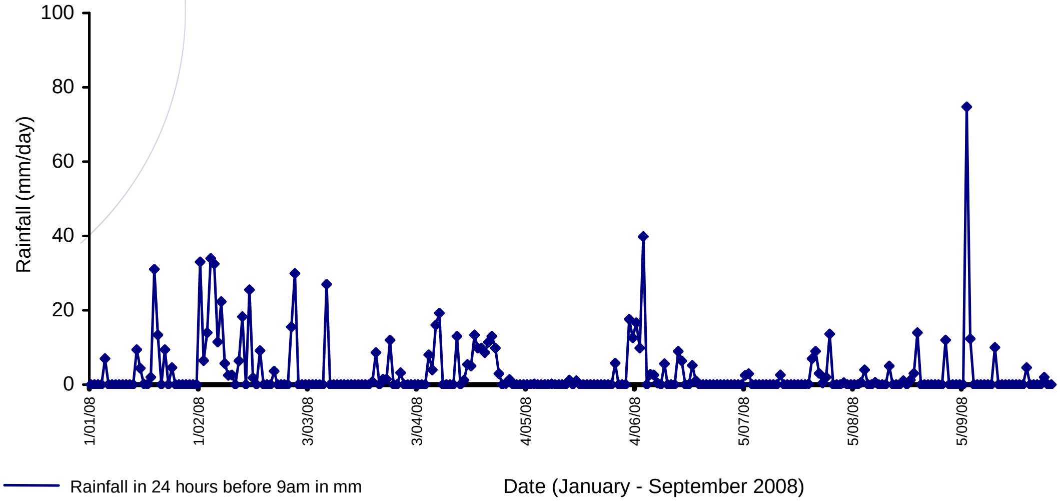
Appendix 3 Rainfall 2004 – 2008








Rainfall (mm/day)
100
80
60
40
20
0
1/01/07
1/02/07
4/03/07
4/04/07
5/05/07
5/06/07
6/07/07
6/08/07
6/09/07
7/10/07
7/11/07
8/12/07
Rainfall in 24 hours before 9am in mm
Date (January - December 2007)


Rainfall (mm/day)
100
80
60
40
20
0
1/01/08
1/02/08
3/03/08
3/04/08
4/05/08
4/06/08
5/07/08
5/08/08
5/09/08
Rainfall in 24 hours before 9am in mm
Date (January - September 2008)

Appendix 4 Macroinvertebrate results

			Archers Ck S5 spring 2004	Archers Ck S5 spring 2004	Archers Ck S5 spring 2004	Archers Ck S5 autumn 2005	Archers Ck S5 autumn 2005	Archers Ck S5 autumn 2005	Archers Ck S5 spring 2005	Archers Ck S5 spring 2005	Archers Ck S5 spring 2005	Archers Ck S5 autumn 2006	Archers Ck S5 autumn 2006	Archers Ck S5 autumn 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 spring 2006	Archers Ck S5 autumn 2007	Archers Ck S5 autumn 2007	Archers Ck S5 autumn 2007	Archers Ck S5 autumn 2007	Archers Ck S5 autumn 2007	Archers Ck S5 spring 2007	Archers Ck S5 spring 2007	Archers Ck S5 spring 2007	Archers Ck S5 spring 2007	Archers Ck S5 spring 2007	Archers Ck S5 spring 2007	Archers Ck S5 Autumn 2008	Archers Ck S5 Autumn 2008	Archers Ck S5 Autumn 2008	Archers Ck S5 Autumn 2008	Archers Ck S5 Autumn 2008	Archers Ck S5 Autumn 2008	Archers Ck S5 Spring 2008	Archers Ck S5 Spring 2008	Archers Ck S5 Spring 2008	Archers Ck S5 Spring 2008	Archers Ck S5 Spring 2008	Archers Ck S5 Spring 2008
Aquatic mites	Acarina	Acarina	1	3	1	3	3				1				1	3	1		4			1										3	9		1						1					
Beetles	Coleoptera	Dytiscidae		3		1	1		2		1																							1					1							
Beetles	Coleoptera	Elmidae																													2															
Beetles	Coleoptera	Hydraenidae													1						1																									
Beetles	Coleoptera	Hydrophilidae																				1																				1				
Beetles	Coleoptera	Psephenidae																																												
Beetles	Coleoptera	Scirtidae																																	1											
Caddisfly larvae	Trichoptera	Antipodoecidae																																												
Caddisfly larvae	Trichoptera	Hydroptilidae	2		3																1								12	3	9				8	2	6		2		18	3	5	14	19	6
Caddisfly larvae	Trichoptera	Leptoceridae		1																																	1									
Dobsonfly larvae	Megaloptera	Corydalidae																																												
Dragonfly larvae	Odonata	Aeshnidae	1	1		2		14	5	5			11	8												3	2	1	1									1	2							
Dragonfly larvae	Odonata	Coenagrionidae	7	5	5	6	3	29	21	7	4	1	7	6		1					5			1			2	1	1									2	4	3				1	2	
Dragonfly larvae	Odonata	Gomphidae																																												
Dragonfly larvae	Odonata	Hemicorduliidae	2	6	1	4	3	18	25			1	7	5				1			2	10	1			3	4		9	1	1	2	9								1		1		1	
Dragonfly larvae	Odonata	Isostictidae																																												
Dragonfly larvae	Odonata	Lestidae			3											1	1		2			3																							1	
Dragonfly larvae	Odonata	Libellulidae	2	4	5	3	9	8	1	15	14	7	2	4		1		1						6		2	2	4	2	1	2	2	1					4	3	1	1	1	1		1	
Dragonfly larvae	Odonata	Megapodagrionidae		2		15	22	5	6		1	2	7	5	1			1			1	6		1	2	7		1		2				1				1	1		1	1	2	1		
Dragonfly larvae	Odonata	Synthemistidae															1										1																			
Dragonfly larvae	Odonata	Telephlebiidae																																												
Fairy shrimps	Decapoda	Atyidae		1		6	11	17				5	1													11	1					2	1													
Flatworms	Turbellaria	Dugesiidae	2	3	1	3	15	7		1	2	1	4	4	9	7	3	10	16	11	9	2	2	5		10	8	1	17	3		18	12	7	2			3	3		15	7	7	5	10	7
Freshwater Sponge	Porifera	Spongillidae																																												
Lacewing	Neuroptera	Osmylidae																																												
Leeches	Arhynchobdellida	Erpobdellidae																																												
Leeches	Arhynchobdellida	Hirudinidae																																												
Leeches	Rhynchobdellida	Glossiphoniidae		1	4		1					6	6	2							1	1		1	3	1	1											2	1	2	3	3	1		1	1
Mayfly larvae	Ephemeroptera	Baetidae			1																			3		2							2					6	7	6						
Moth Larvae	Lepidoptera	Pyralidae																												2										1						
Mussels	Bivalvia	Corbiculidae		1	1			1		3	3																																			
Mussels	Bivalvia	Sphaeriidae		3																	1								12		1	9	13	1							1					
Proboscis Worms	Nemertea	Nemertea																																1												
Round Worms	Nematoda	Nematoda		1	1																									2																
Sand hoppers	Amphipoda	Ceinidae							2																										1											
Sand hoppers	Amphipoda	Talitridae																																												
Slatters	Isopoda	Oniscidae							7		1	3			1	4			1																		1									

			Archers Ck spring 2004 S5	Archers Ck spring 2004 S5	Archers Ck spring 2004 S5	Archers Ck autumn 2005 S5	Archers Ck autumn 2005 S5	Archers Ck autumn 2005 S5	Archers Ck spring 2005 S5	Archers Ck spring 2005 S5	Archers Ck spring 2005 S5	Archers Ck autumn 2006 S5	Archers Ck autumn 2006 S5	Archers Ck autumn 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck spring 2006 S5	Archers Ck autumn 2007 S5	Archers Ck autumn 2007 S5	Archers Ck autumn 2007 S5	Archers Ck autumn 2007 S5	Archers Ck autumn 2007 S5	Archers Ck spring 2007 S5	Archers Ck spring 2007 S5	Archers Ck spring 2007 S5	Archers Ck spring 2007 S5	Archers Ck spring 2007 S5	Archers Ck spring 2007 S5	Archers Ck Autumn 2008 S5	Archers Ck Autumn 2008 S5	Archers Ck Autumn 2008 S5	Archers Ck Autumn 2008 S5	Archers Ck Autumn 2008 S5	Archers Ck Autumn 2008 S5	Archers Ck Spring 2008 S5	Archers Ck Spring 2008 S5	Archers Ck Spring 2008 S5	Archers Ck Spring 2008 S5	Archers Ck Spring 2008 S5	Archers Ck Spring 2008 S5
Snails	Gastropoda	Ancylidae																													1			1					2	2	5	1	3	
Snails	Gastropoda	Hydrobiidae	1	3	2										2	4	1	1	3		7	11	10	5	1				13	12	7	1	11	8	8	13	7	5	8	1	6	2	14	4	10	4
Snails	Gastropoda	Lymnaeidae							1				1									1		1											1										1	
Snails	Gastropoda	Physidae	3	5	10	4	4	1	9	5	13	1	5		8	4	12	15	3	7	8	7	11	7	2	9	13	1	18	10	11	15	12	21	11	5		9	7	1	8	11	16	1	12	4
Snails	Gastropoda	Planorbidae																																												
Stonefly larvae	Plecoptera	Eustheniidae																																												
True bugs	Hemiptera	Belostomatidae																																												
True bugs	Hemiptera	Corixidae					1	10			1																						1	1												
True bugs	Hemiptera	Gelastocoridae													1				1																											
True bugs	Hemiptera	Gerridae									1	1		1																																
True bugs	Hemiptera	Hebridae																																												
True bugs	Hemiptera	Mesoveliidae																																												
True bugs	Hemiptera	Naucoridae																																												
True bugs	Hemiptera	Nepidae																																												
True bugs	Hemiptera	Notonectidae			2			11				2	1	4												2					1	7	12		2	1	9		2	11		2	2	13	1	9
True bugs	Hemiptera	Pleidae																																												
True bugs	Hemiptera	Saldidae																															1													
True bugs	Hemiptera	Veliidae	3	1		6	5	3			3	2	2	1	1		1		2	2	1		2		7	15	3			1					3	2	8	1	3	1	2		1	1		
True Fly larvae	Diptera	Bibionidae																			2																									
True Fly larvae	Diptera	Cecidomyiidae																																												
True Fly larvae	Diptera	Ceratopogonidae																																	4		3	2	3			1				
True Fly larvae	Diptera	Culicidae							17	1		1		1		1			11	6		14										4	3													
True Fly larvae	Diptera	Dixidae																																												
True Fly larvae	Diptera	Dolichopodidae																												1																
True Fly larvae	Diptera	Ephydridae																																												
True Fly larvae	Diptera	Muscidae																			1											1					1									
True Fly larvae	Diptera	Psychodidae																			1										1						1									
True Fly larvae	Diptera	s-f Chironominae	9	10	11	9	5	22	69	94	38	71	72	##	22	15	19	27	6	8	34	32	18	13	34	25	35	23	33	18	40	33	42	24	8	16	9	10	9	17	16	12	18	16	19	15
True Fly larvae	Diptera	s-f Orthocladiinae	1		10	1									7	1		1	2	1	6				3	1	1		3	9	5			1	20	23	22	10	32	14	2		5	16	16	11
True Fly larvae	Diptera	s-f Tanypodinae	1	6	3	1	1	1	7				3	10	2	1		1	1	1	2	2	2	1	1	2	3	1	10	5	1	1	2	5				2			4	1	1		6	1
True Fly larvae	Diptera	Simuliidae													1										1					2	1					1		3							2	
True Fly larvae	Diptera	Stratiomyidae	3	1		1	2	6	1			1		1		1	4		2	6			1	1							5		2	1	1	1	1	1			1		2		4	
True Fly larvae	Diptera	Syrphidae																				1																								
True Fly larvae	Diptera	Tipulidae	1	1										1				2					2								2			2	1	2		1	1		2		2	1		1
Worms	Oligochaeta	Oligochaeta	4	6	12	4	16	15	24	19	11	8	13	14	12	9	8	11	3	1	4	8	3	8	11		10	3	16	23	6	2	8	5	4	5	2	1	3	3	10	8	7	13	8	4
Yabbies	Decapoda	Parastacidae																																												
Yabbie cleaner	Temnocephala	Temnocephalidae																																												

			Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck
			S2 spring 2004	S2 spring 2004	S2 spring 2004	S2 autumn 2005	S2 autumn 2005	S2 autumn 2005	S2 spring 2005	S2 spring 2005	S2 spring 2005	S2 autumn 2006	S2 autumn 2006	S2 autumn 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 spring 2006	S2 autumn 2007	S2 autumn 2007	S2 autumn 2007	S2 autumn 2007	S2 autumn 2007	S2 autumn 2007	S2 spring 2007	S2 spring 2007	S2 spring 2007	S2 spring 2007	S2 spring 2007	S2 spring 2007	S2 Autumn 2008	S2 Autumn 2008	S2 Autumn 2008	S2 Autumn 2008	S2 Autumn 2008	S2 Autumn 2008	S2 Spring 2008	S2 Spring 2008	S2 Spring 2008	S2 Spring 2008	S2 Spring 2008	S2 Spring 2008
Aquatic mites	Acarina	Acarina	1		3	1			1		2	4	5	4		1		2	1	1	4	7	1	1	11	2	4	9	2		1		2	1		6		2		1	1	4		3	11	2	
Beetles	Coleoptera	Dytiscidae																				1																									
Beetles	Coleoptera	Elmidae																																													
Beetles	Coleoptera	Hydraenidae																																													
Beetles	Coleoptera	Hydrophilidae																																					1					1		
Beetles	Coleoptera	Psephenidae																																													
Beetles	Coleoptera	Scirtidae																																													
Caddisfly larvae	Trichoptera	Antipodoecidae																																													
Caddisfly larvae	Trichoptera	Hydroptilidae	2	3																										2	5	3												2	1	1	
Caddisfly larvae	Trichoptera	Leptoceridae			1																																										
Dobsonfly larvae	Megaloptera	Corydalidae																																													
Dragonfly larvae	Odonata	Aeshnidae																								2	4	1	2		1																
Dragonfly larvae	Odonata	Coenagrionidae	3	6		1		2	3			3	1			1		3			1			3	4	1	7	6	1	7	1	13	2	4	2	1	1	1	1			7	1	1	13	3	3
Dragonfly larvae	Odonata	Gomphidae	1																																												
Dragonfly larvae	Odonata	Hemicorduliidae	1	4	2		1					7	4	1		5	2	2	4		1	4			7	1	9	6	14	2		5	2	2	1	2		2	1			1			1		
Dragonfly larvae	Odonata	Isostictidae														1								1	3	3	1	5	7	4	1	8	6	4	1								1		1		
Dragonfly larvae	Odonata	Lestidae			1												1			8		2	3																								
Dragonfly larvae	Odonata	Libellulidae		3						2	4	1		1												1	1	2			2					1				4				1			
Dragonfly larvae	Odonata	Megapodagrionidae		2																		1	1	3	2	8	7	4	4	6	13	8	8			3	2	2		3		1		1			
Dragonfly larvae	Odonata	Synthemistidae																																													
Dragonfly larvae	Odonata	Telephlebiidae																								1																					
Fairy shrimps	Decapoda	Atyidae																																													
Flatworms	Turbellaria	Dugesiidae	2	4	9	14	19	11	14	12	10	7	8	9	4	1		2		8	3	2	2	4	4	4	7	11	1	7	9	13	5	1	1	8	13	17	13	9	17	10	11	4	12	9	5
Freshwater Sponge	Porifera	Spongillidae																																													
Lacewing	Neuroptera	Osmylidae																														1															
Leeches	Arhynchobdellida	Erpobdellidae						9																																							
Leeches	Arhynchobdellida	Hirudinidae																																													
Leeches	Rhynchobdellida	Glossiphoniidae				15	5	9	7	9	12	1	1										1	1												10	2	1			3		6	2	1		1
Mayfly larvae	Ephemeroptera	Baetidae																		1			1		1																						
Moth Larvae	Lepidoptera	Pyralidae																																													
Mussels	Bivalvia	Corbiculidae		4		9	3	10	6	4	12	9	6	3																																	
Mussels	Bivalvia	Sphaeriidae	2	3	10										1																	1		1		3					1		1	1	1	3	
Proboscis Worms	Nemertea	Nemertea																																													
Round Worms	Nematoda	Nematoda	1																																												
Sand hoppers	Amphipoda	Ceinidae																																													
Sand hoppers	Amphipoda	Talitridae																																													
Slatters	Isopoda	Oniscidae							2																1							1											1	1			

			Shrimptons Ck spring 2004 S2	Shrimptons Ck spring 2004 S2	Shrimptons Ck spring 2004 S2	Shrimptons Ck autumn 2005 S2	Shrimptons Ck autumn 2005 S2	Shrimptons Ck autumn 2005 S2	Shrimptons Ck spring 2005 S2	Shrimptons Ck spring 2005 S2	Shrimptons Ck spring 2005 S2	Shrimptons Ck autumn 2006 S2	Shrimptons Ck autumn 2006 S2	Shrimptons Ck autumn 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck spring 2006 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck autumn 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck spring 2007 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Autumn 2008 S2	Shrimptons Ck Spring 2008 S2	Shrimptons Ck Spring 2008 S2	Shrimptons Ck Spring 2008 S2	Shrimptons Ck Spring 2008 S2	Shrimptons Ck Spring 2008 S2	Shrimptons Ck Spring 2008 S2
Snails	Gastropoda	Ancylidae	1	1	1												1	1							1		1			3	2	2	2	5													
Snails	Gastropoda	Hydrobiidae		1							3					1		2					1									1		1								1	4			
Snails	Gastropoda	Lymnaeidae							1			1				1						1						1			1	1	1		1			1				1	1	1			
Snails	Gastropoda	Physidae	6	7	10	17	17	12	14	20	15	5	11	11	13	16	8	13	10	10	13	9	14		1	15	16	8	4	17	17	29	17	9	4	14	8	4	8	6	13	17	10	8	10	14	14
Snails	Gastropoda	Planorbidae	2	3	10	11	2	6	4	11	11	2			3	1	6	1	2											2				3			1						1				
Stonefly larvae	Plecoptera	Eustheniidae																																													
True bugs	Hemiptera	Belostomatidae																																													
True bugs	Hemiptera	Corixidae		3	2				2																1		1	1		1	4		5	2	1		1										
True bugs	Hemiptera	Gelastocoridae						1	1	2											1																										
True bugs	Hemiptera	Gerridae																							1	1			1							1											
True bugs	Hemiptera	Hebridae																																													
True bugs	Hemiptera	Mesoveliidae																								1																					
True bugs	Hemiptera	Naucoridae																																													
True bugs	Hemiptera	Nepidae																									1					1															
True bugs	Hemiptera	Notonectidae															2	2	1	4	2	1	1	2	5	1		2		1			1	1	1	5		3				4			14	1	
True bugs	Hemiptera	Pleidae										1																																			
True bugs	Hemiptera	Saldidae																																													
True bugs	Hemiptera	Veliidae																		1					1	11	4							2													
True Fly larvae	Diptera	Bibionidae																																													
True Fly larvae	Diptera	Cecidomyiidae																																													
True Fly larvae	Diptera	Ceratopogonidae	1												1																								1								
True Fly larvae	Diptera	Culicidae														2					8													1													
True Fly larvae	Diptera	Dixidae																																													
True Fly larvae	Diptera	Dolichopodidae																																													
True Fly larvae	Diptera	Ephydridae																																													
True Fly larvae	Diptera	Muscidae																																4													
True Fly larvae	Diptera	Psychodidae																																													
True Fly larvae	Diptera	s-f Chironominae	12	11	10		1		5	10	15		2	3	21	25	21	20	32	18	18	26	12	8	4	5	17	2	26	30	27	50	7	12	11				1			5	2	6	5	6	12
True Fly larvae	Diptera	s-f Orthocladiinae					1									1							1												1		1				1						
True Fly larvae	Diptera	s-f Tanypodinae														1		1			2		1			1		1			1	1	2	5			1										1
True Fly larvae	Diptera	Simuliidae																																													
True Fly larvae	Diptera	Stratiomyidae		1		1		4	1							1	1			1			1										1												1		
True Fly larvae	Diptera	Syrphidae																																													
True Fly larvae	Diptera	Tipulidae																																													
Worms	Oligochaeta	Oligochaeta	7	6	12	10	9	17	16	13	17	13	11	17	10	4	8	1	8	10	3	3		7	5	4	1		6	12	2	5	5	5	3	3	5	2	4		3	1	6	2	2	8	9
Yabbies	Decapoda	Parastacidae										1			2								1			2	1	3				1					1										
Yabbie cleaner	Temnocephala	Temnocephalidae																								1																					

			autumn 2005 Porters Ck S3	autumn 2005 Porters Ck S3	autumn 2005 Porters Ck S3	spring 2005 Porters Ck S3	spring 2005 Porters Ck S3	spring 2005 Porters Ck S3	autumn 2006 Porters Ck S3	autumn 2006 Porters Ck S3	autumn 2006 Porters Ck S3	autumn 2007 Porters Ck S3	autumn 2007 Porters Ck S3	autumn 2007 Porters Ck S3	autumn 2007 Porters Ck S3	autumn 2007 Porters Ck S3	autumn 2007 Porters Ck S3	spring 2007 Porters Ck S3	spring 2007 Porters Ck S3	spring 2007 Porters Ck S3	spring 2007 Porters Ck S3	spring 2007 Porters Ck S3	spring 2007 Porters Ck S3	Autumn 2008 Porters Ck S3	Autumn 2008 Porters Ck S3	Autumn 2008 Porters Ck S3	Autumn 2008 Porters Ck S3	Autumn 2008 Porters Ck S3	Autumn 2008 Porters Ck S3	Spring 2008 Porters Ck S3	Spring 2008 Porters Ck S3	Spring 2008 Porters Ck S3	Spring 2008 Porters Ck S3	Spring 2008 Porters Ck S3	Spring 2008 Porters Ck S3
Aquatic mites	Acarina	Acarina	1					1		1				1		1																			
Beetles	Coleoptera	Dytiscidae				1	1	2							2	1								2	1	4									
Beetles	Coleoptera	Elmidae																																	
Beetles	Coleoptera	Hydraenidae																																	
Beetles	Coleoptera	Hydrophilidae													3											1									
Beetles	Coleoptera	Psephenidae							1																										
Beetles	Coleoptera	Scirtidae			1										1							1													
Caddisfly larvae	Trichoptera	Antipodoecidae										1														1									
Caddisfly larvae	Trichoptera	Hydroptilidae										3	3	7	4	5	1			1			1										2	3	
Caddisfly larvae	Trichoptera	Leptoceridae	1		1				1	1			3	4		3	1																		
Dobsonfly larvae	Megaloptera	Corydalidae																																	
Dragonfly larvae	Odonata	Aeshnidae	2	2	2	1			3	5	7		2																						
Dragonfly larvae	Odonata	Coenagrionidae	3	10	13	9		2	15	7	12	8	12	2	10	5	7	1	3	1		1		1				2	2				1		
Dragonfly larvae	Odonata	Gomphidae				1																													
Dragonfly larvae	Odonata	Hemicorduliidae	9	8	8	11			5	5	13	10	6	2	9	3	6		2								2		2					1	
Dragonfly larvae	Odonata	Isostictidae	21	19	13	9	5	7	18	7	7	8	6	2	13	13	8	1	8	3	3	2						2	2						2
Dragonfly larvae	Odonata	Lestidae																																	
Dragonfly larvae	Odonata	Libellulidae	1	3	4	2	5	9	5	1	3	5	9	4	6	5	1		1				1	1			1								
Dragonfly larvae	Odonata	Megapodagrionidae	6	14	8	4		2	10	7	26	8	7	2	5	11	5	4	13	10	1	4	8	2	5	3	12	2	10	2	2	1	3	1	
Dragonfly larvae	Odonata	Synthemistidae																																	
Dragonfly larvae	Odonata	Telephlebiidae																																	
Fairy shrimps	Decapoda	Atyidae	5				2		5	5	14	10	8	3	1	10	1									1									
Flatworms	Turbellaria	Dugesiidae	5	3		2						3	2	2					2			1		5	2	1			5				1	3	3
Freshwater Sponge	Porifera	Spongillidae																																	
Lacewing	Neuroptera	Osmylidae																																	
Leeches	Arhynchobdellida	Erpobdellidae				2	2	1						2																					
Leeches	Arhynchobdellida	Hirudinidae																										1							
Leeches	Rhynchobdellida	Glossiphoniidae	2	7	5	3	4	5	8	16	3	2	3		1		2											1	1						
Mayfly larvae	Ephemeroptera	Baetidae	1																																
Moth Larvae	Lepidoptera	Pyralidae																																	
Mussels	Bivalvia	Corbiculidae		4	2																														
Mussels	Bivalvia	Sphaeriidae														1													1			3	1		
Proboscis Worms	Nemertea	Nemertea											1																						
Round Worms	Nematoda	Nematoda																														2			
Sand hoppers	Amphipoda	Ceinidae				3	1																												
Sand hoppers	Amphipoda	Talitridae									1																	1							
Slatters	Isopoda	Oniscidae				1																4													1

			S3 autumn 2005 Porters Ck	S3 autumn 2005 Porters Ck	S3 autumn 2005 Porters Ck	S3 spring 2005 Porters Ck	S3 spring 2005 Porters Ck	S3 spring 2005 Porters Ck	S3 autumn 2006 Porters Ck	S3 autumn 2006 Porters Ck	S3 autumn 2006 Porters Ck	S3 autumn 2007 Porters Ck	S3 autumn 2007 Porters Ck	S3 autumn 2007 Porters Ck	S3 autumn 2007 Porters Ck	S3 autumn 2007 Porters Ck	S3 autumn 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 spring 2007 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Autumn 2008 Porters Ck	S3 Spring 2008 Porters Ck	S3 Spring 2008 Porters Ck	S3 Spring 2008 Porters Ck	S3 Spring 2008 Porters Ck	S3 Spring 2008 Porters Ck	S3 Spring 2008 Porters Ck
Snails	Gastropoda	Ancylidae	1										1			1				3	1		7		1			1						3	2
Snails	Gastropoda	Hydrobiidae	30	22	13	23	13	34	23	10	18	15	33	15	26	18	30	9	18	21	4	28	11	10	8	8	12	7	14	2	1	10		15	15
Snails	Gastropoda	Lymnaeidae																1				1								1			1		
Snails	Gastropoda	Physidae	12	10	7	4	8	7	2	7	3	10	8	6	5	4	9	3	10	14	11	6	6	3	5	5			1	8	6	5	15	17	4
Snails	Gastropoda	Planorbidae	4	6	6		2	2		2	2				2				1		1	1	3		1	1	1			1		1	1	1	4
Stonefly larvae	Plecoptera	Eustheniidae							1																										
True bugs	Hemiptera	Belostomatidae																																	
True bugs	Hemiptera	Corixidae				1	2	9																		1	1							1	
True bugs	Hemiptera	Gelastocoridae																																	
True bugs	Hemiptera	Gerridae								1						1																		1	
True bugs	Hemiptera	Hebridae																																	
True bugs	Hemiptera	Mesoveliidae																																	
True bugs	Hemiptera	Naucoridae																																	
True bugs	Hemiptera	Nepidae				1																													
True bugs	Hemiptera	Notonectidae	2		2	1			4	8		7	8	4	4	9	11				1	2		4	7	10	2	1	1	1		2	4	3	2
True bugs	Hemiptera	Pleidae																																	
True bugs	Hemiptera	Saldidae																																	
True bugs	Hemiptera	Veliidae		3							2																				1				
True Fly larvae	Diptera	Bibionidae																																	
True Fly larvae	Diptera	Cecidomyiidae																										1							
True Fly larvae	Diptera	Ceratopogonidae																																	
True Fly larvae	Diptera	Culicidae				1						1			2											1		1							
True Fly larvae	Diptera	Dixidae																																	
True Fly larvae	Diptera	Dolichopodidae																																	
True Fly larvae	Diptera	Ephydridae																																	
True Fly larvae	Diptera	Muscidae																																	
True Fly larvae	Diptera	Psychodidae													1										1			1							
True Fly larvae	Diptera	s-f Chironominae	34	48	46	77	132	100		10	7	3	14	6	4	17	7	22	22	18	27	20	25	10	13	14	15	16	18	17	10	15		18	
True Fly larvae	Diptera	s-f Orthocladiinae	7	1					1			6	7	5	1	4								6	19	13	1	2	1		1	2	3		
True Fly larvae	Diptera	s-f Tanypodinae	4	2	14					18	11	3	4	5		4		1			1		2			1			1				15		12
True Fly larvae	Diptera	Simuliidae																						1											
True Fly larvae	Diptera	Stratiomyidae		2		1							1		1	1	1	1	3				1	1	4	3		5	3			3		1	
True Fly larvae	Diptera	Syrphidae																																	
True Fly larvae	Diptera	Tipulidae																1	1			1		1		1									
Worms	Oligochaeta	Oligochaeta	3	6	10	10	5	7	6	6	8		3	7	7			8	17	15	2	3	5	2	4	7			4	4	7	4	6	11	1
Yabbies	Decapoda	Parastacidae																																	
Yabbie cleaner	Temnocephala	Temnocephalidae																																	

			Buffalo Ck autumn 2005 S4	Buffalo Ck autumn 2005 S4	Buffalo Ck autumn 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4
Aquatic mites	Acarina	Acarina	2	2	1	6	1	1											1					1											
Beetles	Coleoptera	Dytiscidae					2																												
Beetles	Coleoptera	Elmidae																																	
Beetles	Coleoptera	Hydraenidae																															1		
Beetles	Coleoptera	Hydrophilidae	1		1					1										1					1										
Beetles	Coleoptera	Psephenidae																																	
Beetles	Coleoptera	Scirtidae		1																															
Caddisfly larvae	Trichoptera	Antipodoecidae																																	
Caddisfly larvae	Trichoptera	Hydroptilidae			3							8	3	6	2	3	2		2	2		1			2	7	12	9	11			3			
Caddisfly larvae	Trichoptera	Leptoceridae										1																							
Dobsonfly larvae	Megaloptera	Corydalidae																																	
Dragonfly larvae	Odonata	Aeshnidae	3	1	1			1	3	6	3		2	6	5	4	3							2	3	1	2								
Dragonfly larvae	Odonata	Coenagrionidae	5	8	15				5	6	12	1		4	9	2	4	2	2	5	1				3			1	2						
Dragonfly larvae	Odonata	Gomphidae																																	
Dragonfly larvae	Odonata	Hemicorduliidae	1	16	19	7			13	4	2	1	5	10	6	8	10			2	1	1	4	1	1	1			1						
Dragonfly larvae	Odonata	Isostictidae		1	2	1			2		2	1	1	2	3	6	5	3		8	5		5		2	1		2				1			
Dragonfly larvae	Odonata	Lestidae																																	
Dragonfly larvae	Odonata	Libellulidae		5	2	2	1	13	13	10	4	2		7	3	7		2							2		1		1						
Dragonfly larvae	Odonata	Megapodagrionidae	9	21	19	20		3	9	2	8	2	3	5	5	9	3	1	1	9	10	2	5	8	9	7	9	3	3	1	1	2	3	4	
Dragonfly larvae	Odonata	Synthemistidae		1																															
Dragonfly larvae	Odonata	Telephlebiidae											1																						
Fairy shrimps	Decapoda	Atyidae																																	
Flatworms	Turbellaria	Dugesiidae	4	6	5	3	2	6	3	4	3			3	8	4	4				2	4		5	5	4	6	2	5			2	3		
Freshwater Sponge	Porifera	Spongillidae																																	
Lacewing	Neuroptera	Osmylidae																																	
Leeches	Arhynchobdellida	Erpobdellidae			1																														
Leeches	Arhynchobdellida	Hirudinidae																																	
Leeches	Rhynchobdellida	Glossiphoniidae	2	1	2				4	9		1			2																				
Mayfly larvae	Ephemeroptera	Baetidae								4		14	8	13												1									
Moth Larvae	Lepidoptera	Pyralidae																																	
Mussels	Bivalvia	Corbiculidae	3	8	7	5	1	11	4	6	7																								
Mussels	Bivalvia	Sphaeriidae										1		1		3	9				1		2						1				9	1	
Proboscis Worms	Nemertea	Nemertea																																	
Round Worms	Nematoda	Nematoda													1																				
Sand hoppers	Amphipoda	Ceinidae		1	2	2	8																												
Sand hoppers	Amphipoda	Talitridae								1																									
Slatters	Isopoda	Oniscidae				3	4	2	1																1								1		

			Buffalo Ck autumn 2005 S4	Buffalo Ck autumn 2005 S4	Buffalo Ck autumn 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck spring 2005 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2006 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck autumn 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck spring 2007 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Autumn 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4	Buffalo Ck Spring 2008 S4
Snails	Gastropoda	Ancylidae																				1									1			
Snails	Gastropoda	Hydrobiidae	6	4	18	11	13	7	2			9	12	4	4	2	10	7	10	6	3	5	9		7	10	14	17	4	5	14	6	12	6	19
Snails	Gastropoda	Lymnaeidae							1		1	1	1	4	3	6	2			4	2				1	3	1					1	2		
Snails	Gastropoda	Physidae	4	1	6	7	12	24	8	7	5	14	1	7	15	18	15	12	12	18	14	18	19	7	18	26	2	2	15	5	12	25	16	16	14
Snails	Gastropoda	Planorbidae	2	2	3			1				3			4	8	2	1	1	6		2		5	9	3			1	1			5	1	1
Stonefly larvae	Plecoptera	Eustheniidae																																	
True bugs	Hemiptera	Belostomatidae																																	
True bugs	Hemiptera	Corixidae	1				1								1																				
True bugs	Hemiptera	Gelastocoridae												1							1	1			1										
True bugs	Hemiptera	Gerridae							1	1		1			1		1							1		3									
True bugs	Hemiptera	Hebridae																							1										
True bugs	Hemiptera	Mesoveliidae								1				1																					
True bugs	Hemiptera	Naucoridae																																	
True bugs	Hemiptera	Nepidae																																	
True bugs	Hemiptera	Notonectidae	11	10	10	4	4	1	14	10	14	10	10	11	7	13	12	4	1	2	1	3	2	13	5	14	9	12	7	1	1	1			
True bugs	Hemiptera	Pleidae																					1												
True bugs	Hemiptera	Saldidae																																	
True bugs	Hemiptera	Veliidae												1					1			1			2	2	1						1		
True Fly larvae	Diptera	Bibionidae																																	
True Fly larvae	Diptera	Cecidomyiidae																																	
True Fly larvae	Diptera	Ceratopogonidae			1						2	1								1															
True Fly larvae	Diptera	Culicidae		1			5			1	2								2																
True Fly larvae	Diptera	Dixidae																																	
True Fly larvae	Diptera	Dolichopodidae																																	
True Fly larvae	Diptera	Ephydridae																																	
True Fly larvae	Diptera	Muscidae																																	
True Fly larvae	Diptera	Psychodidae																																	
True Fly larvae	Diptera	s-f Chironominae	9	13	36	26	31	74	78	46	56	14	29	16	20	10	23	51	28	19	9	19	13	8	10	18	17	7	23	6	5	25	18	11	25
True Fly larvae	Diptera	s-f Orthocladiinae	2						2	4	2	2			1										4	5	15	4	18						
True Fly larvae	Diptera	s-f Tanypodinae	2	2	7	2					4	1	6	3	5	2	2		1	4		2	2				3	3							
True Fly larvae	Diptera	Simuliidae					1																												
True Fly larvae	Diptera	Stratiomyidae	2	1	3	1			1	1	5	3		1	2	1	1			1						1	1	2							
True Fly larvae	Diptera	Syrphidae	1																																
True Fly larvae	Diptera	Tipulidae	1																																
Worms	Oligochaeta	Oligochaeta	11	11	9	32	17	18	8	3	10		2		2	9	3	4	1	1	4	2	7		3		4	1	1	1	1	1	10		2
Yabbies	Decapoda	Parastacidae																																	
Yabbie cleaner	Temnocephala	Temnocephalidae																																	

			Terrys Ck spring 2004 S1	Terrys Ck spring 2004 S1	Terrys Ck spring 2004 S1	Terrys Ck autumn 2005 S1	Terrys Ck autumn 2005 S1	Terrys Ck autumn 2005 S1	Terrys Ck spring 2005 S1	Terrys Ck spring 2005 S1	Terrys Ck spring 2005 S1	Terrys Ck autumn 2006 S1	Terrys Ck autumn 2006 S1	Terrys Ck autumn 2006 S1	Terrys Ck autumn 2007 S1	Terrys Ck autumn 2007 S1	Terrys Ck autumn 2007 S1	Terrys Ck autumn 2007 S1	Terrys Ck autumn 2007 S1	Terrys Ck autumn 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck spring 2007 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Autumn 2008 S1	Terrys Ck Spring 2008 S1	Terrys Ck Spring 2008 S1	Terrys Ck Spring 2008 S1	Terrys Ck Spring 2008 S1	Terrys Ck Spring 2008 S1	Terrys Ck Spring 2008 S1
Aquatic mites	Acarina	Acarina				2		1	1	7	4	2	3	2	1	2		2		1			2		5													2
Beetles	Coleoptera	Dytiscidae								1																					1							
Beetles	Coleoptera	Elmidae	1		3	6	1				3	4	1			4				2			1		1		2		1								1	
Beetles	Coleoptera	Hydraenidae																1									1											
Beetles	Coleoptera	Hydrophilidae																																	1			
Beetles	Coleoptera	Psephenidae																																				
Beetles	Coleoptera	Scirtidae	1					1										1		1																		
Caddisfly larvae	Trichoptera	Antipodoecidae																																				
Caddisfly larvae	Trichoptera	Hydroptilidae		1								1			1										4												1	
Caddisfly larvae	Trichoptera	Leptoceridae																																				
Dobsonfly larvae	Megaloptera	Corydalidae										1																										
Dragonfly larvae	Odonata	Aeshnidae				1					1	1				1			2																	1		
Dragonfly larvae	Odonata	Coenagrionidae	1	1	3		3	4			7	7	5	2	5	1		3		2	1	1	1						1									
Dragonfly larvae	Odonata	Gomphidae	1																																			
Dragonfly larvae	Odonata	Hemicorduliidae	2	4	7	2	6	20	21			17	16	26	3	2		5	5	6	3	1		1	10	5						2			1			
Dragonfly larvae	Odonata	Isostictidae			2	6	8	6	8	5	7	4	2	4	3	2	1	10		1					2	5			6	1	1	5			2	2		3
Dragonfly larvae	Odonata	Lestidae							6																													
Dragonfly larvae	Odonata	Libellulidae								14	13	2	1	4	1		2		2	4					1	1	1		1									
Dragonfly larvae	Odonata	Megapodagrionidae	6	10	12	16	26	14	11	8	7	42	17	18	18	11	6	8	16	16	16	9	3	8	8	12	12	7	10	8	13	6	8	11	6	19	10	5
Dragonfly larvae	Odonata	Synthemistidae																												1								
Dragonfly larvae	Odonata	Telephlebiidae																												1								
Fairy shrimps	Decapoda	Atyidae			1																																	
Flatworms	Turbellaria	Dugesiidae	1	3	3	6	14	4	2	2	3	10	2	11	3	2	10	9	8	12	10	14	1	8	2	6	5	2	3	2	3	2	2	1	4		2	5
Freshwater Sponge	Porifera	Spongillidae																																			1	
Lacewing	Neuroptera	Osmylidae																																				
Leeches	Arhynchobdellida	Erpobdellidae																																				
Leeches	Arhynchobdellida	Hirudinidae														1																						
Leeches	Rhynchobdellida	Glossiphoniidae				3	2	1		1	1	2	2		1	1			1											1		1	1					
Mayfly larvae	Ephemeroptera	Baetidae														1	1																					
Moth Larvae	Lepidoptera	Pyralidae																			1																	
Mussels	Bivalvia	Corbiculidae		5	1	3	5	10	2	9	3	9		8																								
Mussels	Bivalvia	Sphaeriidae	4	1	3											4		2	4				4	1	3	4	4						3		1	1	2	12
Proboscis Worms	Nemertea	Nemertea															1																					
Round Worms	Nematoda	Nematoda																																				
Sand hoppers	Amphipoda	Ceinidae				3		1	1	3																												
Sand hoppers	Amphipoda	Talitridae											1	2		1				1					1					1	1		1					1
Slatters	Isopoda	Oniscidae							1																												1	

			Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck
			spring 2004	spring 2004	spring 2004	autumn 2005	autumn 2005	autumn 2005	spring 2005	spring 2005	spring 2005	autumn 2006	autumn 2006	autumn 2006	autumn 2007	autumn 2007	autumn 2007	autumn 2007	autumn 2007	autumn 2007	spring 2007	spring 2007	spring 2007	spring 2007	spring 2007	spring 2007	Autumn 2008	Autumn 2008	Autumn 2008	Autumn 2008	Autumn 2008	Autumn 2008	Spring 2008	Spring 2008	Spring 2008	Spring 2008	Spring 2008	Spring 2008
			S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Snails	Gastropoda	Ancylidae			1																				1								3	1		1		
Snails	Gastropoda	Hydrobiidae	4	7	6	11	10	13		14	11	25	4	14	26	8	10	18	34	12	15	21	17	7	6	13	9	11	8	13	17	17	22	14	13	9	10	12
Snails	Gastropoda	Lymnaeidae	1						5	3		1					1																		1			
Snails	Gastropoda	Physidae	4	4	6	3	8	8	12	11	7	1	9	9	6	1	4	13	10	11	8	6	2	12	7	7	7	4	8	2	9	5	14	4	14	10	10	11
Snails	Gastropoda	Planorbidae		1	5	2	4	4	1		4	2			1			1	1	5		1		1	3	2	1		1								1	2
Stonefly larvae	Plecoptera	Eustheniidae																																				
True bugs	Hemiptera	Belostomatidae	1																																			
True bugs	Hemiptera	Corixidae									5																											
True bugs	Hemiptera	Gelastocoridae						1							1							1															1	1
True bugs	Hemiptera	Gerridae		1				2		1	2	3	3	3				4	2										1			1						
True bugs	Hemiptera	Hebridae																																				
True bugs	Hemiptera	Mesoveliidae																																				
True bugs	Hemiptera	Naucoridae			1		1																															
True bugs	Hemiptera	Nepidae																1																				
True bugs	Hemiptera	Notonectidae			3	11	2	7	4	1	2	5	6	4	3	4	7	11	3	3							4	4	7	6	7	4			2			
True bugs	Hemiptera	Pleidae																																				
True bugs	Hemiptera	Saldidae																																				
True bugs	Hemiptera	Veliidae						3			1	4	1			1	2				1			5							2	1			1	3		
True Fly larvae	Diptera	Bibionidae																																				
True Fly larvae	Diptera	Cecidomyiidae																																				
True Fly larvae	Diptera	Ceratopogonidae						1		2																						1	1			6		
True Fly larvae	Diptera	Culicidae								3			1											9	4													
True Fly larvae	Diptera	Dixidae																							1													
True Fly larvae	Diptera	Dolichopodidae																																				
True Fly larvae	Diptera	Ephydridae																							1													
True Fly larvae	Diptera	Muscidae																																				
True Fly larvae	Diptera	Psychodidae																																				
True Fly larvae	Diptera	s-f Chironominae	8	11	11	3	17	28	33	32	30	2	19	5	8	15	13	9	13	5	41	16	33	17	18	17	5		2	1	3	3	14	19	15		9	6
True Fly larvae	Diptera	s-f Orthocladiinae	2		2	2		1					1		7	5	2			2	1				2		1		1								2	
True Fly larvae	Diptera	s-f Tanypodinae		2	1	3	4	21	11	6	1	1	9	11	14	1	5	8	1	3	1	4	1		1	1	5		2	1			4		1	11	2	
True Fly larvae	Diptera	Simuliidae							1		1					3		3			1		1															
True Fly larvae	Diptera	Stratiomyidae	1			1	2			1		5				1		3	1	1			1					1	2		1		1		1			
True Fly larvae	Diptera	Syrphidae																																				
True Fly larvae	Diptera	Tipulidae				4																		1	1				1									
Worms	Oligochaeta	Oligochaeta	7	10	7	4	15	8	9	15	7	18	14	17	4	8	4	4	1	3	8	8	4	4		2	4	1	3	3	3		7	4	1	3	3	11
Yabbies	Decapoda	Parastacidae																																				
Yabbie cleaner	Temnocephala	Temnocephalidae																																				

Appendix 5 SIMPER output

SIMPER all five creeks reps merged 2005, 2006, 2007 and 2008

```
Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample                                   Creek
S5  Archers Ck
S4  Buffalo Ck
S3  Porters Ck
S2  Shrimptons Ck
S1  Terrys Ck


Group Archers Ck
Average similarity: 56.25

Species                                Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae           9.35      8.64     2.46      15.36    15.36
Snails Physidae                            5.97      5.68     2.75      10.10    25.46
Worms Oligochaeta                          5.35      5.36     2.00       9.53    35.00
Flatworms Dugesiidae                       4.69      3.90     2.00       6.94    41.93
True Fly larvae s-f Tanypodinae            3.05      3.08     2.83       5.47    47.41
Dragonfly larvae Coenagrionidae            3.27      2.92     1.72       5.20    52.60
Dragonfly larvae Megapodagrionidae         3.07      2.88     2.65       5.12    57.72
Dragonfly larvae Hemicorduliidae           3.19      2.79     1.26       4.97    62.69
True bugs Veliidae                         2.99      2.63     2.34       4.67    67.37
Dragonfly larvae Libellulidae              2.49      2.43     2.99       4.32    71.69
True Fly larvae Stratiomyidae              2.33      2.25     3.22       4.01    75.69
True bugs Notonectidae                     2.37      1.48     0.86       2.63    78.32
True Fly larvae s-f Orthocladiinae         3.12      1.40     0.88       2.48    80.80
Snails Hydrobiidae                         3.05      1.39     0.62       2.48    83.28
Leeches Glossiphoniidae                    1.80      1.20     0.87       2.13    85.42
Dragonfly larvae Aeshnidae                 1.89      1.16     0.78       2.07    87.49
True Fly larvae Culicidae                  2.05      1.04     0.66       1.85    89.33
Aquatic mites Acarina                      1.24      0.74     0.95       1.32    90.65


Group Buffalo Ck
Average similarity: 57.09

Species                                Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae           8.26      8.07     2.33      14.13    14.13
Dragonfly larvae Megapodagrionidae         5.17      5.94     9.03      10.41    24.53
Worms Oligochaeta                          4.80      5.29     4.49       9.26    33.80
Snails Hydrobiidae                         5.11      4.94     1.61       8.65    42.44
Snails Physidae                            5.09      4.41     1.20       7.73    50.17
True bugs Notonectidae                     4.35      3.93     2.78       6.88    57.05
Flatworms Dugesiidae                       3.20      3.10     2.57       5.43    62.48
Dragonfly larvae Hemicorduliidae           2.83      2.18     1.35       3.82    66.30
Dragonfly larvae Libellulidae              2.80      2.11     1.22       3.70    69.99
Dragonfly larvae Isostictidae              2.40      2.05     2.35       3.59    73.59
True Fly larvae s-f Tanypodinae            2.36      1.88     1.39       3.30    76.88
Snails Planorbidae                         2.26      1.69     1.08       2.97    79.85
Caddisfly larvae Hydroptilidae             2.43      1.34     0.84       2.34    82.20
True Fly larvae Stratiomyidae              1.70      1.33     1.25       2.33    84.52
Snails Lymnaeidae                          1.71      1.18     0.90       2.06    86.58
Dragonfly larvae Coenagrionidae            2.14      1.06     0.69       1.85    88.44
Dragonfly larvae Aeshnidae                 1.56      0.91     0.80       1.60    90.03
```

```
Group Porters Ck
Average similarity: 58.42

Species                                Av.Abund    Av.Sim    Sim/SD    Contrib%    Cum.%
Snails Hydrobiidae                         7.62      7.95      2.78       13.62    13.62
True Fly larvae s-f Chironominae           7.45      7.07      2.04       12.11    25.73
Snails Physidae                            4.73      4.82      3.45        8.25    33.97
Dragonfly larvae Megapodagrionidae         4.47      4.33      2.79        7.41    41.39
Worms Oligochaeta                          3.81      3.95      2.27        6.77    48.16
Dragonfly larvae Isostictidae              3.90      3.55      1.82        6.08    54.24
Dragonfly larvae Coenagrionidae            3.80      3.28      2.08        5.62    59.86
True bugs Notonectidae                     3.32      2.81      2.12        4.82    64.67
Dragonfly larvae Hemicorduliidae           3.36      2.81      1.87        4.81    69.48
Snails Planorbidae                         2.35      2.56      3.24        4.38    73.86
True Fly larvae s-f Tanypodinae            2.77      2.00      1.04        3.43    77.29
Flatworms Dugesiidae                       2.12      1.90      1.42        3.25    80.53
Dragonfly larvae Libellulidae              2.06      1.66      1.28        2.85    83.38
Leeches Glossiphoniidae                    2.38      1.48      0.81        2.53    85.91
True Fly larvae Stratiomyidae              1.81      1.47      1.32        2.51    88.43
True Fly larvae s-f Orthocladiinae         2.51      1.26      0.78        2.15    90.58


Group Shrimptons Ck
Average similarity: 56.84

Species                                Av.Abund    Av.Sim    Sim/SD    Contrib%    Cum.%
Snails Physidae                            6.88     10.12      3.58       17.80    17.80
Flatworms Dugesiidae                       6.21      9.45      4.30       16.62    34.42
Worms Oligochaeta                          5.74      8.92      4.07       15.70    50.12
True Fly larvae s-f Chironominae           5.68      4.18      1.20        7.35    57.47
Dragonfly larvae Coenagrionidae            3.13      3.69      3.07        6.50    63.97
Aquatic mites Acarina                      2.53      2.66      1.99        4.68    68.64
Dragonfly larvae Hemicorduliidae           2.74      2.54      1.26        4.46    73.11
Leeches Glossiphoniidae                    2.39      2.24      0.84        3.94    77.05
Snails Planorbidae                         2.34      2.20      1.06        3.87    80.92
Snails Lymnaeidae                          1.14      1.33      1.61        2.34    83.26
Dragonfly larvae Libellulidae              1.31      1.31      0.94        2.31    85.57
True bugs Notonectidae                     1.72      1.05      0.61        1.85    87.42
Mussels Corbiculidae                       1.70      1.04      0.34        1.83    89.25
Dragonfly larvae Megapodagrionidae         1.88      0.83      0.58        1.46    90.70


Group Terrys Ck
Average similarity: 67.63

Species                                Av.Abund    Av.Sim    Sim/SD    Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae         7.52      8.41      5.34       12.43    12.43
True Fly larvae s-f Chironominae           7.62      7.22      3.33       10.67    23.10
Worms Oligochaeta                          5.27      5.76      7.29        8.51    31.61
Snails Hydrobiidae                         6.00      5.67      2.79        8.39    40.00
Snails Physidae                            5.36      5.07      2.30        7.50    47.51
Flatworms Dugesiidae                       4.75      4.73      4.20        6.99    54.50
True Fly larvae s-f Tanypodinae            4.24      4.35      4.62        6.44    60.93
Dragonfly larvae Hemicorduliidae           3.71      2.66      1.46        3.93    64.86
Dragonfly larvae Isostictidae              2.41      2.07      2.18        3.07    67.93
True bugs Notonectidae                     2.94      1.95      1.11        2.89    70.81
True bugs Veliidae                         1.84      1.92      3.76        2.85    73.66
Beetles Elmidae                            1.89      1.85      3.85        2.74    76.40
Snails Planorbidae                         1.90      1.79      3.71        2.65    79.04
Aquatic mites Acarina                      2.05      1.64      1.43        2.43    81.47
True Fly larvae Stratiomyidae              1.69      1.63      3.28        2.41    83.88
Dragonfly larvae Coenagrionidae            2.15      1.59      1.27        2.35    86.23
Leeches Glossiphoniidae                    1.43      1.18      1.45        1.75    87.98
True Fly larvae s-f Orthocladiinae         1.61      1.17      1.44        1.74    89.71
Dragonfly larvae Libellulidae              1.95      1.01      0.86        1.49    91.20
```

```
Groups Archers Ck  &  Buffalo Ck
Average dissimilarity = 46.57

                                        Group Archers Ck Group Buffalo Ck
Species                                 Av.Abund          Av.Abund        Av.Diss         Diss/SD     Contrib%    Cum.%
True Fly larvae s-f Chironominae            9.35              8.26           2.97            1.29         6.38     6.38
Snails Hydrobiidae                          3.05              5.11           2.42            1.26         5.19    11.58
Snails Physidae                             5.97              5.09           2.22            1.44         4.76    16.34
True Fly larvae s-f Orthocladiinae          3.12              1.82           1.97            1.04         4.24    20.58
Caddisfly larvae Hydroptilidae              2.28              2.43           1.88            1.23         4.03    24.61
True bugs Notonectidae                      2.37              4.35           1.81            1.45         3.88    28.49
Flatworms Dugesiidae                        4.69              3.20           1.68            1.37         3.62    32.11
Dragonfly larvae Coenagrionidae             3.27              2.14           1.65            1.26         3.54    35.65
Dragonfly larvae Megapodagrionidae          3.07              5.17           1.58            1.97         3.38    39.03
Dragonfly larvae Isostictidae               0.00              2.40           1.55            1.82         3.33    42.36
True bugs Veliidae                          2.99              0.81           1.50            1.39         3.23    45.59
Worms Oligochaeta                           5.35              4.80           1.50            1.64         3.22    48.80
Snails Planorbidae                          0.00              2.26           1.48            1.51         3.17    51.97
Dragonfly larvae Hemicorduliidae            3.19              2.83           1.41            1.33         3.02    54.99
True Fly larvae Culicidae                   2.05              0.91           1.23            1.16         2.65    57.64
Mussels Corbiculidae                        0.43              1.78           1.22            1.02         2.61    60.25
Fairy shrimps Atyidae                       1.70              0.00           1.16            0.81         2.49    62.74
Dragonfly larvae Aeshnidae                  1.89              1.56           1.13            1.23         2.43    65.18
Dragonfly larvae Libellulidae               2.49              2.80           1.11            1.33         2.39    67.57
Leeches Glossiphoniidae                     1.80              1.08           1.11            1.24         2.37    69.94
Mayfly larvae Baetidae                      1.00              1.27           1.05            0.91         2.26    72.20
True Fly larvae s-f Tanypodinae             3.05              2.36           0.99            1.18         2.13    74.34
Mussels Sphaeriidae                         1.00              1.07           0.96            0.89         2.06    76.39
Snails Lymnaeidae                           0.75              1.71           0.89            1.55         1.91    78.30
Aquatic mites Acarina                       1.24              1.01           0.78            1.17         1.68    79.99
True Fly larvae Stratiomyidae               2.33              1.70           0.78            1.18         1.68    81.66
Slatters Oniscidae                          1.00              0.86           0.77            1.16         1.66    83.32
True Fly larvae Tipulidae                   1.21              0.14           0.75            1.19         1.61    84.93
True Fly larvae Ceratopogonidae             0.56              0.63           0.57            0.95         1.22    86.15
True bugs Corixidae                         0.72              0.43           0.55            0.81         1.19    87.34
True Fly larvae Simuliidae                  0.89              0.14           0.54            1.17         1.17    88.50
Snails Ancylidae                            0.70              0.29           0.52            0.72         1.11    89.62
True bugs Gerridae                          0.30              0.74           0.50            1.01         1.08    90.70

Groups Archers Ck  &  Porters Ck
Average dissimilarity = 47.10

                                        Group Archers Ck Group Porters Ck
Species                                 Av.Abund          Av.Abund        Av.Diss         Diss/SD     Contrib%    Cum.%
Snails Hydrobiidae                          3.05              7.62           3.37            1.48         7.16     7.16
True Fly larvae s-f Chironominae            9.35              7.45           3.02            1.33         6.41    13.57
Dragonfly larvae Isostictidae               0.00              3.90           2.58            1.96         5.49    19.06
True Fly larvae s-f Orthocladiinae          3.12              2.51           1.97            1.11         4.18    23.24
Flatworms Dugesiidae                        4.69              2.12           1.88            1.27         4.00    27.24
Snails Physidae                             5.97              4.73           1.68            1.45         3.57    30.81
Worms Oligochaeta                           5.35              3.81           1.62            1.44         3.45    34.26
True bugs Veliidae                          2.99              0.59           1.61            1.47         3.43    37.69
Caddisfly larvae Hydroptilidae              2.28              1.21           1.61            0.99         3.41    41.10
Snails Planorbidae                          0.00              2.35           1.57            2.83         3.32    44.42
Fairy shrimps Atyidae                       1.70              2.18           1.50            1.21         3.18    47.60
True bugs Notonectidae                      2.37              3.32           1.46            1.47         3.10    50.71
Dragonfly larvae Megapodagrionidae          3.07              4.47           1.42            1.46         3.01    53.72
Dragonfly larvae Coenagrionidae             3.27              3.80           1.38            1.33         2.93    56.64
Dragonfly larvae Hemicorduliidae            3.19              3.36           1.33            1.38         2.83    59.48
True Fly larvae s-f Tanypodinae             3.05              2.77           1.27            1.57         2.70    62.18
True Fly larvae Culicidae                   2.05              0.59           1.27            1.10         2.69    64.87
Leeches Glossiphoniidae                     1.80              2.38           1.27            1.29         2.69    67.55
Dragonfly larvae Aeshnidae                  1.89              1.25           1.17            1.18         2.49    70.04
Snails Ancylidae                            0.70              1.34           0.92            1.13         1.95    72.00
Dragonfly larvae Libellulidae               2.49              2.06           0.87            1.20         1.84    73.84
True Fly larvae Stratiomyidae               2.33              1.81           0.80            1.37         1.70    75.54
Mussels Sphaeriidae                         1.00              0.57           0.77            0.71         1.64    77.18
True bugs Corixidae                         0.72              0.84           0.76            0.89         1.61    78.79
True Fly larvae Tipulidae                   1.21              0.45           0.73            1.24         1.55    80.35
Slatters Oniscidae                          1.00              0.57           0.71            1.11         1.51    81.85
Beetles Dytiscidae                          0.64              0.91           0.66            1.16         1.41    83.26
Mayfly larvae Baetidae                      1.00              0.14           0.65            0.72         1.39    84.65
Aquatic mites Acarina                       1.24              0.63           0.65            1.01         1.37    86.02
True Fly larvae Simuliidae                  0.89              0.14           0.54            1.17         1.15    87.17
Caddisfly larvae Leptoceridae               0.13              0.88           0.53            0.83         1.13    88.30
Snails Lymnaeidae                           0.75              0.40           0.48            1.63         1.02    89.32
Mussels Corbiculidae                        0.43              0.35           0.45            0.64         0.96    90.28
```

```
Groups Buffalo Ck  &  Porters Ck
Average dissimilarity = 42.36

      Group Buffalo Ck                Group Porters Ck
Species                               Av.Abund         Av.Abund          Av.Diss         Diss/SD     Contrib%    Cum.%
True Fly larvae s-f Chironominae          8.26             7.45             2.63            1.23         6.20     6.20
Snails Hydrobiidae                        5.11             7.62             2.28            1.33         5.38    11.59
Snails Physidae                           5.09             4.73             2.14            1.31         5.05    16.64
Dragonfly larvae Coenagrionidae           2.14             3.80             1.80            1.44         4.25    20.89
True Fly larvae s-f Orthocladiinae        1.82             2.51             1.68            1.17         3.97    24.87
True bugs Notonectidae                    4.35             3.32             1.57            1.37         3.71    28.57
Dragonfly larvae Isostictidae             2.40             3.90             1.54            1.22         3.62    32.20
Caddisfly larvae Hydroptilidae            2.43             1.21             1.50            1.20         3.54    35.74
Dragonfly larvae Hemicorduliidae          2.83             3.36             1.44            1.38         3.41    39.15
Leeches Glossiphoniidae                   1.08             2.38             1.42            1.21         3.35    42.50
Fairy shrimps Atyidae                     0.00             2.18             1.38            1.05         3.26    45.76
True Fly larvae s-f Tanypodinae           2.36             2.77             1.37            1.29         3.25    49.01
Dragonfly larvae Megapodagrionidae        5.17             4.47             1.29            1.41         3.04    52.05
Dragonfly larvae Libellulidae             2.80             2.06             1.26            1.28         2.97    55.02
Mussels Corbiculidae                      1.78             0.35             1.23            0.93         2.90    57.92
Worms Oligochaeta                         4.80             3.81             1.19            1.09         2.81    60.73
Flatworms Dugesiidae                      3.20             2.12             1.10            1.42         2.59    63.33
Dragonfly larvae Aeshnidae                1.56             1.25             1.03            1.21         2.42    65.75
Snails Lymnaeidae                         1.71             0.40             1.01            1.34         2.38    68.12
Snails Planorbidae                        2.26             2.35             0.98            1.68         2.32    70.44
Snails Ancylidae                          0.29             1.34             0.85            1.11         2.00    72.45
True Fly larvae Stratiomyidae             1.70             1.81             0.84            1.24         1.99    74.43
Mayfly larvae Baetidae                    1.27             0.14             0.80            0.68         1.89    76.32
Mussels Sphaeriidae                       1.07             0.57             0.71            1.04         1.68    78.01
Aquatic mites Acarina                     1.01             0.63             0.64            1.10         1.52    79.52
True bugs Corixidae                       0.43             0.84             0.64            0.80         1.51    81.03
Beetles Dytiscidae                        0.20             0.91             0.63            0.89         1.48    82.51
Slatters Oniscidae                        0.86             0.57             0.62            1.02         1.46    83.97
True Fly larvae Culicidae                 0.91             0.59             0.61            1.13         1.43    85.41
True bugs Veliidae                        0.81             0.59             0.56            1.17         1.32    86.73
Caddisfly larvae Leptoceridae             0.14             0.88             0.54            0.83         1.29    88.01
True bugs Gerridae                        0.74             0.43             0.52            1.16         1.24    89.25
Beetles Hydrophilidae                     0.63             0.39             0.45            1.16         1.05    90.30


Groups Archers Ck  &  Shrimptons Ck
Average dissimilarity = 50.32

      Group Archers Ck                Group Shrimptons Ck
Species                               Av.Abund          Av.Abund         Av.Diss         Diss/SD     Contrib%    Cum.%
True Fly larvae s-f Chironominae        9.35              5.68              4.59            1.39         9.11     9.11
Flatworms Dugesiidae                    4.69              6.21              2.07            1.46         4.12    13.23
True Fly larvae s-f Orthocladiinae      3.12              0.60              1.97            0.92         3.92    17.15
Snails Hydrobiidae                      3.05              0.92              1.96            1.16         3.90    21.05
True bugs Veliidae                      2.99              0.80              1.91            1.53         3.80    24.85
Dragonfly larvae Megapodagrionidae      3.07              1.88              1.90            1.50         3.78    28.63
Snails Physidae                         5.97              6.88              1.78            1.40         3.53    32.16
Snails Planorbidae                      0.00              2.34              1.76            1.30         3.49    35.65
Caddisfly larvae Hydroptilidae          2.28              0.38              1.64            0.82         3.26    38.91
True Fly larvae s-f Tanypodinae         3.05              1.08              1.61            1.57         3.19    42.11
Dragonfly larvae Hemicorduliidae        3.19              2.74              1.58            1.39         3.13    45.24
True bugs Notonectidae                  2.37              1.72              1.55            1.29         3.09    48.32
Leeches Glossiphoniidae                 1.80              2.39              1.54            1.28         3.05    51.38
True Fly larvae Culicidae               2.05              0.25              1.47            1.05         2.93    54.30
Mussels Corbiculidae                    0.43              1.70              1.45            0.92         2.89    57.19
Dragonfly larvae Coenagrionidae         3.27              3.13              1.39            1.22         2.77    59.95
Dragonfly larvae Aeshnidae              1.89              0.50              1.38            1.12         2.74    62.70
Worms Oligochaeta                       5.35              5.74              1.33            1.42         2.65    65.35
Fairy shrimps Atyidae                   1.70              0.00              1.29            0.81         2.57    67.92
Aquatic mites Acarina                   1.24              2.53              1.28            1.23         2.55    70.46
True Fly larvae Stratiomyidae           2.33              0.90              1.13            1.55         2.25    72.71
Dragonfly larvae Libellulidae           2.49              1.31              1.04            1.29         2.06    74.77
Mussels Sphaeriidae                     1.00              0.86              0.99            0.85         1.97    76.74
True Fly larvae Tipulidae               1.21              0.00              0.85            1.17         1.68    78.42
True bugs Corixidae                     0.72              0.97              0.83            1.00         1.65    80.07
Snails Ancylidae                        0.70              0.82              0.78            0.84         1.56    81.63
Slatters Oniscidae                      1.00              0.60              0.78            1.07         1.55    83.17
Mayfly larvae Baetidae                  1.00              0.30              0.75            0.78         1.50    84.67
Dragonfly larvae Isostictidae           0.00              1.09              0.70            0.72         1.40    86.07
Dragonfly larvae Lestidae               0.67              0.47              0.67            0.79         1.34    87.41
Yabbies Parastacidae                    0.00              0.90              0.63            1.10         1.25    88.67
True Fly larvae Simuliidae              0.89              0.00              0.62            1.16         1.23    89.90
Beetles Dytiscidae                      0.64              0.13              0.49            0.90         0.98    90.88
```

```
Groups Buffalo Ck  &  Shrimptons Ck
Average dissimilarity = 49.78

                                        Group Buffalo Ck Group Shrimptons Ck
Species                                 Av.Abund          Av.Abund        Av.Diss         Diss/SD    Contrib%    Cum.%
True Fly larvae s-f Chironominae            8.26              5.68           4.13            1.49        8.29     8.29
Snails Hydrobiidae                          5.11              0.92           3.34            1.50        6.71    15.00
Dragonfly larvae Megapodagrionidae          5.17              1.88           2.87            1.85        5.76    20.75
Snails Physidae                             5.09              6.88           2.59            1.78        5.20    25.95
Flatworms Dugesiidae                        3.20              6.21           2.44            1.49        4.90    30.85
True bugs Notonectidae                      4.35              1.72           2.29            1.46        4.61    35.46
Leeches Glossiphoniidae                     1.08              2.39           1.77            1.15        3.55    39.01
Dragonfly larvae Coenagrionidae             2.14              3.13           1.71            1.39        3.43    42.43
Mussels Corbiculidae                        1.78              1.70           1.68            0.96        3.37    45.80
Caddisfly larvae Hydroptilidae              2.43              0.38           1.67            1.11        3.36    49.16
Dragonfly larvae Hemicorduliidae            2.83              2.74           1.59            1.32        3.19    52.36
Dragonfly larvae Isostictidae               2.40              1.09           1.50            1.39        3.02    55.38
Dragonfly larvae Libellulidae               2.80              1.31           1.49            1.38        3.00    58.37
Aquatic mites Acarina                       1.01              2.53           1.45            1.30        2.91    61.29
Snails Planorbidae                          2.26              2.34           1.42            1.34        2.85    64.14
Worms Oligochaeta                           4.80              5.74           1.36            1.59        2.74    66.88
True Fly larvae s-f Tanypodinae             2.36              1.08           1.31            1.47        2.63    69.51
True Fly larvae s-f Orthocladiinae          1.82              0.60           1.28            0.87        2.58    72.09
Dragonfly larvae Aeshnidae                  1.56              0.50           1.12            1.18        2.25    74.34
Snails Lymnaeidae                           1.71              1.14           0.93            1.45        1.87    76.21
True Fly larvae Stratiomyidae               1.70              0.90           0.92            1.34        1.85    78.06
Mayfly larvae Baetidae                      1.27              0.30           0.92            0.73        1.84    79.90
Mussels Sphaeriidae                         1.07              0.86           0.88            1.18        1.77    81.67
True bugs Veliidae                          0.81              0.80           0.81            1.04        1.63    83.30
True bugs Corixidae                         0.43              0.97           0.69            1.00        1.38    84.68
True Fly larvae Culicidae                   0.91              0.25           0.68            1.06        1.36    86.04
Slatters Oniscidae                          0.86              0.60           0.67            0.99        1.35    87.39
Yabbies Parastacidae                        0.00              0.90           0.65            1.09        1.31    88.70
Snails Ancylidae                            0.29              0.82           0.63            0.87        1.26    89.96
True bugs Gerridae                          0.74              0.34           0.58            0.98        1.17    91.12

Groups Porters Ck  &  Shrimptons Ck
Average dissimilarity = 52.48

                                        Group Porters Ck Group Shrimptons Ck
Species                                 Av.Abund         Av.Abund         Av.Diss         Diss/SD    Contrib%    Cum.%
Snails Hydrobiidae                          7.62             0.92            5.01            2.40        9.55     9.55
True Fly larvae s-f Chironominae            7.45             5.68            3.90            1.42        7.43    16.97
Flatworms Dugesiidae                        2.12             6.21            3.18            2.08        6.07    23.04
Dragonfly larvae Megapodagrionidae          4.47             1.88            2.51            1.63        4.78    27.82
Dragonfly larvae Isostictidae               3.90             1.09            2.47            1.47        4.71    32.53
Snails Physidae                             4.73             6.88            2.02            1.42        3.84    36.37
True bugs Notonectidae                      3.32             1.72            1.77            1.44        3.37    39.73
Leeches Glossiphoniidae                     2.38             2.39            1.73            1.29        3.30    43.03
True Fly larvae s-f Tanypodinae             2.77             1.08            1.72            1.20        3.28    46.31
True Fly larvae s-f Orthocladiinae          2.51             0.60            1.64            1.15        3.12    49.43
Dragonfly larvae Hemicorduliidae            3.36             2.74            1.61            1.45        3.07    52.50
Worms Oligochaeta                           3.81             5.74            1.60            1.30        3.05    55.54
Dragonfly larvae Coenagrionidae             3.80             3.13            1.54            1.41        2.93    58.47
Fairy shrimps Atyidae                       2.18             0.00            1.52            1.05        2.91    61.37
Mussels Corbiculidae                        0.35             1.70            1.48            0.83        2.82    64.20
Aquatic mites Acarina                       0.63             2.53            1.45            1.21        2.77    66.97
Snails Planorbidae                          2.35             2.34            1.22            1.57        2.33    69.30
Snails Ancylidae                            1.34             0.82            1.05            1.10        2.00    71.30
Dragonfly larvae Libellulidae               2.06             1.31            1.05            1.24        1.99    73.29
True Fly larvae Stratiomyidae               1.81             0.90            1.00            1.21        1.91    75.20
Dragonfly larvae Aeshnidae                  1.25             0.50            0.97            0.96        1.85    77.05
Caddisfly larvae Hydroptilidae              1.21             0.38            0.91            0.89        1.74    78.79
True bugs Corixidae                         0.84             0.97            0.91            0.98        1.73    80.52
True bugs Veliidae                          0.59             0.80            0.72            0.90        1.38    81.90
Mussels Sphaeriidae                         0.57             0.86            0.70            1.02        1.33    83.23
Snails Lymnaeidae                           0.40             1.14            0.70            1.71        1.33    84.56
Beetles Dytiscidae                          0.91             0.13            0.68            0.87        1.30    85.86
Yabbies Parastacidae                        0.00             0.90            0.65            1.10        1.23    87.10
Leeches Erpobdellidae                       0.52             0.38            0.60            0.67        1.14    88.24
Caddisfly larvae Leptoceridae               0.88             0.00            0.58            0.78        1.10    89.35
Slatters Oniscidae                          0.57             0.60            0.56            1.04        1.07    90.42
```

```
Groups Archers Ck  &  Terrys Ck
Average dissimilarity = 44.17

                                        Group Archers Ck Group Terrys Ck
Species                                 Av.Abund         Av.Abund         Av.Diss         Diss/SD    Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae          3.07             7.52            2.79            2.69        6.33     6.33
True Fly larvae s-f Chironominae            9.35             7.62            2.62            1.35        5.92    12.25
Snails Hydrobiidae                          3.05             6.00            2.55            1.41        5.78    18.03
True Fly larvae s-f Orthocladiinae          3.12             1.61            1.58            0.96        3.59    21.62
Snails Physidae                             5.97             5.36            1.55            1.45        3.50    25.12
Flatworms Dugesiidae                        4.69             4.75            1.51            1.73        3.43    28.55
Dragonfly larvae Isostictidae               0.00             2.41            1.51            2.19        3.42    31.97
Dragonfly larvae Hemicorduliidae            3.19             3.71            1.48            1.36        3.36    35.32
True bugs Notonectidae                      2.37             2.94            1.43            1.34        3.23    38.56
Caddisfly larvae Hydroptilidae              2.28             0.71            1.42            0.92        3.21    41.77
True Fly larvae Culicidae                   2.05             0.91            1.24            1.16        2.82    44.58
Dragonfly larvae Coenagrionidae             3.27             2.15            1.22            1.12        2.77    47.36
Worms Oligochaeta                           5.35             5.27            1.18            1.68        2.68    50.04
Mussels Sphaeriidae                         1.00             1.55            1.18            1.03        2.67    52.71
Snails Planorbidae                          0.00             1.90            1.18            3.23        2.66    55.38
Mussels Corbiculidae                        0.43             1.73            1.13            1.02        2.55    57.93
Fairy shrimps Atyidae                       1.70             0.00            1.09            0.82        2.48    60.41
Beetles Elmidae                             0.18             1.89            1.08            2.50        2.45    62.86
Dragonfly larvae Libellulidae               2.49             1.95            1.06            1.38        2.40    65.26
Dragonfly larvae Aeshnidae                  1.89             0.82            0.98            1.10        2.23    67.49
True Fly larvae s-f Tanypodinae             3.05             4.24            0.97            1.52        2.20    69.69
Aquatic mites Acarina                       1.24             2.05            0.91            1.57        2.06    71.75
True bugs Veliidae                          2.99             1.84            0.90            1.08        2.03    73.79
Leeches Glossiphoniidae                     1.80             1.43            0.83            1.46        1.89    75.67
True bugs Gerridae                          0.30             1.43            0.79            1.37        1.79    77.47
True Fly larvae Tipulidae                   1.21             0.63            0.68            1.28        1.54    79.00
True Fly larvae Ceratopogonidae             0.56             0.87            0.67            1.02        1.53    80.53
Slatters Oniscidae                          1.00             0.29            0.64            0.98        1.46    81.99
Mayfly larvae Baetidae                      1.00             0.20            0.63            0.73        1.43    83.41
Sand hoppers Talitridae                     0.00             1.00            0.62            1.47        1.41    84.83
True Fly larvae Stratiomyidae               2.33             1.69            0.59            1.43        1.34    86.16
True Fly larvae Simuliidae                  0.89             0.75            0.58            1.24        1.31    87.48
Snails Ancylidae                            0.70             0.46            0.57            0.78        1.30    88.77
True bugs Corixidae                         0.72             0.32            0.56            0.76        1.26    90.03
```

```
Groups Buffalo Ck  &  Terrys Ck
Average dissimilarity = 39.36

                                        Group Buffalo Ck Group Terrys Ck
Species                                  Av.Abund        Av.Abund         Av.Diss         Diss/SD     Contrib%    Cum.%
True Fly larvae s-f Chironominae             8.26            7.62            2.28            1.36         5.80     5.80
Snails Physidae                              5.09            5.36            2.09            1.57         5.32    11.13
Snails Hydrobiidae                           5.11            6.00            1.73            1.32         4.41    15.53
Dragonfly larvae Megapodagrionidae           5.17            7.52            1.65            1.60         4.20    19.73
True bugs Notonectidae                       4.35            2.94            1.65            1.41         4.18    23.91
Dragonfly larvae Hemicorduliidae             2.83            3.71            1.64            1.36         4.16    28.08
True Fly larvae s-f Tanypodinae              2.36            4.24            1.39            1.29         3.53    31.60
Dragonfly larvae Libellulidae                2.80            1.95            1.35            1.32         3.43    35.03
Caddisfly larvae Hydroptilidae               2.43            0.71            1.33            1.13         3.38    38.41
Mussels Corbiculidae                         1.78            1.73            1.32            0.98         3.34    41.75
Flatworms Dugesiidae                         3.20            4.75            1.28            1.36         3.26    45.01
Dragonfly larvae Coenagrionidae              2.14            2.15            1.28            1.47         3.25    48.25
Beetles Elmidae                              0.00            1.89            1.21            3.37         3.07    51.33
True Fly larvae s-f Orthocladiinae           1.82            1.61            1.19            1.12         3.03    54.36
Mussels Sphaeriidae                          1.07            1.55            1.05            1.14         2.67    57.03
Worms Oligochaeta                            4.80            5.27            0.99            1.40         2.51    59.54
Aquatic mites Acarina                        1.01            2.05            0.98            1.45         2.49    62.03
Snails Lymnaeidae                            1.71            0.83            0.95            1.43         2.40    64.43
Dragonfly larvae Isostictidae                2.40            2.41            0.91            1.38         2.32    66.75
Snails Planorbidae                           2.26            1.90            0.90            1.62         2.30    69.05
Leeches Glossiphoniidae                      1.08            1.43            0.88            1.53         2.24    71.28
Dragonfly larvae Aeshnidae                   1.56            0.82            0.81            1.30         2.05    73.33
Mayfly larvae Baetidae                       1.27            0.20            0.78            0.70         1.97    75.31
True bugs Gerridae                           0.74            1.43            0.77            1.24         1.96    77.26
True bugs Veliidae                           0.81            1.84            0.75            1.63         1.92    79.18
True Fly larvae Culicidae                    0.91            0.91            0.74            1.11         1.89    81.07
True Fly larvae Stratiomyidae                1.70            1.69            0.61            1.33         1.55    82.62
Sand hoppers Talitridae                      0.14            1.00            0.60            1.41         1.53    84.15
Slatters Oniscidae                           0.86            0.29            0.54            0.88         1.36    85.52
True Fly larvae Ceratopogonidae              0.63            0.87            0.54            1.02         1.36    86.88
True Fly larvae Simuliidae                   0.14            0.75            0.47            0.90         1.21    88.08
Sand hoppers Ceinidae                        0.39            0.57            0.47            0.85         1.20    89.29
True Fly larvae Tipulidae                    0.14            0.63            0.43            0.86         1.09    90.38
```

```
Groups Porters Ck  &  Terrys Ck
Average dissimilarity = 41.28

                                        Group Porters Ck Group Terrys Ck
Species                                  Av.Abund         Av.Abund       Av.Diss       Diss/SD    Contrib%    Cum.%
True Fly larvae s-f Chironominae             7.45             7.62          2.22          1.37        5.39     5.39
Dragonfly larvae Megapodagrionidae           4.47             7.52          2.13          1.53        5.17    10.55
Snails Hydrobiidae                           7.62             6.00          1.92          1.47        4.65    15.20
Flatworms Dugesiidae                         2.12             4.75          1.71          1.63        4.15    19.35
Dragonfly larvae Hemicorduliidae             3.36             3.71          1.51          1.29        3.67    23.02
True Fly larvae s-f Tanypodinae              2.77             4.24          1.43          1.47        3.46    26.48
True bugs Notonectidae                       3.32             2.94          1.42          1.47        3.43    29.92
Dragonfly larvae Coenagrionidae              3.80             2.15          1.42          1.39        3.43    33.35
Snails Physidae                              4.73             5.36          1.41          1.35        3.41    36.76
Dragonfly larvae Isostictidae                3.90             2.41          1.38          1.35        3.35    40.11
True Fly larvae s-f Orthocladiinae           2.51             1.61          1.34          1.36        3.24    43.34
Fairy shrimps Atyidae                        2.18             0.00          1.31          1.06        3.16    46.51
Beetles Elmidae                              0.00             1.89          1.21          3.42        2.92    49.43
Leeches Glossiphoniidae                      2.38             1.43          1.19          1.54        2.88    52.31
Mussels Corbiculidae                         0.35             1.73          1.14          0.92        2.76    55.07
Worms Oligochaeta                            3.81             5.27          1.13          1.25        2.73    57.80
Dragonfly larvae Libellulidae                2.06             1.95          1.09          1.24        2.65    60.45
Aquatic mites Acarina                        0.63             2.05          1.03          1.65        2.49    62.94
Mussels Sphaeriidae                          0.57             1.55          0.99          1.01        2.41    65.35
True bugs Veliidae                           0.59             1.84          0.84          1.66        2.03    67.37
Snails Ancylidae                             1.34             0.46          0.83          1.13        2.01    69.38
Caddisfly larvae Hydroptilidae               1.21             0.71          0.81          1.08        1.96    71.35
True bugs Gerridae                           0.43             1.43          0.79          1.39        1.91    73.26
Dragonfly larvae Aeshnidae                   1.25             0.82          0.75          1.13        1.81    75.06
True Fly larvae Culicidae                    0.59             0.91          0.66          0.94        1.59    76.65
True bugs Corixidae                          0.84             0.32          0.65          0.79        1.58    78.23
True Fly larvae Stratiomyidae                1.81             1.69          0.62          1.20        1.51    79.74
Beetles Dytiscidae                           0.91             0.29          0.60          1.02        1.46    81.19
True Fly larvae Ceratopogonidae              0.00             0.87          0.58          0.92        1.41    82.61
Sand hoppers Talitridae                      0.29             1.00          0.56          1.36        1.36    83.97
Snails Lymnaeidae                            0.40             0.83          0.56          1.05        1.36    85.33
Snails Planorbidae                           2.35             1.90          0.56          1.26        1.35    86.68
Caddisfly larvae Leptoceridae                0.88             0.00          0.50          0.77        1.21    87.89
True Fly larvae Tipulidae                    0.45             0.63          0.50          0.98        1.20    89.10
True Fly larvae Simuliidae                   0.14             0.75          0.47          0.90        1.14    90.24
```

```
Groups Shrimptons Ck  &  Terrys Ck
Average dissimilarity = 47.30

                                        Group Shrimptons Ck Group Terrys Ck
Species                                 Av.Abund          Av.Abund       Av.Diss       Diss/SD    Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae          1.88             7.52          4.20          2.10        8.88     8.88
Snails Hydrobiidae                          0.92             6.00          3.69          1.98        7.80    16.68
True Fly larvae s-f Chironominae            5.68             7.62          3.58          1.61        7.57    24.25
True Fly larvae s-f Tanypodinae             1.08             4.24          2.32          2.04        4.90    29.15
Dragonfly larvae Hemicorduliidae            2.74             3.71          1.80          1.35        3.81    32.96
True bugs Notonectidae                      1.72             2.94          1.69          1.32        3.57    36.53
Snails Physidae                             6.88             5.36          1.62          1.33        3.43    39.96
Mussels Corbiculidae                        1.70             1.73          1.56          1.00        3.29    43.26
Dragonfly larvae Isostictidae               1.09             2.41          1.43          1.56        3.01    46.27
Flatworms Dugesiidae                        6.21             4.75          1.37          1.24        2.90    49.17
Leeches Glossiphoniidae                     2.39             1.43          1.34          1.13        2.83    52.00
Beetles Elmidae                             0.00             1.89          1.34          3.40        2.83    54.84
Dragonfly larvae Coenagrionidae             3.13             2.15          1.26          1.41        2.66    57.49
True bugs Veliidae                          0.80             1.84          1.17          2.18        2.47    59.97
Mussels Sphaeriidae                         0.86             1.55          1.13          1.08        2.39    62.35
Dragonfly larvae Libellulidae               1.31             1.95          1.11          1.21        2.34    64.70
Snails Planorbidae                          2.34             1.90          1.11          1.32        2.34    67.04
Aquatic mites Acarina                       2.53             2.05          1.11          1.37        2.34    69.38
True bugs Gerridae                          0.34             1.43          0.92          1.34        1.93    71.31
True Fly larvae s-f Orthocladiinae          0.60             1.61          0.84          1.17        1.78    73.10
Worms Oligochaeta                           5.74             5.27          0.82          1.36        1.73    74.82
True Fly larvae Stratiomyidae               0.90             1.69          0.75          1.39        1.58    76.40
Sand hoppers Talitridae                     0.00             1.00          0.71          1.46        1.51    77.90
True bugs Corixidae                         0.97             0.32          0.71          0.96        1.50    79.41
Snails Ancylidae                            0.82             0.46          0.67          0.87        1.41    80.82
True Fly larvae Culicidae                   0.25             0.91          0.66          0.78        1.40    82.21
Dragonfly larvae Aeshnidae                  0.50             0.82          0.65          1.29        1.38    83.59
Snails Lymnaeidae                           1.14             0.83          0.64          1.26        1.35    84.94
True Fly larvae Ceratopogonidae             0.25             0.87          0.62          0.94        1.30    86.24
Yabbies Parastacidae                        0.90             0.00          0.61          1.10        1.29    87.53
Caddisfly larvae Hydroptilidae              0.38             0.71          0.55          1.05        1.15    88.69
True Fly larvae Simuliidae                  0.00             0.75          0.50          0.82        1.06    89.75
Dragonfly larvae Lestidae                   0.47             0.35          0.49          0.55        1.04    90.79
```

SIMPER Archers Creek 2005, 2006, 2007, and 2008

```
Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample Season Year
S5     Autumn 2005
S5     Spring 2005
S5     Autumn 2006
S5     Spring 2006
S5     Autumn 2007
S5     Spring 2007
S5     Autumn 2008
S5     Spring 2008


Group Autumn 2005
Average similarity: 68.02

Species                                      Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
Dragonfly larvae Megapodagrionidae               3.60      7.56     2.16    11.11      11.11
Fairy shrimps Atyidae                            3.30      7.18     8.38    10.56      21.67
Worms Oligochaeta                                3.29      6.80     3.09     9.99      31.67
True Fly larvae s-f Chironominae                 3.31      6.58     5.68     9.67      41.33
Dragonfly larvae Libellulidae                    2.52      5.47     4.54     8.04      49.37
Flatworms Dugesiidae                             2.75      5.32     5.50     7.82      57.19
Dragonfly larvae Coenagrionidae                  3.19      5.20     4.94     7.65      64.83
True bugs Veliidae                               2.14      5.09     3.65     7.49      72.32
Dragonfly larvae Hemicorduliidae                 2.66      4.82     8.37     7.08      79.40
Snails Physidae                                  1.67      3.65     1.80     5.36      84.77
True Fly larvae Stratiomyidae                    1.62      2.98     7.13     4.38      89.15
True Fly larvae s-f Tanypodinae                  1.00      2.65     8.58     3.90      93.04


Group Spring 2005
Average similarity: 58.85

Species                                   Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
True Fly larvae s-f Chironominae              8.06     19.91     6.33       33.83   33.83
Worms Oligochaeta                             4.19     10.61     6.70       18.04   51.87
Snails Physidae                               2.95      7.20     6.86       12.24   64.11
Dragonfly larvae Coenagrionidae               3.08      6.42     6.60       10.90   75.01
Dragonfly larvae Libellulidae                 2.87      6.04     1.03       10.27   85.28
Dragonfly larvae Aeshnidae                    1.49      2.00     0.58        3.40   88.68
Mussels Corbiculidae                          1.15      1.97     0.58        3.36   92.04


Group Autumn 2006
Average similarity: 72.35

Species                                      Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
True Fly larvae s-f Chironominae                 9.12     23.36    19.19       32.29   32.29
Worms Oligochaeta                                3.39      8.50    11.35       11.74   44.04
Leeches Glossiphoniidae                          2.10      4.91     2.60        6.79   50.82
Dragonfly larvae Megapodagrionidae               2.10      4.62     4.53        6.39   57.21
Dragonfly larvae Libellulidae                    2.02      4.46     4.33        6.17   63.38
Dragonfly larvae Coenagrionidae                  2.03      4.02     1.99        5.56   68.94
Dragonfly larvae Hemicorduliidae                 1.96      3.84     2.25        5.30   74.24
Flatworms Dugesiidae                             1.67      3.63     2.69        5.02   79.26
True bugs Veliidae                               1.28      3.17     3.92        4.38   83.63
True bugs Notonectidae                           1.47      3.16     4.33        4.36   88.00
Dragonfly larvae Aeshnidae                       2.05      2.45     0.58        3.38   91.38
```

Group Spring 2006

```
Average similarity: 60.22

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                 4.35     14.93     4.12      24.80   24.80
Snails Physidae                                  2.81     10.04     3.55      16.68   41.47
Flatworms Dugesiidae                             2.63      8.66     2.75      14.39   55.86
Worms Oligochaeta                                2.43      7.87     2.82      13.07   68.93
Snails Hydrobiidae                               1.81      4.51     1.47       7.48   76.41
True Fly larvae s-f Tanypodinae                  1.07      3.38     1.76       5.62   82.03
True bugs Veliidae                               0.80      1.96     0.79       3.25   85.28
True Fly larvae s-f Orthocladiinae               1.06      1.92     0.79       3.18   88.47
True Fly larvae Stratiomyidae                    0.87      1.55     0.57       2.58   91.05
```

Group Autumn 2007

```
Average similarity: 57.33

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                 5.02     17.66     4.21      30.81   30.81
Worms Oligochaeta                                2.53      6.59     1.30      11.49   42.30
Snails Physidae                                  2.35      6.46     3.17      11.27   53.57
Flatworms Dugesiidae                             2.20      4.54     1.22       7.93   61.50
True Fly larvae s-f Tanypodinae                  1.19      4.00     5.04       6.99   68.48
Dragonfly larvae Libellulidae                    1.50      3.89     1.21       6.79   75.27
True bugs Veliidae                               1.93      3.06     0.75       5.35   80.62
Leeches Glossiphoniidae                          1.08      2.51     1.28       4.38   85.00
Dragonfly larvae Megapodagrionidae               1.01      1.90     0.77       3.31   88.31
Dragonfly larvae Aeshnidae                       0.98      1.76     0.78       3.07   91.38
```

Group Spring 2007

```
Average similarity: 61.15

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                 5.57     14.94     7.60      24.43   24.43
Snails Physidae                                  3.77     10.20     7.13      16.67   41.10
Snails Hydrobiidae                               2.81      6.69     2.42      10.94   52.04
Worms Oligochaeta                                2.95      6.47     3.33      10.58   62.62
Flatworms Dugesiidae                             2.70      4.97     1.23       8.13   70.76
True Fly larvae s-f Tanypodinae                  1.84      3.95     2.50       6.46   77.22
Mussels Sphaeriidae                              2.01      3.08     1.02       5.04   82.26
Dragonfly larvae Hemicorduliidae                 1.57      2.37     1.15       3.88   86.14
Dragonfly larvae Libellulidae                    1.04      2.14     1.29       3.50   89.63
True Fly larvae s-f Orthocladiinae               1.33      1.78     0.73       2.91   92.55
```

Group Autumn 2008

```
Average similarity: 61.49

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Orthocladiinae               4.42     13.77     5.31      22.39   22.39
True Fly larvae s-f Chironominae                 3.35     10.77     5.75      17.51   39.91
Snails Hydrobiidae                               2.52      7.04     2.73      11.45   51.35
Worms Oligochaeta                                1.69      5.05     3.62       8.21   59.56
True bugs Veliidae                               1.62      4.32     4.25       7.03   66.59
Snails Physidae                                  2.03      4.28     1.16       6.96   73.55
True bugs Notonectidae                           1.69      3.42     1.06       5.56   79.10
Caddisfly larvae Hydroptilidae                   1.35      2.21     0.74       3.59   82.69
True Fly larvae Ceratopogonidae                  1.15      2.07     0.78       3.36   86.05
Mayfly larvae Baetidae                           1.26      1.64     0.48       2.66   88.72
True Fly larvae Stratiomyidae                    0.67      1.43     0.79       2.33   91.05
```

Group Spring 2008

```
Average similarity: 69.72

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                 3.99     12.17    10.20      17.46   17.46
Flatworms Dugesiidae                             2.87      8.16     7.17      11.70   29.16
Worms Oligochaeta                                2.85      8.05     6.36      11.55   40.71
Caddisfly larvae Hydroptilidae                   3.13      7.69     3.78      11.04   51.75
Snails Physidae                                  2.77      6.64     2.38       9.53   61.28
Snails Hydrobiidae                               2.46      6.11     5.80       8.77   70.04
True Fly larvae s-f Orthocladiinae               2.49      4.74     1.09       6.80   76.84
True bugs Notonectidae                           1.74      3.20     1.03       4.58   81.43
Snails Ancylidae                                 1.30      2.59     1.31       3.72   85.15
True Fly larvae s-f Tanypodinae                  1.24      2.29     1.29       3.29   88.43
Leeches Glossiphoniidae                          1.08      2.28     1.24       3.27   91.70
```

SIMPER Shrimptons Creek 2005, 2006, 2007 and 2008

```
Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample  Season Year
S2      Autumn 2005
S2      Spring 2005
S2      Autumn 2006
S2      Spring 2006
S2      Autumn 2007
S2      Spring 2007
S2      Autumn 2008
S2      Spring 2008


Group Autumn 2005
Average similarity: 75.89

Species                         Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Physidae                     3.90     16.31     7.41      21.49    21.49
Flatworms Dugesiidae                3.81     15.30     9.53      20.16    41.65
Worms Oligochaeta                   3.43     13.48    44.44      17.77    59.41
Leeches Glossiphoniidae             3.04     10.94     8.30      14.42    73.83
Mussels Corbiculidae                2.63      9.41     3.56      12.40    86.23
Snails Planorbidae                  2.39      7.68     3.56      10.12    96.35


Group Spring 2005
Average similarity: 76.54

Species                                     Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Physidae                                 4.03     13.28    19.85      17.35    17.35
Worms Oligochaeta                               3.91     13.08    46.28      17.09    34.44
Flatworms Dugesiidae                            3.46     11.45    11.43      14.97    49.41
Leeches Glossiphoniidae                         3.04      9.70    10.63      12.67    62.08
True Fly larvae s-f Chironominae                3.09      8.94     4.43      11.68    73.76
Snails Planorbidae                              2.88      8.57     3.06      11.20    84.96
Mussels Corbiculidae                            2.64      7.51    12.72       9.82    94.78


Group Autumn 2006
Average similarity: 76.70

Species                                     Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Worms Oligochaeta                               3.68     16.90    13.74      22.03    22.03
Flatworms Dugesiidae                            2.82     13.43     9.18      17.51    39.55
Snails Physidae                                 2.96     13.00     3.19      16.95    56.50
Aquatic mites Acarina                           2.08      9.91    14.34      12.92    69.42
Mussels Corbiculidae                            2.39      9.70     6.21      12.64    82.06
Dragonfly larvae Hemicorduliidae                1.88      6.51     2.65       8.49    90.55


Group Spring 2006
Average similarity: 62.17

Species                                     Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                4.59     20.77     7.14      33.41    33.41
Snails Physidae                                 3.41     15.57    10.74      25.04    58.46
Worms Oligochaeta                               2.05      7.05     1.41      11.35    69.80
Flatworms Dugesiidae                            1.31      3.75     1.10       6.03    75.83
True bugs Notonectidae                          1.03      3.23     1.14       5.19    81.03
Aquatic mites Acarina                           1.12      3.02     1.10       4.86    85.89
Dragonfly larvae Hemicorduliidae                1.12      2.85     0.79       4.58    90.47
```

```
Group Autumn 2007
Average similarity: 60.39

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 2.95      8.39     2.58      13.89    13.89
Dragonfly larvae Megapodagrionidae               2.10      6.97     5.43      11.55    25.44
Flatworms Dugesiidae                             2.16      6.71     3.12      11.10    36.54
Aquatic mites Acarina                            2.02      5.61     3.42       9.28    45.83
Dragonfly larvae Coenagrionidae                  1.80      5.41     2.78       8.96    54.79
Dragonfly larvae Isostictidae                    1.72      5.19     3.30       8.59    63.38
Dragonfly larvae Hemicorduliidae                 2.14      4.74     1.11       7.85    71.23
Worms Oligochaeta                                1.72      4.72     1.08       7.81    79.04
Snails Physidae                                  2.28      4.63     1.08       7.67    86.71
True bugs Notonectidae                           1.01      2.01     0.75       3.33    90.04


Group Spring 2007
Average similarity: 63.13

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 4.53     12.18     4.26      19.29    19.29
Snails Physidae                                  3.79     10.55     5.00      16.72    36.01
Worms Oligochaeta                                2.22      6.38     4.93      10.10    46.12
Flatworms Dugesiidae                             2.25      5.37     2.58       8.51    54.62
Dragonfly larvae Coenagrionidae                  2.01      4.99     3.48       7.90    62.53
Dragonfly larvae Isostictidae                    1.88      4.87     3.27       7.71    70.23
Dragonfly larvae Megapodagrionidae               1.95      3.26     0.78       5.17    75.41
Snails Ancylidae                                 1.37      3.05     1.34       4.83    80.24
True bugs Corixidae                              1.28      2.94     1.28       4.65    84.89
Dragonfly larvae Hemicorduliidae                 1.25      2.90     1.35       4.59    89.48
True bugs Notonectidae                           0.67      1.56     0.78       2.48    91.96


Group Autumn 2008
Average similarity: 57.63

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Flatworms Dugesiidae                             3.55     20.83     4.34      36.15    36.15
Snails Physidae                                  2.91     16.00     4.67      27.76    63.91
Worms Oligochaeta                                1.52      6.57     1.29      11.39    75.30
Dragonfly larvae Megapodagrionidae               1.05      3.47     0.77       6.02    81.32
Leeches Glossiphoniidae                          1.22      2.81     0.76       4.87    86.19
Aquatic mites Acarina                            0.98      2.63     0.78       4.57    90.76


Group Spring 2008
Average similarity: 62.97

Species                                   Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Physidae                               3.46     15.55     5.33      24.69    24.69
Flatworms Dugesiidae                          2.86     12.16     5.11      19.31    44.00
True Fly larvae s-f Chironominae              2.37      9.80     3.96      15.56    59.56
Worms Oligochaeta                             2.02      7.51     2.08      11.93    71.48
Dragonfly larvae Coenagrionidae               1.95      6.57     2.85      10.43    81.91
Aquatic mites Acarina                         1.41      2.94     0.78       4.66    86.58
Leeches Glossiphoniidae                       0.98      2.04     0.77       3.24    89.82
Mussels Sphaeriidae                           0.79      1.84     0.78       2.92    92.73
```

SIMPER Buffalo Creek 2005, 2006, 2007 and 2008

```
Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample   Season Year
S4       Autumn 2005
S4       Spring 2005
S4       Autumn 2006
S4       Autumn 2007
S4       Spring 2007
S4       Autumn 2008
S4       Spring 2008


Group Autumn 2005
Average similarity: 76.18

Species                                      Av.Abund    Av.Sim    Sim/SD   Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae               3.98      7.79      6.42      10.23    10.23
True Fly larvae s-f Chironominae                 4.20      7.27     13.67       9.54    19.77
True bugs Notonectidae                           3.21      7.22      9.55       9.48    29.25
Worms Oligochaeta                                3.21      7.12      6.08       9.34    38.59
Dragonfly larvae Coenagrionidae                  2.98      5.52     11.31       7.24    45.83
Snails Hydrobiidae                               2.90      4.90      7.43       6.43    52.26
Flatworms Dugesiidae                             2.23      4.73     14.18       6.21    58.47
Mussels Corbiculidae                             2.40      4.59      5.43       6.02    64.49
Dragonfly larvae Hemicorduliidae                 3.12      4.36      1.27       5.73    70.22
Snails Planorbidae                               1.52      3.23      9.55       4.24    74.46
True Fly larvae s-f Tanypodinae                  1.82      3.23      9.55       4.24    78.70
Snails Physidae                                  1.82      3.02      2.42       3.97    82.67
Aquatic mites Acarina                            1.28      2.63      3.13       3.46    86.12
True Fly larvae Stratiomyidae                    1.38      2.59      4.88       3.40    89.52
Leeches Glossiphoniidae                          1.28      2.59      4.88       3.40    92.92


Group Spring 2005
Average similarity: 66.97

Species                                   Av.Abund    Av.Sim    Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae              6.42     14.61      9.20      21.82    21.82
Worms Oligochaeta                             4.67     11.55     20.99      17.24    39.06
Snails Physidae                               3.67      8.14      4.59      12.16    51.22
Snails Hydrobiidae                            3.19      7.97      6.51      11.90    63.12
Slatters Oniscidae                            1.72      4.22      7.11       6.30    69.42
Flatworms Dugesiidae                          1.87      4.20     15.55       6.27    75.69
Mussels Corbiculidae                          2.18      3.84      2.27       5.74    81.43
True bugs Notonectidae                        1.67      3.71      2.25       5.54    86.97
Dragonfly larvae Libellulidae                 2.01      3.13      6.71       4.68    91.65


Group Autumn 2006
Average similarity: 75.41

Species                                      Av.Abund    Av.Sim    Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 7.70     15.95     22.99      21.15    21.15
True bugs Notonectidae                           3.55      7.62     12.00      10.11    31.25
Dragonfly larvae Libellulidae                    2.92      5.42      3.65       7.19    38.44
Snails Physidae                                  2.57      5.39     10.50       7.15    45.60
Dragonfly larvae Coenagrionidae                  2.72      5.25     12.79       6.96    52.56
Mussels Corbiculidae                             2.37      4.90      6.84       6.50    59.06
Worms Oligochaeta                                2.57      4.75      3.53       6.30    65.36
Dragonfly larvae Megapodagrionidae               2.41      4.27      2.42       5.66    71.02
Flatworms Dugesiidae                             1.82      3.94     40.60       5.22    76.24
Dragonfly larvae Aeshnidae                       1.97      3.94     40.60       5.22    81.47
Dragonfly larvae Hemicorduliidae                 2.34      3.66      4.91       4.85    86.31
True Fly larvae s-f Orthocladiinae               1.61      3.22     40.60       4.27    90.58
```

```
Group Autumn 2007
Average similarity: 69.52

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 4.26      9.71     5.15      13.97    13.97
True bugs Notonectidae                           3.23      7.79     6.96      11.21    25.18
Snails Physidae                                  3.23      6.36     2.24       9.14    34.32
Snails Hydrobiidae                               2.51      5.25     2.69       7.55    41.88
Dragonfly larvae Hemicorduliidae                 2.47      5.09     2.72       7.33    49.20
Dragonfly larvae Megapodagrionidae               2.06      4.40     6.84       6.33    55.54
Caddisfly larvae Hydroptilidae                   1.93      4.09     4.75       5.88    61.42
True Fly larvae s-f Tanypodinae                  1.71      3.53     3.54       5.07    66.49
Dragonfly larvae Isostictidae                    1.64      3.19     4.05       4.59    71.08
Snails Lymnaeidae                                1.60      3.15     4.78       4.53    75.61
Dragonfly larvae Aeshnidae                       1.64      2.85     1.35       4.10    79.71
Dragonfly larvae Coenagrionidae                  1.57      2.28     1.24       3.28    83.00
Flatworms Dugesiidae                             1.43      1.76     0.79       2.53    85.53
Mayfly larvae Baetidae                           1.70      1.71     0.48       2.46    87.99
True Fly larvae Stratiomyidae                    1.02      1.68     1.33       2.42    90.41


Group Spring 2007
Average similarity: 65.17

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 4.63     14.76     4.83      22.65    22.65
Snails Physidae                                  3.92     14.38    11.29      22.07    44.72
Snails Hydrobiidae                               2.54      8.68     5.00      13.33    58.05
Dragonfly larvae Megapodagrionidae               1.97      5.33     2.53       8.17    66.22
Worms Oligochaeta                                1.68      5.09     2.75       7.81    74.03
True bugs Notonectidae                           1.43      4.64     4.77       7.12    81.15
Dragonfly larvae Isostictidae                    1.51      2.99     0.78       4.58    85.73
Dragonfly larvae Coenagrionidae                  1.01      1.86     0.77       2.85    88.58
True Fly larvae s-f Tanypodinae                  0.97      1.81     0.77       2.78    91.36


Group Autumn 2008
Average similarity: 63.54

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 3.63      9.91     6.68      15.60    15.60
True bugs Notonectidae                           3.12      9.02     3.62      14.19    29.79
Snails Physidae                                  3.11      6.90     2.31      10.86    40.65
Dragonfly larvae Megapodagrionidae               2.49      6.89     3.97      10.85    51.50
Flatworms Dugesiidae                             2.10      6.11     4.67       9.62    61.12
Snails Hydrobiidae                               2.61      5.21     1.25       8.20    69.32
Caddisfly larvae Hydroptilidae                   2.31      4.66     1.15       7.34    76.66
True Fly larvae s-f Orthocladiinae               2.39      4.48     1.24       7.04    83.70
Snails Planorbidae                               1.33      1.85     0.71       2.91    86.61
Dragonfly larvae Aeshnidae                       0.93      1.51     0.75       2.38    88.99
Worms Oligochaeta                                0.96      1.37     0.77       2.16    91.14


Group Spring 2008
Average similarity: 66.36

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Physidae                                  3.74     19.33     4.65      29.12    29.12
True Fly larvae s-f Chironominae                 3.71     17.61     4.48      26.53    55.65
Snails Hydrobiidae                               3.12     15.91     3.89      23.97    79.62
Dragonfly larvae Megapodagrionidae               1.19      4.58     1.30       6.90    86.52
Worms Oligochaeta                                1.26      4.10     1.29       6.19    92.71
```

SIMPER Porters Creek 2005, 2006, 2007 and 2008

```
Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample   Season Year
S3       Autumn 2005
S3       Spring 2005
S3       Autumn 2006
S3       Autumn 2007
S3       Spring 2007
S3       Autumn 2008
S3       Spring 2008


Group Autumn 2005
Average similarity: 77.34

Species                                      Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
True Fly larvae s-f Chironominae                 6.51     12.97    10.80       16.77   16.77
Snails Hydrobiidae                               4.59      8.36     7.06       10.81   27.58
Dragonfly larvae Isostictidae                    4.18      8.13    10.32       10.51   38.09
Dragonfly larvae Hemicorduliidae                 2.89      5.97    60.48        7.72   45.80
Snails Physidae                                  3.09      5.94    11.11        7.68   53.48
Dragonfly larvae Megapodagrionidae               3.01      5.44    11.33        7.03   60.51
Dragonfly larvae Coenagrionidae                  2.83      4.66     2.66        6.03   66.54
Snails Planorbidae                               2.30      4.54     8.09        5.87   72.40
Worms Oligochaeta                                2.45      4.16     4.70        5.38   77.78
Leeches Glossiphoniidae                          2.10      3.56     3.53        4.61   82.39
True Fly larvae s-f Tanypodinae                  2.39      3.40     4.45        4.40   86.79
Dragonfly larvae Aeshnidae                       1.41      2.98    60.48        3.86   90.65


Group Spring 2005
Average similarity: 72.69

Species                                   Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
True Fly larvae s-f Chironominae             10.09     23.35     7.12       32.12   32.12
Snails Hydrobiidae                            4.74     10.08     8.73       13.86   45.98
Worms Oligochaeta                             2.68      5.99    19.38        8.24   54.22
Dragonfly larvae Isostictidae                 2.63      5.99    19.38        8.24   62.46
Snails Physidae                               2.49      5.65     4.31        7.77   70.24
Leeches Glossiphoniidae                       1.99      4.63     6.74        6.37   76.61
Dragonfly larvae Libellulidae                 2.22      4.33     2.89        5.95   82.56
True bugs Corixidae                           1.80      2.91     3.64        4.00   86.56
Leeches Erpobdellidae                         1.28      2.88     4.62        3.97   90.53


Group Autumn 2006
Average similarity: 71.92

Species                                      Av.Abund    Av.Sim   Sim/SD    Contrib%   Cum.%
Snails Hydrobiidae                               4.07      8.77     4.85       12.20   12.20
Dragonfly larvae Coenagrionidae                  3.33      7.27     5.23       10.10   22.30
Dragonfly larvae Megapodagrionidae               3.64      7.01     7.28        9.75   32.05
Dragonfly larvae Isostictidae                    3.18      6.57    18.65        9.14   41.19
Worms Oligochaeta                                2.58      6.08    18.65        8.46   49.65
Dragonfly larvae Hemicorduliidae                 2.69      5.55    18.65        7.72   57.37
Fairy shrimps Atyidae                            2.74      5.55    18.65        7.72   65.09
Leeches Glossiphoniidae                          2.85      5.24     2.96        7.29   72.38
Dragonfly larvae Aeshnidae                       2.20      4.69    10.46        6.53   78.91
Snails Physidae                                  1.93      3.76    15.62        5.23   84.14
Dragonfly larvae Libellulidae                    1.66      3.11     2.72        4.32   88.46
True Fly larvae s-f Tanypodinae                  2.52      2.58     0.58        3.58   92.04
```

Group Autumn 2007

```
Average similarity: 71.28

Species                                       Av.Abund   Av.Sim   Sim/SD   Contrib%   Cum.%
Snails Hydrobiidae                                4.72    10.58     6.69      14.84   14.84
Snails Physidae                                   2.61     5.88     5.12       8.24   23.09
True bugs Notonectidae                            2.63     5.79     5.28       8.12   31.21
Dragonfly larvae Isostictidae                     2.79     5.76     3.27       8.08   39.29
True Fly larvae s-f Chironominae                  2.78     5.51     4.23       7.73   47.02
Dragonfly larvae Coenagrionidae                   2.63     5.44     3.69       7.64   54.66
Dragonfly larvae Megapodagrionidae                2.45     5.12     4.50       7.18   61.84
Dragonfly larvae Hemicorduliidae                  2.37     4.88     3.60       6.85   68.68
Dragonfly larvae Libellulidae                     2.15     4.36     3.65       6.11   74.80
Caddisfly larvae Hydroptilidae                    1.89     3.85     4.08       5.41   80.20
Fairy shrimps Atyidae                             2.15     3.77     2.18       5.29   85.49
True Fly larvae s-f Orthocladiinae                1.72     2.70     1.17       3.79   89.28
True Fly larvae s-f Tanypodinae                   1.33     1.79     0.78       2.51   91.80
```

Group Spring 2007

```
Average similarity: 67.64

Species                                       Av.Abund   Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                  4.72    18.60     7.09      27.50   27.50
Snails Hydrobiidae                                3.74    12.08     4.54      17.86   45.36
Snails Physidae                                   2.81     9.67     4.32      14.29   59.65
Worms Oligochaeta                                 2.70     8.17     3.30      12.08   71.73
Dragonfly larvae Megapodagrionidae                2.43     7.43     3.03      10.98   82.71
Dragonfly larvae Isostictidae                     1.45     3.67     1.28       5.42   88.13
Snails Planorbidae                                0.79     1.59     0.78       2.35   90.48
```

Group Autumn 2008

```
Average similarity: 60.24

Species                                       Av.Abund   Av.Sim   Sim/SD   Contrib%   Cum.%
True Fly larvae s-f Chironominae                  3.77    14.57     6.12      24.18   24.18
Snails Hydrobiidae                                3.11    11.74     5.98      19.48   43.67
Dragonfly larvae Megapodagrionidae                2.24     7.00     3.00      11.61   55.28
True Fly larvae s-f Orthocladiinae                2.30     5.76     2.29       9.57   64.85
True bugs Notonectidae                            1.87     5.35     3.11       8.87   73.72
True Fly larvae Stratiomyidae                     1.45     3.74     1.24       6.21   79.93
Worms Oligochaeta                                 1.34     2.46     0.78       4.09   84.02
Snails Physidae                                   1.20     2.10     0.73       3.49   87.51
Flatworms Dugesiidae                              1.15     2.00     0.70       3.31   90.82
```

Group Spring 2008

```
Average similarity: 52.26

Species                                       Av.Abund   Av.Sim   Sim/SD   Contrib%   Cum.%
Snails Physidae                                   2.92    12.47     4.82      23.87   23.87
Worms Oligochaeta                                 2.24     9.31     2.70      17.81   41.68
True Fly larvae s-f Chironominae                  2.57     7.72     0.77      14.77   56.44
Snails Hydrobiidae                                2.22     6.22     1.09      11.90   68.35
True bugs Notonectidae                            1.26     4.09     1.34       7.82   76.17
Dragonfly larvae Megapodagrionidae                1.09     4.04     1.19       7.72   83.89
Snails Planorbidae                                1.00     3.25     1.33       6.23   90.12
```

SIMPER Terrys Creek 2005, 2006, 2007 and 2008

```
Data worksheet
Name: Terrys(2)
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups
Sample   Season Year
S1       Autumn 2005
S1       Spring 2005
S1       Autumn 2006
S1       Autumn 2007
S1       Spring 2007
S1       Autumn 2008
S1       Spring 2008


Group Autumn 2005
Average similarity: 69.53

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae               4.28      8.68     8.63      12.48    12.48
Snails Hydrobiidae                               3.36      7.27    14.80      10.45    22.93
True Fly larvae s-f Chironominae                 3.72      5.63     2.01       8.10    31.03
Dragonfly larvae Isostictidae                    2.58      5.54    13.25       7.97    39.00
Worms Oligochaeta                                2.90      5.12     5.83       7.36    46.36
Flatworms Dugesiidae                             2.73      4.89     5.00       7.04    53.39
Snails Physidae                                  2.46      4.70     3.87       6.76    60.16
Mussels Corbiculidae                             2.38      4.28     8.30       6.15    66.31
True Fly larvae s-f Tanypodinae                  2.77      4.11    14.09       5.91    72.22
True bugs Notonectidae                           2.46      4.09     2.80       5.89    78.11
Dragonfly larvae Hemicorduliidae                 2.78      3.94     3.39       5.67    83.78
Snails Planorbidae                               1.80      3.62     5.83       5.20    88.98
Leeches Glossiphoniidae                          1.38      2.60     3.43       3.74    92.72


Group Spring 2005
Average similarity: 64.98

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 5.63     13.05    19.49      20.08    20.08
Snails Physidae                                  3.14      6.76     7.02      10.41    30.49
Worms Oligochaeta                                3.17      6.51    11.44      10.02    40.52
Dragonfly larvae Megapodagrionidae               2.93      6.38    16.31       9.82    50.33
Dragonfly larvae Isostictidae                    2.57      5.61     6.89       8.63    58.96
Mussels Corbiculidae                             2.05      3.57    12.60       5.50    64.46
True Fly larvae s-f Tanypodinae                  2.26      3.50     1.77       5.38    69.84
Flatworms Dugesiidae                             1.52      3.33    20.76       5.13    74.97
Aquatic mites Acarina                            1.88      3.10     2.59       4.78    79.74
True bugs Notonectidae                           1.47      2.70     3.90       4.15    83.90
Dragonfly larvae Libellulidae                    2.45      2.70     0.58       4.15    88.04
Snails Hydrobiidae                               2.35      2.48     0.58       3.82    91.86


Group Autumn 2006
Average similarity: 72.76

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Dragonfly larvae Megapodagrionidae               4.95      8.98    18.42      12.34    12.34
Dragonfly larvae Hemicorduliidae                 4.41      8.71    18.55      11.98    24.31
Worms Oligochaeta                                4.04      8.33    18.95      11.45    35.77
Snails Hydrobiidae                               3.58      5.51     2.85       7.58    43.34
True bugs Notonectidae                           2.23      4.48    14.83       6.16    49.50
Flatworms Dugesiidae                             2.63      4.25     2.15       5.85    55.35
True bugs Gerridae                               1.73      3.74    15.97       5.14    60.48
Snails Physidae                                  2.33      3.70     1.32       5.08    65.57
True Fly larvae s-f Tanypodinae                  2.44      3.70     1.32       5.08    70.65
True Fly larvae s-f Chironominae                 2.67      3.68     2.86       5.06    75.71
Dragonfly larvae Coenagrionidae                  2.10      3.62     3.89       4.98    80.69
Dragonfly larvae Isostictidae                    1.80      3.45     5.69       4.75    85.44
Aquatic mites Acarina                            1.52      3.05    15.97       4.19    89.63
Dragonfly larvae Libellulidae                    1.47      2.44     5.69       3.36    92.99
```

Group Autumn 2007

```
Average similarity: 65.81

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Hydrobiidae                               4.10      9.26     5.36      14.08    14.08
Dragonfly larvae Megapodagrionidae               3.47      8.29     5.44      12.60    26.68
True Fly larvae s-f Chironominae                 3.19      7.79     4.33      11.84    38.52
Flatworms Dugesiidae                             2.60      5.83     2.72       8.85    47.37
Snails Physidae                                  2.59      5.46     2.48       8.29    55.66
True bugs Notonectidae                           2.19      5.03     6.23       7.64    63.30
Worms Oligochaeta                                1.93      4.37     3.50       6.64    69.94
True Fly larvae s-f Tanypodinae                  2.09      3.92     2.41       5.96    75.90
Dragonfly larvae Hemicorduliidae                 1.68      3.07     1.30       4.66    80.56
Dragonfly larvae Isostictidae                    1.38      2.07     1.31       3.15    83.71
True Fly larvae s-f Orthocladiinae               1.29      1.75     0.77       2.66    86.36
Dragonfly larvae Libellulidae                    0.97      1.40     0.76       2.13    88.50
Dragonfly larvae Coenagrionidae                  1.06      1.28     0.76       1.95    90.45
```

Group Spring 2007

```
Average similarity: 64.85

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
True Fly larvae s-f Chironominae                 4.77     14.86     7.37      22.92    22.92
Snails Hydrobiidae                               3.55     10.82     3.75      16.68    39.60
Dragonfly larvae Megapodagrionidae               2.98      8.85     4.52      13.66    53.26
Snails Physidae                                  2.57      7.67     4.19      11.83    65.08
Flatworms Dugesiidae                             2.43      6.32     2.15       9.75    74.83
Worms Oligochaeta                                1.85      4.55     1.27       7.01    81.85
Dragonfly larvae Hemicorduliidae                 1.52      2.87     1.21       4.42    86.27
True Fly larvae s-f Tanypodinae                  1.00      2.33     1.35       3.60    89.87
Mussels Sphaeriidae                              1.12      1.98     0.73       3.06    92.93
```

Group Autumn 2008

```
Average similarity: 66.65

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Hydrobiidae                               3.50     14.68     4.25      22.02    22.02
Dragonfly larvae Megapodagrionidae               3.03     12.52     7.16      18.78    40.81
True bugs Notonectidae                           2.29      9.65     6.24      14.48    55.29
Snails Physidae                                  2.35      8.98     5.21      13.48    68.77
Flatworms Dugesiidae                             1.66      6.76     7.68      10.14    78.90
Worms Oligochaeta                                1.37      4.27     1.31       6.40    85.30
True Fly larvae s-f Chironominae                 1.35      3.72     1.29       5.59    90.89
```

Group Spring 2008

```
Average similarity: 62.32

Species                                      Av.Abund    Av.Sim   Sim/SD   Contrib%    Cum.%
Snails Hydrobiidae                               3.61     13.40     7.59      21.51    21.51
Snails Physidae                                  3.19     11.41     6.79      18.30    39.81
Dragonfly larvae Megapodagrionidae               3.06     10.77     4.55      17.28    57.09
True Fly larvae s-f Chironominae                 2.90      8.27     1.26      13.28    70.36
Worms Oligochaeta                                2.07      6.50     3.20      10.43    80.79
Flatworms Dugesiidae                             1.34      3.50     1.31       5.62    86.41
Mussels Sphaeriidae                              1.44      2.95     1.30       4.74    91.15
```

Appendix 6 BIOENV output

BIOENV of all five creeks with replicates merged for 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data1
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name:All five creek reps merged
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall
 13 Altitude
 14 Bedrock
 15 Boulder
 16 Cobble
 17 Total Length Pipe
 18 No. Outlets
 19 Ratio TLP/CA
 20 Ratio NO/CA
 21 Catchment Area

Best results
No.Vars    Corr. Selections
      5    0.328 4,9,16,17,20
      5    0.325 3,4,9,16,17
      5    0.322 3,6,12,16,17
      5    0.322 3,4,9,17,20
      5    0.320 4,6,9,16,17
      5    0.319 6,12,16,17,20
      5    0.318 6,9,16,17,20
      5    0.318 3,4,12,16,17
      5    0.317 3,6,12,17,20
      4    0.316 4,9,16,17
```

BIOENV of Archers Creek 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data4
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Archers Creek
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall

Best results
No.Vars    Corr. Selections
      3    0.379 4,5,12
      4    0.373 4,5,8,12
      3    0.371 5,8,12
      2    0.370 5,12
      5    0.370 4,5,7,8,12
      4    0.368 4,5,7,12
      4    0.368 3-5,12
      3    0.366 4,5,8
      5    0.364 3-5,8,12
      5    0.360 3-5,7,12
```

BIOENV of Shrimptons Creek 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data10
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Shrimptons Creek
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall

Best results
No.Vars    Corr. Selections
      1    0.355 8
      2    0.329 8,12
      2    0.313 5,8
      2    0.292 8,11
      3    0.290 8,11,12
      3    0.289 5,8,12
      3    0.288 7,8,12
      3    0.281 3,8,12
      2    0.276 7,8
      3    0.275 5,8,11
```

BIOENV of Buffalo Creek 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data6
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Buffalo Creek
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall

Best results
No.Vars    Corr. Selections
      4    0.406 2,3,10,12
      5    0.394 2,3,5,10,12
      5    0.390 2,3,7,10,12
      5    0.389 2,3,6,10,12
      3    0.382 2,3,12
      4    0.382 2,3,5,12
      5    0.381 2-4,10,12
      4    0.379 2,5,10,12
      3    0.370 2,10,12
      5    0.369 2,3,5,6,12
```

BIOENV of Porters Creek 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data8
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Porters Creek
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall

Best results
No.Vars    Corr. Selections
      3    0.508 5,8,12
      2    0.505 8,12
      3    0.500 2,8,12
      4    0.486 1,5,8,12
      1    0.482 8
      4    0.480 1,2,8,12
      5    0.476 1,2,5,8,12
      4    0.474 2,5,8,12
      2    0.474 5,8
      5    0.472 1,5,6,8,12
```

BIOENV of Terrys Creek 2005, 2006, 2007, 2008

```
Data worksheet
Name: Data12
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Terrys Creek
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 Log 10 Faecal Coliform
  2 Log 10 Ammonia
  3 Log 10 Oxidised Nitrogen
  4 Log 10 Total Phosphorus
  5 Log 10 Total Kjeldahl Nitrogen
  6 Alkalinity (Total)
  7 Log 10 Turbidity
  8 Log 10 Total Dissolved Solids
  9 pH
 10 DO
 11 Temp
 12 Rainfall

Best results
No.Vars    Corr. Selections
      2    0.276 6,12
      3    0.273 5,11,12
      2    0.270 5,12
      5    0.269 5,6,10-12
      1    0.269 12
      4    0.267 5,10-12
      4    0.265 6,10-12
      5    0.263 4,5,10-12
      5    0.263 2,5,10-12
      5    0.263 3,5,10-12
```