Ecowise Environmental

Final REPORT

"Biological and Water Quality Monitoring of Five Core Sites in Autumn 2006"

Contract No. EP/WQM/E1/04

for

City of Ryde

July 2006

The management of water resources is an integral part of environmental management and an essential requirement for supporting the economic, social and environmental objectives of our society

July 2006

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Executive Summary

Urban streams (such as those affected by runoff and discharges from urban areas) are an important subset of Australia's waterways. Most are degraded biologically, physically and chemically and therefore require specialised methods for health assessment and management. It is within this context that the City of Ryde has initiated a 7 year Biological/Chemical Monitoring Strategy which focuses on biological and water quality monitoring of 5 key urban creek systems within its area of operations.

Ecowise Environmental was commissioned by the City of Ryde to conduct the second year of sampling as part of a 7 year Biological/Chemical Monitoring Strategy, and this report covers the sampling event conducted in Autumn 2006. Core sampling sites were selected by Council and included sites on Terrys Ck, Shrimptons Ck, Porters Ck, Buffalo Ck and Archer Ck.

Autumn sampling was conducted in March (9th & 10th), April (9th & 10th) and May (9th & 10th). Sampling protocols defined in the "NSW Australian River Assessment System (AusRivAS) Sampling and Processing Manual, NSW EPA, July 2004" (Turak and Waddell, 2001) were adopted including physical and in-stream habitat descriptions. During each sampling event, water samples were collected and analysed for Total Dissolved solids, Total Phosphorus, Total Nitrogen, Ammonia, Total Alkalinity and Faecal Coliforms. In addition, an assessment of *in situ* water quality was undertaken which included pH, Dissolved Oxygen, Electrical Conductivity, turbidity and water temperature.

A review of the water quality data showed that dissolved oxygen concentrations fell below the recommended ANZECC and ARMCANZ guideline value of 85% saturation across all sites for all sampling events in Autumn 2006 except for Porters Ck (site 3) which was above 85% saturation for all sampling events. Electrical Conductivity in Porters Ck (Sites 3) recorded values above the ANZECC and ARMCANZ (2000) guideline for Aquatic Ecosystems during the April, May and March sampling events.

A total of 42 aquatic macroinvertebrate families were recorded over the three Autumn sampling events, with insects the most dominant (29 taxa) followed by gastropods (4 taxa), and crustaceans (4 taxa).

Following the identification and enumeration of the macroinvertebrate samples, the data were analysed using a number of univariate and multivariate techniques, including AusRivAS modelling. Both types of techniques provide differing levels of information. Univariate indices concentrate mainly on assessing the condition or "health" of the sites, whilst multivariate analysis routines allow patterns (if any) between sites/samples to be identified (Classification and Ordination), the key taxa from each sample which may be contributing to these differences (SIMPER), and the isolation of environmental variables that could be responsible for observed patterns (BVSTEP).

All sites within the City of Ryde study are indicative of urban creeks, with significant to severe impairment of ecological health. The main influences on these sites, and the creeks on which they are located, include poor water quality (exceeding recommended ANZECC and ARMCANZ, 2000 guidelines), and poor habitat diversity. Biodiversity and ecosystem health results from the Autumn 2006 sampling program are similar to those obtained in earlier monitoring programs, including the previous sampling program in Spring 2005. However, a comparison of results from Autumn 2002 to 2005 (Robyn Tuft and Associates and Ecowise) for Terrys Ck, Buffalo Ck and Porters Ck indicated an improvement in the ecological health of these creeks in 2006.

The Autumn 2006 sampling program has demonstrated that the design and methodology adopted for this project are appropriate to achieve the objectives of the City of Ryde program.

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1 INTRODUCTION

Urban streams are an important subset of Australia's waterways. Most are degraded biologically, physically and chemically and therefore require specialised methods for health assessment and management. The Urban Research and Development Program of the National River Health Program defines health in urban waterways as "the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition, diversity and functional organisation as comparable as practicable to that of natural habitats of the region".

The increasing urbanisation of catchments results in four broad inter-related forms of disturbance or degradation that can affect stream ecology:

- Disturbance of hydrological and hydraulic patterns
- Disturbance to stream geomorphology
- Degradation of water quality, and
- Habitat degradation or simplification

We now recognise that the benefits we derive from our cities have come at a considerable environmental cost. Urbanisation and associated human activity has profoundly affected rivers and streams around the world and the importance of the links between stream health and human health is increasingly being recognised both internationally and nationally. Streams in urban areas have received relatively little scientific attention when compared with systems in natural (minimally disturbed) or rural areas.

1.1 Background

The City of Ryde initiated a Biological/Chemical Water Quality Monitoring Strategy targeting 5 main creek systems within its area of operations. The program commenced in September 2004 and will be delivered over a 7 year period.

Shrimptons, Archer, Porters, Buffalo and Terrys Creeks have been targeted in this Strategy and it is proposed that one core monitoring site near the exit point of each of these creek systems be monitored within the terms of the Strategy.

The Strategy (COR Quotation No.: EP/WQM/E1/04) will enable the City of Ryde to:

- Evaluate chemical and biological water quality monitoring both for short and long term interpretation of creek health,
- 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 and accessibility,
- Prescribe how to sample macroinvertebrates at each site, 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 a standard suite of analyses to determine status and trends in water quality including calculation of the AusRivAS index,
- Provide the basis for an appraisal of the capacity of a standard monitoring program, eg. Streamwatch, and
- 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.

Ecowise Environmental was commissioned by City of Ryde to conduct the first year of sampling beginning in Spring 2004. This report covers the second sampling program for the Biological/Chemical Water Quality Monitoring Strategy in Autumn 2006.

1.2 Scope of Works

The scope of works for the Autumn 2006 sampling program, as specified in the project brief (Quotation No: EP/WQM/E1/04), included:

1. Measure aquatic macroinvertebrates and water chemistry at the 5 core sites selected by City of Ryde,
2. Sample in Autumn 2006 (March, April and May). Each site, as a minimum should be sampled once per month and sampling shall be undertaken strictly in accordance with NSW AusRivAS protocols,
3. Collect macroinvertebrates and chemical data at each core site,
4. Characterise each core site according to AusRivAS protocols for physico-chemical properties and sample the recommended chemical data,
5. Sample macroinvertebrates from the same 5 edge habitats at each core site,
6. Identify samples of macroinvertebrates to family level, and
7. Preserve specimens from selected families to allow for morphospecies identification if a SIGNAL2 was not apparent from the data collected at each geo-referenced point.

1.3 Historical sampling programs

A number of macroinvertebrate studies have previously been undertaken on the 5 core sites.

Shrimptons and Archer Creeks

- BioTrack (Dec, 2001) "Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde". Progress Report prepared for Ryde City Council.
- BioTrack (July, 2002) "Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde". Prepared for Ryde City Council.
- BioTrack (June, 2004) "Post restoration macroinvertebrate sampling of Archer Creek, Ryde". Prepared for Ryde City Council.
- Ecowise Environmental (2004) Biological Monitoring Program for City of Ryde.
- Ecowise Environmental (2005) Biological Monitoring Program for City of Ryde.

The BioTrack (2001; 2002) programs were designed to provide baseline biological water quality monitoring data to assist Ryde City Council in assessing the effectiveness of remediation works. Three sites were assessed, with two sites on Shrimptons Ck (one upstream and one downstream of the proposed remediation works) and one site on Archer Ck to be used as a benchmark. Samples were collected monthly between June 01 and May 02, using NSW AusRivAS protocols. The program results indicated both systems were typical of an urban creek environment, with abundant pollution tolerant taxa, and overall poor ecosystem health. This result was further enhanced by the post-restorative monitoring program conducted on Archer Ck at Maze Park by BioTrack (2004), with a dramatic reduction in taxa diversity when compared to the 2001 results. Several suggestions were thought to have caused this reduction including the sampling effort was less (only 3 sampling events), sampling was conducted over summer (conditions were unfavourable in Spring), and there was a reduced flow in the creek (no riffles were present).

Terrys, Porters and Buffalo Creeks

- Robyn Tuft & Associates (2002) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2002". Prepared for Lane Cove River Catchment Councils.
- Robyn Tuft & Associates (2003a) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2003". Prepared for Lane Cove River Catchment Councils.
- Robyn Tuft & Associates (2003b) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Spring 2003". Prepared for Lane Cove River Catchment Councils.

- Robyn Tuft & Associates (2004) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2004". Prepared for Lane Cove River Catchment Councils.
- Ecowise Environmental (2004) Biological Monitoring Program for City of Ryde.
- Ecowise Environmental (2005) Biological Monitoring Program for City of Ryde.

These programs were aimed at providing information on stream ecology, habitat, and hydrological impacts as well as providing an integrated index of water quality for key stream sites in the catchment area of Lane Cove. Single sampling events were conducted twice yearly from Autumn 2002 to Autumn 2004, using the NSW AusRivAS methodology. Results were assessed using AusRivAS models, SIGNAL2 Indices and the Riparian Channel-Environmental Inventory (RCE) field observations. The three sites of interest (Porters Ck, Terrys Ck, and Buffalo Ck) were reported as being moderate to poor ecological health with impacts from stormwater runoff and scouring flows during high storm events.

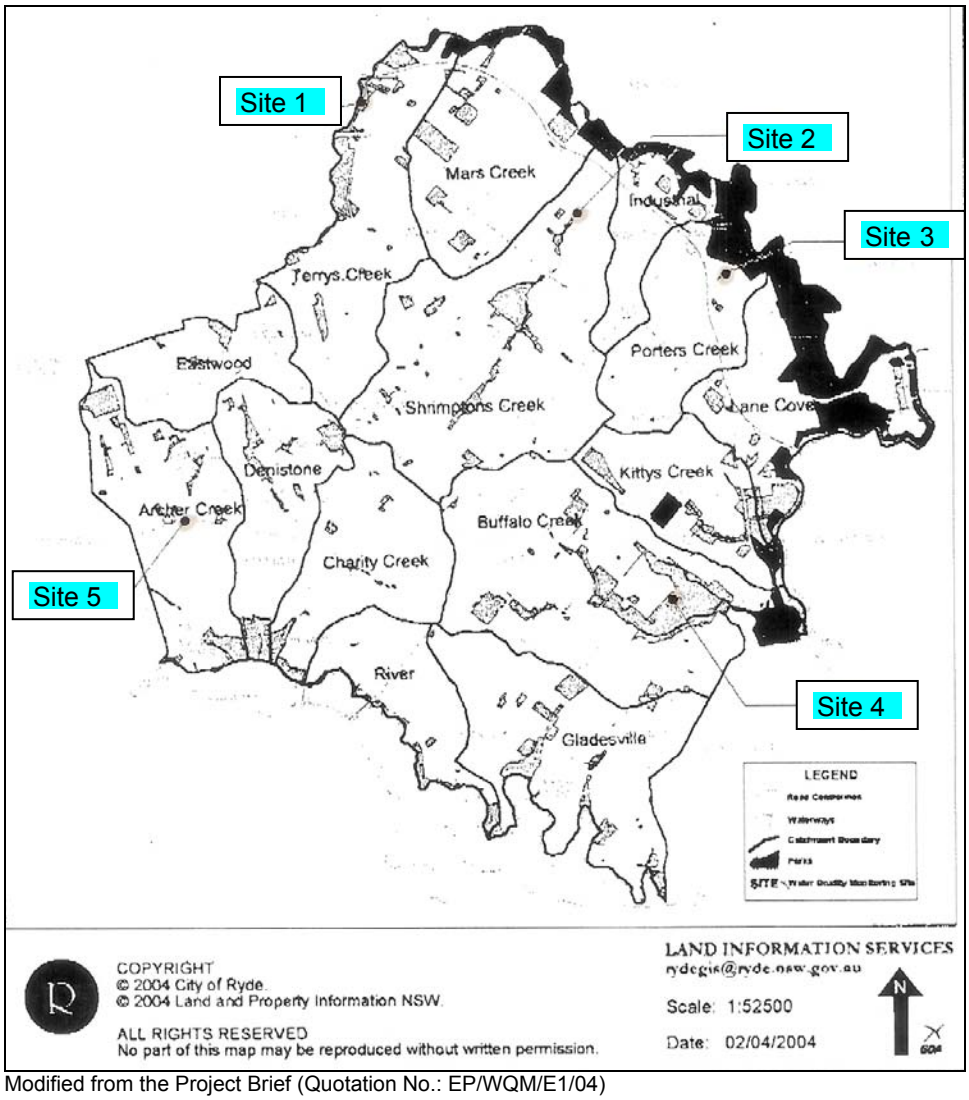
2 STUDY AREA

2.1 Site Locations

Core sample sites were pre-selected by City of Ryde, and include the following:

- Site 1 – Terrys Ck near the M2 motorway at the end of Somerset Rd, North Epping,
- Site 2 – Shrimptons Ck at Wilga Park,
- Site 3 - Porters Ck, accessed through the Ryde Council Depot, *after* the creek is piped under the Depot, and
- Site 4 - Buffalo Ck, accessed through private property (52 Higginbotham Rd).
- Site 5 – Archer Ck at Maze Park.

The locality of water quality monitoring sites, within their respective stormwater catchment areas, is presented in Figure 1 (City of Ryde Quotation No: EP/WQM/E1/04).



Modified from the Project Brief (Quotation No.: EP/WQM/E1/04)

Figure 1: Site locations for the Macroinvertebrate and Water Quality Monitoring Strategy for the City of Ryde, Autumn 2006.

2.2 Autumn 2006 Sampling Events

A total of three sampling events were conducted during the Autumn 2006 monitoring program, with all sampling events in separate months as required by the City of Ryde project brief (Quotation No: EP/WQM/E1/04):

- Event 1 – 9th and 10th March,
- Event 2 – 19th and 20th April, and
- Event 3 – 9th and 10th May.

3 METHODS

3.1 Physical Habitat Description

Physical and in-stream habitat descriptions were conducted in accordance with the River Bioassessment Manual and NSW AusRivAS protocols (MRHI, 1994; Turak *et al.*, 2004). Descriptions include using visual estimates of streambed composition (percentage of total for each substrate category), amount of in-stream organic material, and area of aquatic habitats. The mode width, mean depth and channel widths were also determined.

3.2 Water Quality Assessment

At each site, *in situ* dissolved oxygen, pH, electrical conductivity, and water temperature were measured using a Hydrolab DS4 multi-parameter water quality meter coupled to a Surveyor 4 digital display. This meter was fully calibrated in the laboratory in accordance with Ecowise Quality System requirements prior to deployment in the field. Turbidity was measured using a Hach 2100P Turbidimeter.

Water samples were collected for the chemical analyses of Total Dissolved Solids, Total Phosphorus, Total Alkalinity, and Faecal Coliforms, as specified by the City of Ryde project brief. Additional water samples were also collected during the Autumn 2006 sampling event for Total Nitrogen, Total Oxidised Nitrogen and Ammonia.

Water quality data was evaluated using default trigger values for Aquatic Ecosystems of south-east Australian lowland rivers, and the Recreational Waters and Aesthetics for Primary and Secondary Uses as outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000) (Table 1).

Table 1: Parameters and relevant water quality guidelines and criteria (ANZECC and ARMCANZ, 2000).

Indicator	Units	ANZECC and ARMCANZ Guidelines (2000)		
		Aquatic Ecosystems	Recreational Waters	
			Primary Contact	Secondary Contact
Conductivity	µS/cm	125 - 2,200	*N/G*	*N/G*
pH	pH units	6.5 - 8.0	5.0 – 9.0	*N/G*
Dissolved Oxygen	% sat	85 - 110	*N/G*	*N/G*
Turbidity	NTU	6 - 50	*N/G*	*N/G*
Total Phosphorus	µg/L	50	*N/G*	*N/G*
Total Nitrogen	µg/L	500	*N/G*	*N/G*
NOx	µg/L	40	*N/G*	*N/G*
Ammonium	µg/L	20	*N/G*	*N/G*
Water Temperature	°C	*N/G*	15 - 35	*N/G*
Faecal Coliforms	orgs/100ml	*N/G*	150	1000

N/G – No guideline

3.3 Macroinvertebrate Sampling

Sampling was undertaken by Ecowise in strict accordance with the protocols defined in the 'NSW Australian River Assessment System (AusRivAS) Sampling and Processing Manual, NSW EPA, July 2004' (Turak *et al.,* 2004). All procedures were diligently followed.

One 10 metre sample was collected from each of the edge and riffle habitats (where these existed) at each site. All sampling was undertaken with ISO DIS/7828 250 μm mesh nets (ISO, 1983). Nets were washed thoroughly in creek water between sampling events to remove any invertebrates retained on them.

3.3.1 Edge Sampling

At each site, the littoral or edge habitat (area along creek bank with little or no current) was sampled by sweeping the sample net along the edge of the stream. The net was swept around overhanging vegetation, against snags if present, in backwaters, and through beds of macrophytes. This process was continued, working upstream, over approximately 10 metres of edge.

3.3.2 Previous Sampling Program Methods

The sampling methods employed by previous sampling programs outlined in Section 1.3 have several differences when compared to the standard NSW AusRivAS protocols (Turak and Waddell, 2001; Turak *et al.,* 2004) employed by Ecowise.

Programs managed by Robyn Tuft and Associates state that samples were collected at each site for a period of 10 minutes and the complete sample was assessed at each site (Robyn Tuft and Ass, 2002; 2003a; 2003b; 2004). In comparison, Turak *et al.,* (2004) require a total length of 10 metres to be sampled of each habitat and the use of a live-picking method on each sample to capture the widest diversity of taxa. Robyn Tuft and Associates (2002; 2003a; 2003b; 2004) did not reference the AusRivAS manual (Turak *et al.,* 2004).

Programs managed by BioTrack reference the AusRivAS manual (Turak *et al.,* 2004) as the methods employed (BioTrack, 2001; 2002; 2004).

3.3.3 Sample Processing

For each sample, the collected material was placed into a sorting tray and macroinvertebrates picked for a minimum of 40 minutes by professionally qualified and experienced aquatic biologists using forceps and pipettes. If new taxa were collected between 30 and 40 minutes, sorting continued for a further 10 minutes. If no new taxa (not previously detected in sample) were found after the 10 minutes, then processing ceased. If new taxa were found, the 10-minute processing cycles were continued up to a maximum total sorting time of 1 hour. There is no set minimum or maximum number of animals collected using the NSW protocols (Turak *et al.,* 2004)

Samples were preserved in 80% ethanol and clearly labelled with information including site, habitat, sampling method, date and sampler. Samples were returned to the laboratory for identification using a dissecting microscope.

Most macroinvertebrate identification was to family level with some exceptions. Chironomidae (Diptera), were identified to sub-family, (Orthocladiinae, Tanypodinae, Chironominae etc.), Collembola, Nematoda and Oligochaeta were identified to class or order level in accordance with accepted convention (MRHI, 1994; Turak *et al.,* 2004) as were the microcrustacea, Ostracoda, Copepoda and Cladocera.

Samples were then preserved in an ethanol/water/glycerol mix for long term archiving and for future morphospecies identification if required.

3.3.4 Data Analysis

After the identification and enumeration of the macroinvertebrates samples, the data was analysed using a number of univariate and multivariate techniques. Both types of techniques provide differing levels of information, with univariate indices concentrating mainly on assessing the condition or "health" of the sites, whilst multivariate analyses allows comparisons between the sites based upon the community structure to determine if relationships exist between relevant environmental variables and macroinvertebrate communities.

Rapid bioassessment sampling (such as the NSW AusRivAS methods) does not provide a quantitative estimate of the abundance of each taxon in a sample and all macroinvertebrate data was converted to binary form (ie. presence/absence data) prior to analysis.

Univariate Analyses

Richness

Richness refers to the number of different taxa contained in the sample. Unlike some biological indices, a higher number does not always indicate better in-stream conditions. Higher values of this value may indicate favourable conditions in terms of availability of food and/or the quality of habitat. However, in some cases, high richness values can also occur when altered conditions provide habitats that may not occur naturally (e.g. riffle habitats due to altered flow conditions). Each richness value must be assessed individually with a final assessment based upon changes from natural or reference/control condition.

AusRivAS

AusRivAS (Australian River Assessment System) is a prediction system that uses macroinvertebrates to assess the biological health of Australian rivers. AusRivAS uses site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress. The expected fauna from sites with similar sets of predictor variables such as physical and chemical characteristics which can not be influenced due to human activities (e.g. altitude),

are then compared to the observed fauna. The ratio derived from this comparison is used to indicate the extent of any impact.

Several AusRivAS models currently exist for NSW, including:

- Single-Season models:
  - Spring Edge and Spring Riffle,
  - Autumn Edge and Autumn Riffle, and
- Combined-Season models:
  - Eastern Edge and Western Edge,
  - Riffle.

The Combined-Seasons model involves combining the biological results from Autumn and Spring sampling events for an overall health assessment of sites. However, using a Combined-Seasons model does not allow changes in condition to be detected between season sampling events. As the City of Ryde strategy aims to evaluate chemical and biological water quality monitoring both for short and long term interpretation of creek health, it was not deemed appropriate to use a Combined-Seasons model for the City of Ryde program at this stage.

To run the models, a number of variables are required from each site, depending upon the habitats present. The variables necessary to run the NSW Autumn Edge model are presented in Table 2 below.

Table 2: Variables required from each site to run the NSW Autumn Edge and AusRivAS models.

Edge Habitat	Description
ALKALINITY	Total Carbonates (mg/L)
ALTITUDE	Height above sea level (m)
BEDROCK	Percent bedrock in habitat (%)
BOULDER	Percent boulder in habitat (%)
COBBLE	Percent cobble in habitat (%)
LATITUDE	Latitude of site (decimal degrees to 4dp)
LOGDFSM	Log 10 (x) Distance from source
LOGMODEWIDTH	Log 10 (x) average of Mode stream width at site
LOGSLOPE1KUS	Log 10 (x) Slope: Elevation difference in metres between the middle of the site and a point 1km upstream.
LONGITUDE	Longitude of site (decimal degrees to 4dp)
RAINFALL	Mean annual rainfall (mm)

Observed / Expected Ratios

The Observed / Expected (O/E) ratio can range from zero, when none of the expected taxa are found at a site, to around one, when all the expected taxa are present. The value can also be greater than one when more families are found at the site than expected by the model. The O/E scores derived from the model can be placed in bands delineated by the Monitoring River Health Initiative (Table 3), which allows assessment of the level of environmental health at a site.

Table 3: Key to AusRivAS O/E family scores and bands for NSW Autumn Edge and Riffle habitats.

Band Label	O/E50 scores	Band Name	Comments
	Edge		
Band X	Infinity	More biologically diverse than reference sites.	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
Band A	1.17	Reference condition.	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
Band B	0.81	Significantly impaired.	Fewer families than expected. Potential impact either on water quality or habitat quality or both resulting in loss of taxa.
Band C	0.46	Severely impaired.	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
Band D	0.11	Extremely impaired.	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

Taxa Probability

The AusRivAS output also allows the ability to identify any *'indicator taxa'* collected or missing from the sample by measuring a taxa's probability of occurrence. The AusRivAS output includes:

- Taxa expected to be in the sample, that ***is*** collected; and
- Taxa expected to be in the sample, that is ***not*** collected.

Any taxa with a greater than 50% probability of occurrence, as indicated by the AusRivAS model, is expected to be collected if the site is in a healthy reference condition.

Indicator taxa are defined in this report as taxa within the PET (Plecoptera - stoneflies, Ephemeroptera - mayflies, and Trichoptera - caddisflies) orders, and/or with a SIGNAL2 score of equal to or greater than 6, having a moderate to high level of sensitivity to pollution. PET taxa have been found in many biomonitoring programs to be the orders most sensitive to environmental disturbance, and usually taxa belonging to these orders are the first to disappear following disturbance (EHMP, 2004).

This information, along with the taxa's SIGNAL2 score, will allow an assessment to be made of potential 'indicator taxa' present or absent from samples, which may be influencing the assessment of river health.

SIGNAL2

SIGNAL2 (Stream Invertebrate Grade Number Average Level - Version 2) (Chessman, 2003) is a simple scoring system for macroinvertebrates of Australian rivers and is derived from known responses of macroinvertebrate taxa to water pollution. Each taxon is assigned a number from 1 (tolerant) to 10 (sensitive). The site index has been calculated in the past by summing the sensitivity scores for all families present and then dividing by the number of families present (average of scores for all families in a sample).

The interpretation of the more recent SIGNAL2 data follows that suggested by Chessman (2003) and Coysh *et al*. (2000). In order to overcome natural variation, Chessman (2003) suggests using the observed / expected (O/E) SIGNAL2 scores predicted using AusRivAS. The observed (O) SIGNAL2 score is the sum of the grades of taxa collected, divided by the number of families collected. The expected (E) SIGNAL2 score is obtained by multiplying the grade of each taxon by its probability of collection, summing the products, and dividing by the sum of the probabilities.

The example below (Table 4) used by Chessman (2003) best explains this equation.

Table 4: Simplified hypothetical example of the suggested use of AusRivAS computer outputs to calculate a predicted SIGNAL2 score (Chessman, 2003)

Taxon	SIGNAL2 grade	Probability of collection	Grade x Probability	Taxon Collected?
Family A	5	1	5	yes
Family B	3	0.8	2.4	no
Family C	10	0.6	6	no
Family D	7	0.6	4.2	yes
Family E	8	0.5	4	yes
Family F	4	0.3	1.2	yes
Family G	7	0.1	0.7	no
Family H	9	0.1	0.9	no
Family I	5	0	0	no
Family J	1	0	0	yes
Sum		**4**	**24.4**	

Observed Score = (5 + 7 + 8 + 4 + 1) / 5 = 5.0
Expected Score = 24.4 / 4.0 = 6.1

O/E50SIGNAL2 = 5.0 / 6.1 = 0.82

Currently, no bandings have been developed for this analysis (Coysh *et al.,* 2000; Chessman *pers comm*); however, an O/E50 SIGNAL2 score of around 1 would suggest the observed SIGNAL2 score was similar to what was expected at the site.

Multivariate Analyses

The use of multivariate analysis techniques allow exploration into the patterns of the macroinvertebrate communities of which univariate techniques cannot. The routines used in this study will allow patterns (if any) between sites/samples to be identified (Classification and Ordination), the key taxa from each sample which may be contributing to these differences (SIMPER) and the isolation of environmental variables that could be responsible for observed patterns (BVSTEP).

Community multivariate analyses can be significantly altered due to rare or uncommon taxa occurring. In this study, rare taxa were excluded prior to analysis primarily due to their occurrence being more a matter of chance rather than being properly represented in the community. Rare taxa do not contribute information to the patterns existing within the data, rather they can create 'noise' which has the effect of masking patterns (Clarke and Warwick, 2001). A common cut-off level used in presence/absence data is greater than 5% occurrence in samples (Clarke and Warwick, 2001) and this level was applied for this study. All multivariate analyses were performed using the statistical package PRIMER Version 5.2.9 (PRIMER-E: Plymouth Marine Laboratory, UK).

Classification

Classification (also called *cluster analysis*) is a mathematical method of grouping entities according to the relative similarity of their attributes. In an ecological setting these techniques can be used to group sites according to the similarity of the organisms found within them.

The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Bray & Curtis, 1957; Clifford & Stephenson, 1975). From this matrix, hierarchical agglomerative clustering was obtained. This classification formed the basis for the construction of a dendrogram, which presents the sites as groups based on a pattern of branching points, each defined by a level of similarity.

Ordination

Like classification, ordination provides a representation of the relative similarity of entities (i.e. site samples) based on their attributes (i.e. macroinvertebrate community composition) within a reduced dimensional space. The more similar sites are to each other, the closer they are located within the ordination space. This procedure is useful to display the samples' interrelations on a continuous scale and allows a check to see how "real" the groups identified in the classification technique are.

A Non-metric Multi-Dimensional Scaling (NMDS) ordination was performed on the similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient. The number of axes used in the ordinations was based on resultant stress levels. The stress level is a measure of the distortion produced by compressing multi-dimensional data into a reduced set of dimensions and will increase as the number of axes (i.e. dimensions) is reduced. All ordinations were initially calculated for two axes; however, if the resultant stress level exceeded 0.30, the ordination was recalculated for three axes (i.e. 3 dimensions). A stress level of <0.2 is considered a useful ordination.

SIMPER

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

BVSTEP

The proportion of macroinvertebrate variation explained by measured environmental variables (e.g. water depth, substrate composition etc) was calculated using the BVSTEP routine. BVSTEP is a procedure that calculates agreement between the macroinvertebrate similarity matrix (Bray-Curtis) and multiple Euclidean distance matrices derived from environmental variables (Clarke and Gorley, 2001). It is important to quantify the factors that may be

contributing to the differences between sites, as it is a means of directly associating the changes related to an environmental factor and eliminates the "guess work" in identifying the possible causes in changing community composition.

4 RESULTS

4.1 Rainfall Data

Daily rainfall data collected from a weather station in Marsfield over the past twelve months is indicated in Figure 2. All events were found to have minimal rainfall in the week preceding sampling (<10mm in 7 days). The highest volume of rainfall was recorded on the 30/06/2005 with 50.4mm recorded and 27/02/2006 with a result of 46 mm/day two weeks prior to the March sampling. No significant difference in Rainfall prior to Spring and Autumn sampling is obvious.

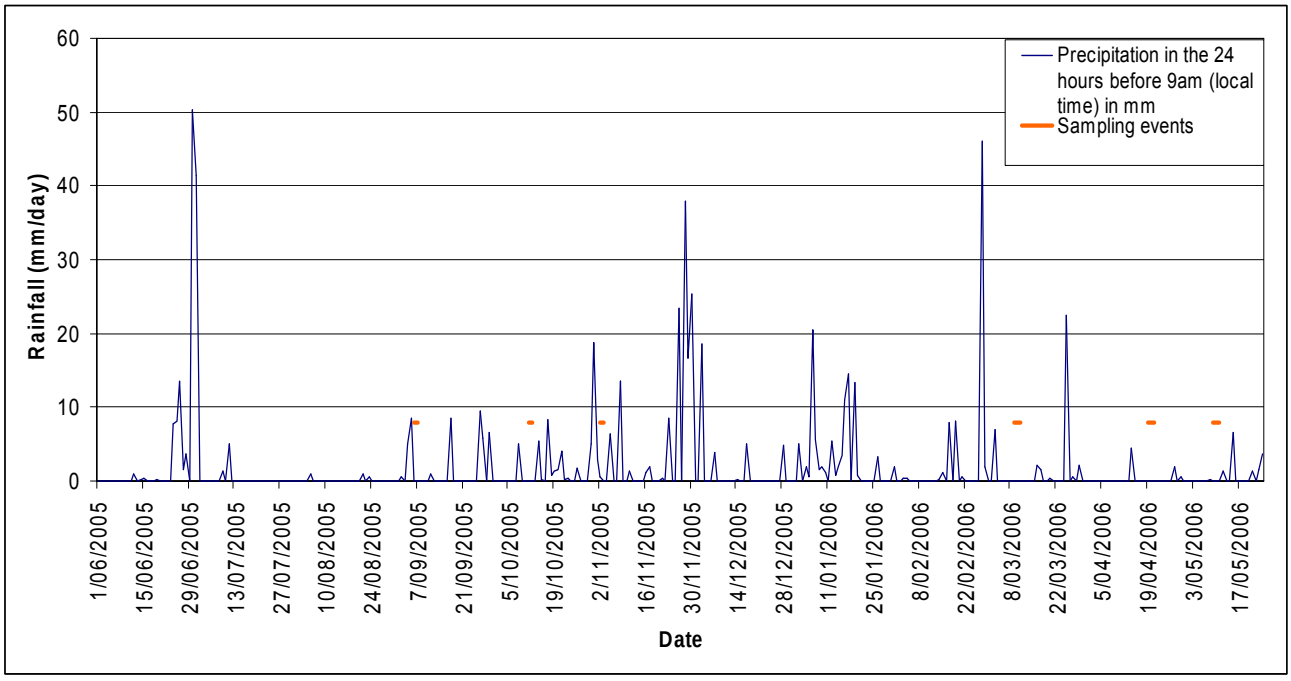


Figure 2: Daily rainfall data (mm) from Marsfield (Bureau Of Meteorology Station #066156) between June 2005 to May 2006. The sampling events during Spring 2005 and Autumn 2006 are indicated.

4.2 Water Quality

4.2.1 *In situ* results

The results for *in situ* water quality parameters measured at each of the macroinvertebrate sites over the course of the program are presented in Table 5.

Table 5: In situ water quality results from the seven sites within the City of Ryde, Autumn 2006. Results outside the ANZECC and ARMCANZ (2000) guidelines have been highlighted in red.

Site	Sampling Event	Time sampled	Water Temp. (°C)	Conductivity (µS/cm)	pH	DO (mg/L)	DO (%sat.)	Turbidity (NTU)
*Aquatic Ecosystems			N/A	125 - 2200	6.5 – 8.0	N/A	85 - 110	50
^Primary Contact			15-35	N/A	5.0 – 9.0	N/A	N/A	N/A
1	March	14:00	20.16	380.5	6.82	4.99	54.8	2.27
	April	09:45	15.69	305.9	6.95	2.40	24.9	3.20
	May	10:00	11.90	358.4	7.07	3.98	37.0	2.35
2	March	11:30	21.06	435.2	6.74	2.13	23.6	4.56
	April	14:00	16.82	281.0	6.74	4.61	48.6	5.0
	May	14:30	13.07	264.4	6.76	5.04	48.9	7.69
3	March	15:00	25.21	3712	7.40	7.42	90.2	1.88
	April	13:00	19.78	3792	7.63	8.30	91.50	2.3
	May	12:30	15.30	2916	7.34	8.33	85.2	1.17
4	March	12:23	22.09	738.1	7.19	4.36	49.5	7.96
	April	12:00	19.18	749.1	7.23	4.64	49.9	5.1
	May	10:30	11.68	667.1	7.32	4.72	44.8	4.39
5	March	10.00	20.61	1482	6.98	4.09	44.9	2.52
	April	09:30	18.36	259.0	7.09	4.38	46.0	4.1
	May	09:00	12.35	245.2	7.19	6.31	60.1	5.13

* - ANZECC and ARMCANZ (2000) guidelines for Aquatic Ecosystems – lowland rivers of south eastern Australia
^ - ANZECC and ARMCANZ (2000) guidelines for Recreational Water Quality and Aesthetics (Primary eg swimming; Secondary eg. Boating).

A review of the water quality data showed that dissolved oxygen concentrations fell below the recommended ANZECC and ARMCANZ guideline value of 85% saturation across all sites for all sampling events in Autumn 2006 except Porters Ck (site 3) which was above 85% saturation for all sampling events.

Electrical Conductivity in Porters Ck (Site 3) was above the ANZECC and ARMCANZ (2000) guideline for Aquatic Ecosystems during the March, April, and May sampling events.

Water temperature was the other significant result with a drop of at least 7.5°C at the five sites between April and May sampling events. All other *in-situ* water quality fell within ANZECC and ARMCANZ (2000) Guidelines for Aquatic Ecosystems on all occasions in Autumn 2006.

4.2.2 Laboratory Water Quality Results

Results for the laboratory analyses of water samples at each of the macroinvertebrate sites over the course of the program are presented in Table 6.

Table 6: Laboratory analysed water quality results from the five sites within the City of Ryde, Autumn 2006. Results outside ANZECC and ARMCANZ (2000) guidelines have been highlighted in red.

Site	Sampling Event	Time sampled	TDS (mg/L)	TP (µg/L)	TN (µg/L)	NOx (µg/L)	TKN (µg/L)	NH_4^+ (µg/L)	Faecal Coliforms (orgs/100ml)	Total Alk. ($CaCO_3$)
*Aquatic Ecosystems			N/A	50	500	40	N/A	20	N/A	N/A
^Primary Contact			N/A	N/A	N/A	N/A	N/A	N/A	150	N/A
^Secondary Contact			N/A	N/A	N/A	N/A	N/A	N/A	1000	N/A
1	March	14:00	180	30	370	60	310	<10	160	50
	April	09:45	180	100	1200	90	1100	450	560	45
	May	10:00	220	50	620	240	380	70	66	60
2	March	11:30	230	50	390	<10	380	40	330	85
	April	14:00	160	80	510	30	480	30	860	40
	May	14:30	140	80	380	40	340	20	750	35
3	March	15:00	2200	20	2300	760	1500	820	9800	48
	April	13:00	2100	20	1300	630	700	350	290	45
	May	12:30	1700	10	1400	650	800	400	40	0.25
4	March	12:23	390	70	1000	470	500	130	220	90
	April	12:00	400	60	920	450	470	90	170	70
	May	10:30	400	60	720	480	240	60	110	90
5	March	10.00	830	100	600	80	520	90	140	95
	April	09:30	150	70	860	470	390	90	240	45
	May	09:00	120	40	670	370	300	50	28	55

* : ANZECC and ARMCANZ (2000) guidelines for Aquatic Ecosystems – lowland rivers of south eastern Australia
^ : ANZECC and ARMCANZ (2000) guidelines for Recreational Water Quality and Aesthetics (Primary eg swimming; Secondary eg. Boating).

High nutrient levels of Nitrogen and Ammonia were recorded in all creeks during the Autumn 2006 sampling program, with Porters Ck recording the highest results. Site 3 recorded over 15 times the recommended trigger level set by ANZECC and ARMCANZ (2000) for Ammonia, and over four times the trigger level for Total Nitrogen, during the March sampling program.

Total Phosphorus levels above the guidelines were recorded for 4 sites during the April event, (sites 1, 2, 4 and 5) and for 3 sites during the May event (sites 2,4 and 5). Total Phosphorus results for Porters Ck (site 3) were below the guideline level during the all three (March, April and May) sampling events. All sites except for Shrimptons Ck (site 2) showed values outside the ANZECC and ARMCANZ (2000) trigger levels for Total Oxidised Nitrogen (NOx).

Faecal coliform results were above the primary contact guideline at all sites during at least one sampling event in Autumn 2006. Porters Ck (Ssite 3) during March was above the secondary contact results, with a recorded level 9.8 times the secondary contact guideline limit. Faecal coliform results for site 3 were below the secondary contact level during the April event and had reduced to well below the primary contact guideline limit during the May 2006 events.

4.3 Macroinvertebrate Results

4.3.1 General Characteristics of Aquatic Macroinvertebrates

A total of 42 different families were recorded over the three Autumn sampling events, with insects the most dominant (29 taxa) followed by gastropods (4 taxa), and crustaceans (4 taxa). A full macroinvertebrate taxa list is presented in **Appendix A**.

4.3.2 Univariate Analyses

Macroinvertebrate Taxa Richness

Taxa richness for each of the macroinvertebrate sites over the three events is presented in Table 7.

Table 7: Macroinvertebrate taxa richness from five sites within the City of Ryde, Autumn 2006.

Site	Habitat	Sampling Event			Combined sample diversity
		March	April	May	
1	Edge	25	21	17	29
2	Edge	14	10	9	16
3	Edge	16	18	17	24
4	Edge	20	20	20	28
5	Edge	16	15	16	20

Taxa richness was highest in the edge habitat at Site 1 (Terry's Ck) during the March and April sampling event, and had the highest combined sample diversity for the Autumn 2006 program. Site 4 (Buffalo Ck) recorded the highest taxa richness for the May sampling event. The lowest taxa richness was recorded in the edge habitat at Site 2 (Shrimptons Ck) during each event and also resulted in the lowest combined sample diversity for Autumn 2006.

SIGNAL2

SIGNAL2 scores for each of the five sites over the three events are presented in Figure 3.

Most O/E50Signal results were between 0.7 and 1.0. The edge samples collected at Site 4 during March, April and May resulted in an O/E50Signal Score of below 0.8.

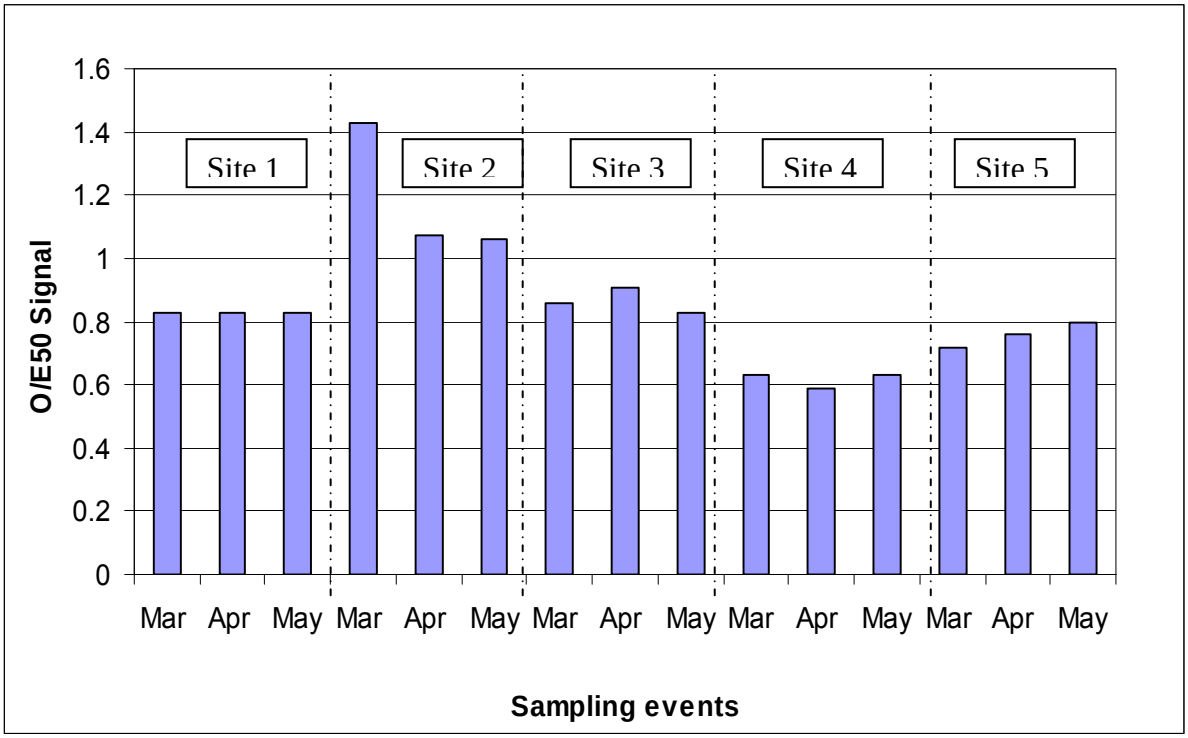


Figure 3: O/E50SIGNAL scores from the five sites within the City of Ryde, Autumn 2006.

AusRivAS

Observed / Expected Ratios

AusRivAS results for each of the core sites over the three events are presented in Figure 4.

The majority of AusRivAS results were recorded in Band 'B' or 'C', with 6 out of 15 results being within Band 'B' and 7 samples with a Band value of 'C', and one result in each Band 'A' and Band 'D'. Site 5 (Archer's Ck) recorded all sampling events in Band B, while Site 2 (Shrimpton's Ck) recorded two samples in Band C and one in Band D. Shrimptons ck shows some difference of results for Signal 2 and AusRivAS bandings. This is due to numerous sensitive taxa (Signal score <6) being observed in the sample but not being predicted to occur.

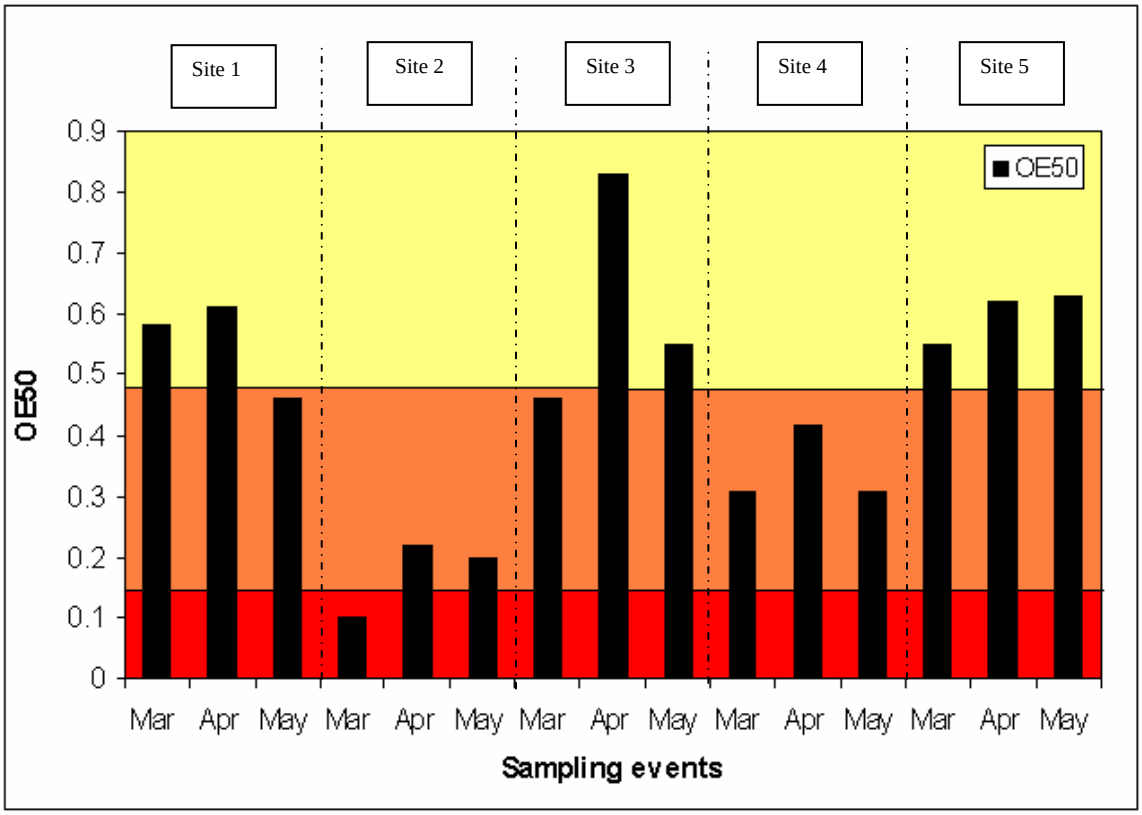


Figure 4: AusRivAS results from the five sites within the City of Ryde,Autumn 2006. The AusRivAS bandings are also presented; D – Red, C – Orange, B – Yellow.

Taxa Probabilities

The AusRivAS taxa probability results for the Autumn 2006 program are presented in **Appendices B** and **C**. A total of 17 expected taxa were missing from samples collected over the Autumn 2006 sampling event, with 3 of those missing within the PET taxa orders.

The PET taxa which had a >50% expectation at each site included:

- Leptophlebiidae (8) – Ephemeroptera (mayflies);
- Leptoceridae (8) - Trichoptera (caddisflies); and
- Baetidae (5) - Ephemeroptera (mayflies).

Leptophlebiidae (8) was not collected in any of the samples yet was considered to have an 86-100% probability of occurrence in all samples. In contrast, Baetidae (5) was collected in one sample in Site 4 (Buffalo Ck) yet was only expected at 50-53% in samples at Site 1 (Terrys Ck). Leptoceridae (8) was expected (>90%) in all samples across all sampling events yet was only collected in 2 samples at Site 3 (March and April, Porters Ck).

Other indicator taxa expected in the samples included:

- Acarina (6) – mites,
- Scirtidae (6) – beetles, and
- Elmidae (7) – beetles.

A number of samples collected Acarina (7 out of 15 samples) which were >50% expected in all samples. Scirtidae, with an expectancy of >50% for all samples was not observed at any of the sites over the sampling period March to May. Elmidae was only expected to be at site 1 during the May sampling event but was not observed in this sample.

The remaining taxa >50% expected but not observed in the samples were all considered to be pollution tolerant taxa.

The taxa collected during all three events during Autumn 2006 at each site, and dominating the samples, are presented in Table 8. The dominant taxa across all sites was Oligochaeta (2) (worms) and Physidae (1) (snails), both taxa tolerant of pollution. Other taxa dominating most sites included Chironominae (3) (biting midges) and Megapodagrionidae (5) (damselfly).

Table 8: Taxa collected in all samples during all three events at each site, Autumn 2006 City of Ryde.

Site 1	Site 2	Site 3	Site 4	Site 5
Chironominae	Corbiculidae	Oligochaeta	Chironominae	Chironominae
Oligochaeta	Oligochaeta	Physidae	Oligochaeta	Oligochaeta
Physidae	Physidae	Atyidae	Orthocladinae	Coenagrionidae
Tanypodinae	Dugesidae	Hydrobiidae	Culicidae	Hemicordulidae
Gerridae	Acarina	Glossiphoniidae	Stratiomyidae	Megapodagrionidae
Coenagrionidae	Hemicordulidae	Aeshnidae	Physidae	Dugesidae
Dugesidae		Coenagrionidae	Dugesiidae	Libellulidae
Hydrobiidae		Isostictidae	Coenagrionidae	Veliidae
Libellulidae		Megapodagrionidae	Hemicordulidae	Notonectidae
Notonectidae		Hemicordulidae	Megapodagrionidae	Glossiphoniidae
Hemicordulidae		Libellulidae	Notonectidae	Aeshnidae
Isostictidae		Chironominae	Corbiculidae	
Megapodagrionidae			Libellulidae	
Acarina				

Taxa Comparison with Spring 2005

A comparison of macroinvertebrate taxa observed in samples from Sites 1 to 5 in Spring 2005 and Autumn 2006 are presented in Table 9.

The most dominant taxa present in all samples across both sampling programs were Oligochaeta (worms), Physidae (snails), and Chironominae (biting midges).

Other very common taxa present in most samples from both programs included:

- Coenagrionidae (2) and Megapodagrionidae (5) – Odonata: damselflies,
- Hemicordulidae (5) – Odonata: dragonflies,

- Corbiculidae/Sphaeriidae (4/5) – Bivalvia: freshwater mussels,
- Hydrobiidae (4) and Planorbidae (2) – Gastropoda: snails, and
- Stratiomyidae (4) – Diptera: soldier flies.

Table 9: Comparison of macroinvertebrate taxa observed in City of Ryde samples for Sites 1 to 5 in Spring 2005 and Autumn 2006 (■ taxa present in three samples, ● taxa present in two samples, ▼ taxa present in one sample). Signal grades for each taxa are presented in brackets.

Taxa	Site 1		Site 2		Site 3		Site 4		Site 5	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Acarina (6)	■	■	●	■	▼	▼	■		▼	
Aeshnidae (4)	▼	■		●	▼	●	▼	■	▼	■
Atyidae (3)		■			▼					●
Baetidae (5)								▼		
Corydalidae (7)		▼								
Ceinidae (2)	●				●		●		▼	
Ceratopogonidae (4)	▼							▼		
Chironominae (3)	■	■	■	■	■	■	■	■	■	■
Cladocera	●									
Coenagrionidae (2)	▼	■	▼	●		■		■	●	■
Copepoda	●	●	■	●	●	▼	■	●	●	
Corbiculidae/ Sphaeriidae (4/5)	■	●	■	■		▼	■	■		●
Corixidae (2)	▼		▼		●		●			
Culicidae (1)	▼	▼			▼		▼	▼	●	●
Dugesiidae (2)		■		■				■		■
Dytiscidae (2)	▼		■				▼		●	
Elmidae (7)	▼	●								
Erpobdellidae (1)					■					
Eustheniidae (10)						▼				
Gelastocoridae (5)			●							
Gerridae (4)	●	■				▼		●	▼	●
Glossiphoniidae (1)	●	●	■	●	■	■		●		■
Gomphidae (5)					▼					
Hemicorduliidae (5)	▼	■		■	▼	■	▼	■	▼	■
Hydrobiidae (4)	●	■	▼		●	■	●	▼		
Hydrophilidae (2)								▼		
Hydroptilidae (4)		▼								
Isostictidae (3)	■	■			■	■	▼	●		
Leptoceridae (6)				●						
Libellulidae (4)	●	■	●	●	■	■	■	■	■	■
Lymnaeidae (1)	●	▼	▼	▼				●		▼
Megapodagrionidae (5)	■	■			●	■	●	■	●	■
Mesoveliidae (2)								▼		
Nepidae (3)					▼					
Notonectidae (1)	■	■			▼	●	■	■		■
Oligochaeta (2)	■	■	■	■	■	■	■	■	■	■
Oniscidae (2)	▼		▼		▼		■	▼	▼	▼
Orthocladiinae (4)		▼				▼		■		
Ostracoda		▼	▼	▼	▼		■	▼		
Parastacidae (4)				▼						
Physidae (1)	■	■	■	■	■	■	■	■	■	●
Planorbidae (2)	●	▼	■	▼	●	●	▼			
Pleidae (2)				▼						
Simuliidae (4)	●						▼			
Stratiomyidae (4)	▼	▼	▼		▼		▼	■	▼	●
Synlestidae (7)	▼									
Talitridae (3)		●				▼		▼		
Tanypodinae (4)	■	■				●	▼	▼	▼	●
Tipulidae (4)										▼
Veliidae (1)	▼	●				▼			▼	■

Most taxa observed during a single season program only were only present in <20% of samples collected for that season, suggesting those taxa are rare in the study area. A total of 23 taxa from the 50 taxa observed were isolated to one sampling program only, and only six of those taxa were collected in more than two samples. They were:

- Ceinidae (2) (amphipods) – 7 samples, isolated to Spring 2005 only,
- Corixidae (2) (hemiptera) – 6 samples, isolated to Spring 2005 only,
- Dugesidae (2) (flatworms) 12 samples isolated to Autumn 2006,
- Dytiscidae (2) (beetles) – 7 samples, isolated to Spring 2005 only,
- Orthocladiinae (4) (Diptera) – 5 samples, isolated to Autumn 2006 only, and
- Talitridae (3) (amphipods) - 4 samples, isolated to autumn 2006 only.

A total of 10 taxa were isolated to the Spring program only, with no taxa classified as indicator taxa. During autumn there were 13 taxa isolated with 3 of the 13 taxa present classified as indicator taxa (2 x Trichoptera and 1 x Ephemeroptera).

4.3.3 Multivariate Analyses

Classification and Ordination

Classification of the edge habitat samples over the three events revealed 3 out of the 5 sites had a 70% or greater similarity in macroinvertebrate community composition, including Sites 1, 3, 4, and 5 (Figure 5).

Site 2 samples were revealed to be the most dissimilar to the other samples based on macroinvertebrate community composition, separating from the remaining samples at the 55% similarity. Site 3 samples were the second group to separate at the 78% similarity. The remaining samples did not separate out until the 70% and greater similarity level.

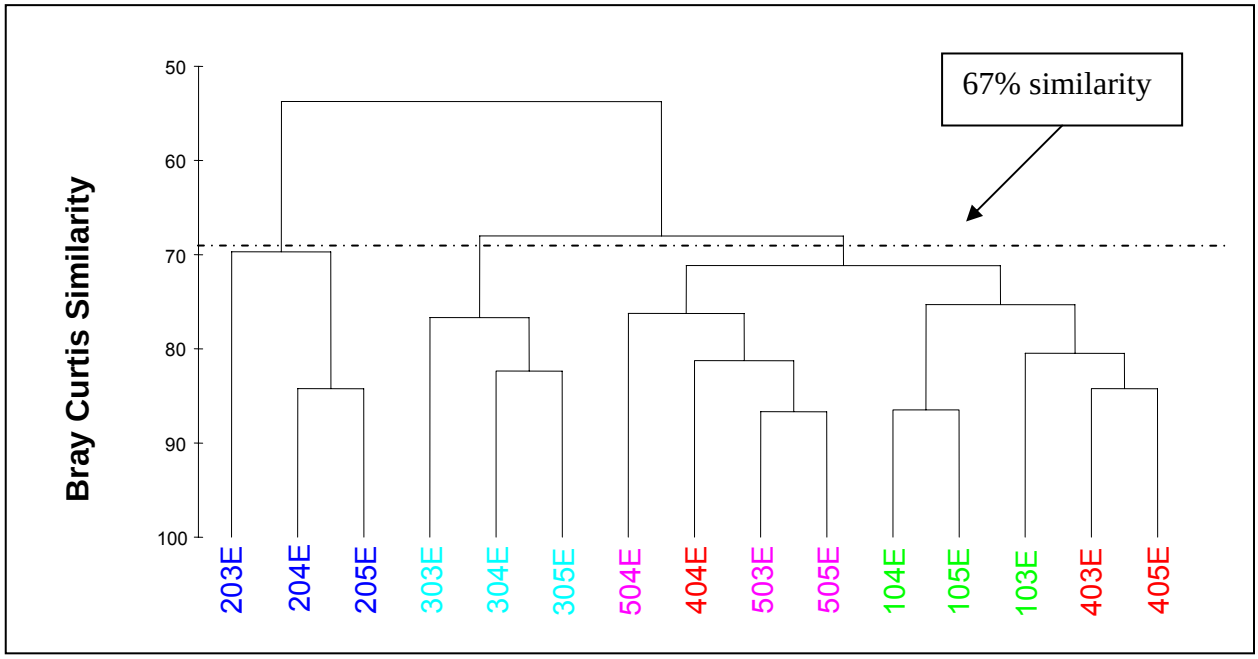


Figure 5: Classification of macroinvertebrate samples collected from five sites during the Autumn 2006 monitoring program, City of Ryde. Samples labelled with site code (eg. 1 – Terrys Ck), sampling month (eg. 03 - March) and habitat (E – edge). 67% similarity is indicated.

The groupings presented in Figure 5 are further enhanced in the NMDS plot (Figure 6) at the 67% similarity level.

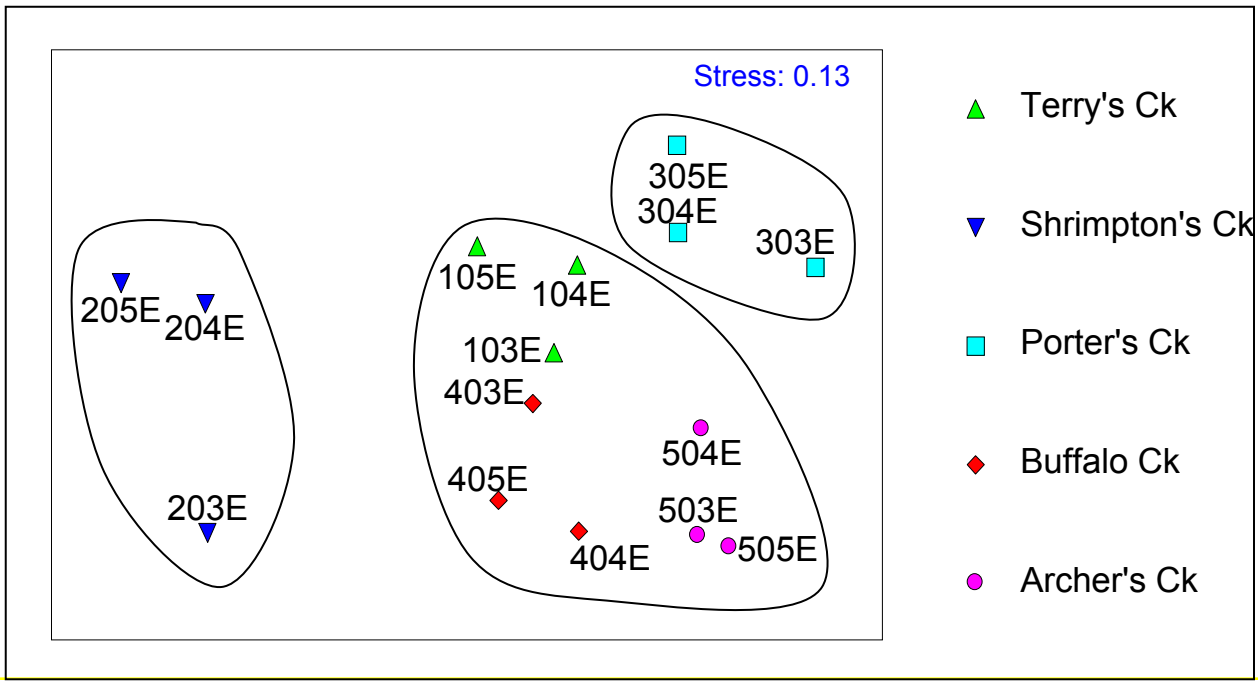


Figure 6: Non-metric Multi-dimensional Scaling (NMDS) ordination of macroinvertebrate samples collected from five sites during the Autumn 2006 monitoring program, City of Ryde. Superimposed groupings refer to the 67% similarity level from the classification. (stress was calculated at 2 dimensions).

SIMPER

The SIMPER average dissimilarity results based on community composition between the five sites is presented in Table 10. The raw data is presented in **Appendix E.**

Table 10: Average dissimilarity (%) results for community composition data from samples collected at five sites during the Autumn 2006 monitoring program, City of Ryde.

Site	1	2	3	4	5
1					
2	40.59				
3	28.69	52.52			
4	24.69	42.67	34.58		
5	30.42	49.20	32.74	27.90	

The highest dissimilarity was recorded between Sites 2 (Shrimpton's Ck) and 3 (Porters Ck) (52.52%). Both sites contained taxa only present in one of the two sites. Site 2 (Shrimptons Ck) recorded Hydrobiidae (snails), Atyidae (decapoda), Aeshnidae (dragon flies), Isostictidae and Megapodagrionidae (damselflies) in all three samples during Autumn while these were not collected in any samples at Site 3 (Porters Ck). Conversely Site 3 (Porters Ck) recorded Dugesidae (flatworms), and Corbiculidae (bivalves) in all samples which were not collected in any samples from Site 2 (Shrimptons Ck).

The lowest dissimilarity (most similar) result was recorded between Sites 1 (Terrys Ck) and 4 (Buffalo Ck) (24.69%). The main difference between the sites are the indicator taxa, Acarina were observed in all samples collected from Site 1 and not collected in any of the Site 4 samples.

BVSTEP

The output from the BVSTEP routine on the results from the five sites is presented in **Appendix F**.

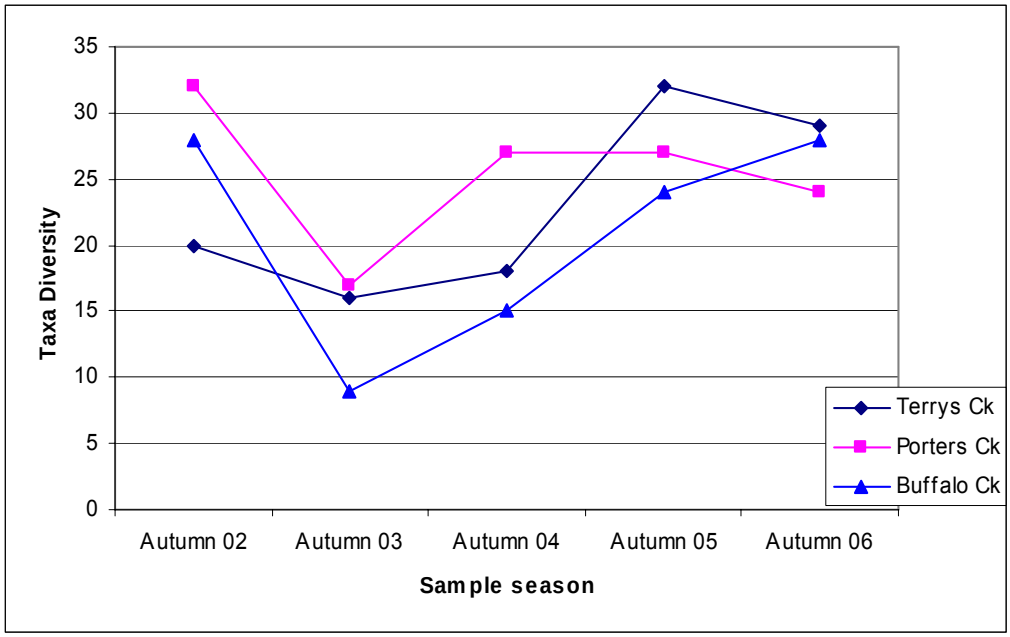
BVSTEP found 8 environmental variables to attribute a 32% (0.568 correlation) difference between samples. The variables included:

- Mean wetted width
- pH
- Bedrock substrate composition (%)
- Cobble substrate composition (%)
- Shading of sample area (%)
- Presence of sticks in sample area (%)
- Presence of branches in sample area (%)
- Presence of macrophytes in sample area (%)

This result suggests that habitat characteristics, mainly substrate composition not water quality, are causing the differences in community composition; however the correlation is only moderate.

Historical Data Comparison

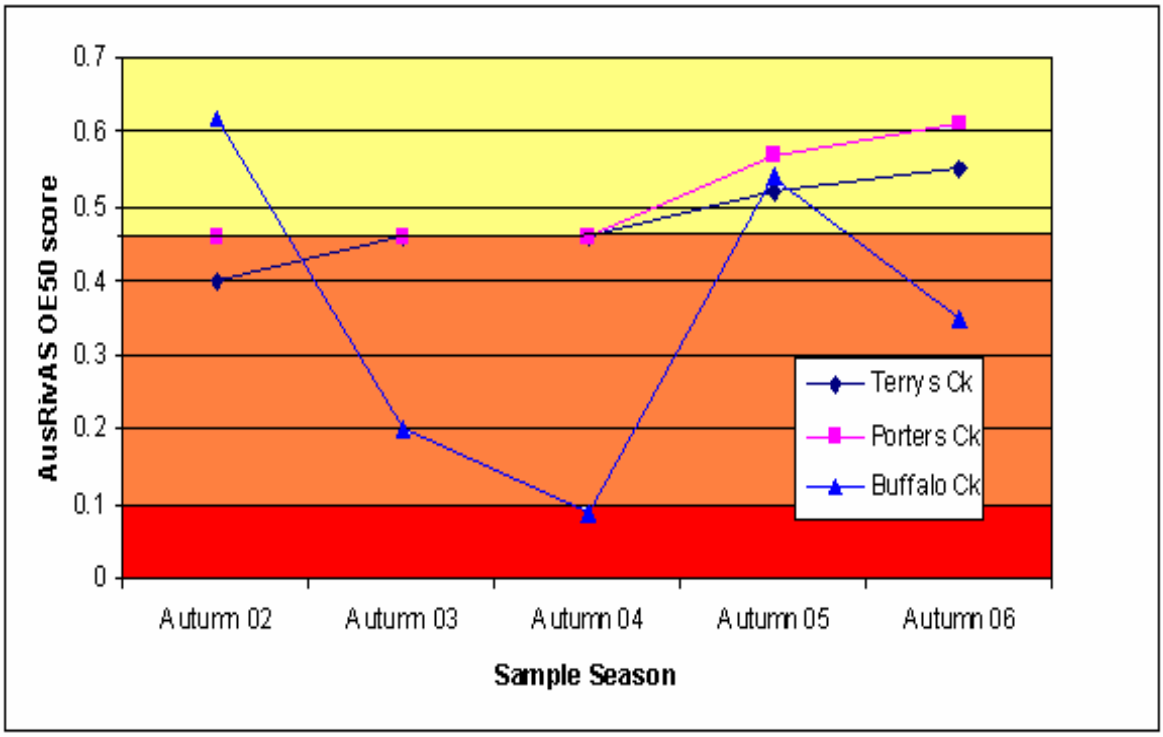
Historical taxa diversity and AusRivAS O/E50 scores could be compared between those sites undertaken by Robyn Tuft and Associates (Site 1 – Terry's Ck, Site 3 – Porters Ck, and Site 4 – Buffalo Ck), although with some limitations (Figure 7 and Figure 8). The Robyn Tuft and Associates programs collected single samples during each season, compared with three events over three months during the Ecowise Autumn 2005 and Autumn 2006 program. For comparative purposes, the Autumn 2005 and Autumn 2006 data was combined for diversity, and averaged for the AusRivAS O/E50 scores.



Data sourced from Robyn Tuft and Associates (2004) report.

Figure 7: Taxa diversity for three of the core sites measured by Robyn Tuft and Associates during Autumn 2002 to Autumn 2004 and Ecowise Autumn 2005 to Autumn 2006, City of Ryde. Ecowise Autumn data was combined for the three events.

The results show an increasing trend in taxa diversity (except for Porter's Ck) since Autumn 2003, with a significant improvement in results at Buffalo Ck from 15 taxa in 2004 to 28 taxa in 2006. However the improved result for Buffalo Ck is not reflected in the O/E50 score for the site during the same time period, which declined from a Band B rating to a Band C rating. Taxa diversity results for Terry's Ck and Porter's Ck both showed only minor decreases in the number of taxa observed between Autumn 2005 and Autumn 2006.



Data sourced from Robyn Tuft and Associates (2004) report.

Figure 8: Comparison of AusRivAS O/E50 scores for the core creeks sampled by Robyn Tuft and Associates in Autumn 2002 to Autumn 2004, and Ecowise Autumn 2005 to 2006, City of Ryde. Ecowise Autumn 2005 and 2006 AusRivAS O/E50 data was averaged for the three events for this comparison. The AusRivAS bandings (Table 3) are also presented; D – Red, C – Orange, B – Yellow.

5 DISCUSSION

5.1 General Discussion

The results of the Autumn 2006 sampling program indicate that the five City of Ryde sites are typical of urban creeks with moderate to poor ecological health, dominated by pollution tolerant taxa and poor water quality, including low dissolved oxygen and high nutrient levels. These results are comparable with past sampling events conducted by Robyn Tuft and Associates (2002; 2003a&b; 2004), BioTrack (2001; 2002; 2004) and Ecowise Environmental (2005).

Low concentrations of dissolved oxygen can adversely affect many aquatic organisms that depend upon oxygen for their survival (ANZECC and ARMCANZ, 2000). Low dissolved oxygen levels can have a direct (eg. toxic) and an indirect effect (eg. changing the redox potential of soils and releasing Phosphorus into the water column) on biota (ANZECC and ARMCANZ, 2000). Dissolved oxygen regularly fell below the recommended ANZECC and ARMCANZ trigger value of 85% saturation at all sites for all sampling event during Autumn 2006 program. The exception being for Porters Ck (Site 3) which was above 85% saturation on all occasions.

The ANZECC and ARMCANZ (2000) guidelines recommend that even in highly modified ecosystems, dissolved oxygen concentrations, determined over at least one diurnal cycle, should not fall below 60% saturation. However, it must be recognised that under natural conditions dissolved oxygen concentrations can vary considerably over a daily period, and can also be influenced by other water quality variables such as water temperature, salinity, microbial activity and photosynthetic activity. Meaningful interpretation of dissolved oxygen values should be based on data incorporating the full daily range of values, and if possible, the diurnal (daily) range over a few days (ANZECC and ARMCANZ, 2000). The measurements taken during this study provide a ‘snapshot’ of dissolved oxygen values within each creek and are only indicative of conditions prevailing at the time of assessment.

Urban catchments are known to deposit high volumes of nutrients into creeks from stormwater runoff, artificial fertilisers and sediment. Nutrients present in a river system can either be directly toxic to biota (eg. ammonia), or indirectly toxic through a direct effect on other stressors of biota (eg. nutrients which can result in excessive algal growth) (ANZECC and ARMCANZ, 2000). Ammonia levels were recorded above the ANZECC and ARMCANZ (2000) guidelines for all sampling occasions at all sites in Autumn 2005, with some sites measuring over 15 times the recommended trigger level.

Total Nitrogen and Oxidised Nitrogen levels were also much higher than the trigger levels for most sites. Only samples taken at Terrys Creek during March and Shrimptons Creek during March and May recorded values below the ANZECC and ARMCANZ (2000) high trigger value. Total oxidised Nitrogen values at Shrimptons Creek during all sampling events were the only sample to have values within the ANZECC and ARMCANZ (2000) guidelines. Total

Phosphorus was recorded in exceedence of the trigger level on 8 occasions from 15 samples. The lack of increased algal growth at most sites suggests Phosphorus to be the limiting nutrient in these urban creeks. Iron Bacteria was observed at Buffalo Ck (Site 4) during the May sampling event.

Excessive levels of Faecal Coliforms were recorded in terms of secondary contact levels at only Porters Ck (site 3), during the March event, with a recorded value of 9800 orgs/100ml. Faecal Coliform organisms are a measure of bacterial content and recorded levels of over 9.8 times the secondary contact trigger level is cosidered public health risk. All other sites recorded values for Faecal Coliforms above the ANZECC and ARMCANZ (2000) primary contact limit on at least one of the three sampling events. The levels recorded at Site 5 during the March 2006 and sites 1, 3, 4 and 5 during the May 2006 sampling events were below the primary trigger levels and posed no risk to public health.

All sites were dominated by pollution tolerant taxa, including Oligochaeta – worms (2), Physidae – snails (1), and to a lesser extent Chironominae – biting midges (3). The sites lacked many of the sensitive taxa present in high quality reference condition freshwaters, resulting in AusRivAS bandings of 'B' or lower. This result suggested the sites were significantly impaired with fewer taxa observed than expected, and may be a result of water quality and/or habitat condition. Urban creek catchments are generally impacted by poor/no riparian zones, channelisation, stormwater runoff and human impacts (illegal dumping of weeds, rubbish, contaminants etc), which could all contribute to poor species diversity. Many Chironomidae species are tolerant to heavy metals and the dominance of Chironomid and Oligochaeta in a sample could also suggest organic enrichment (Yandora, 1998). Physidae is an introduced taxa indicative of poor water quality and nutrient enrichment (Gooderham and Tsyrlin, 2003).

Many expected taxa highlighted in the AusRivAS output were found to be missing from the five sites, which suggested the creeks to be in a degraded state. The absence of these animals indicates poor water quality and poor in-stream habitat diversity. Six of the seventeen expected (but missing) taxa occurred from families with a low sensitivity to pollution (SIGNAL2 scores <5); however, the presence of several families of Odonata (dragonflies and damsel flies) such as Megapodagrionidae (5) (all sites), Hemicordulidae (5) (all sites), Coenagrionidae (2) (all sites), and Aeshnidae (4) (all Sites except site 2), in most samples at all sites suggests the creeks do have a limited capacity to support some larger predatory animals.

The multivariate analyses highlighted differences and similarities between the five sites, including the separation of samples from Sites 2 and 3 to the remaining samples. The remaining sites were considered to be at least 70% similar in macroinvertebrate community composition. Major taxonomic differences creating the separation of Shrimpton's Creek and Porter's Creek samples included the orders Odonata (Megapodagrionidae, Isostictidae, and Aeshnidae), Gastropoda (Hydrobiidae), Decapoda and (Atyidae).

5.2 Individual Site Assessments

5.2.1 Site 1: Terrys Ck

Figure 9: Site 1 (Terrys Ck) facing downstream in April 2006.

The Terrys Ck site contained a moderate diversity of macroinvertebrate fauna, with 29 different taxa collected from the edge habitat over the 3 Autumn sampling events. There are a number of microhabitats within the reach including shallow and deep slow-flowing sections, undercut banks, trailing bank vegetation, and shading from riparian vegetation, all of which provide quality habitat for macroinvertebrates.

The AusRivAS results classify the creek as severely (Band 'C') to significantly (Band 'B') impaired, which is similar to Spring 2005 results. Taxa differences between Spring and Autumn included the presence of Ceinidae (2), Ceratopogonidae (4), Corixidae (2), Dytiscidae (2) and Oniscidae (2) only in the spring results, compared to Atyidae (3), Dugesiidae (2), Hydroptilidae (4), Orthocladiinae (2), and Talitridae (4) only in Autumn results.

Ten taxa had a >50% probability of occurrence, but were not collected in any samples from the creek during the Autumn 2006 event. These included the indicator taxa Leptophlebiidae (8) and Leptoceridae (6) and Baetidae (5). Several indicator taxa including Acarina(6) and Elmidae (7), were collected in some samples but were missing from others, suggesting the creek has the capacity to sustain pollution sensitive taxa.

Impacts which may be affecting the presence of more pollution sensitive taxa include low dissolved oxygen levels, poor water quality (stormwater, sewage overflows, illegal discharges etc.) and scouring flows through the system. There is evidence of high flows through this site with scouring along the banks and the presence of rubbish and debris in surrounding riparian vegetation.

5.2.2 Site 2: Shrimptons Ck

Figure 10:Site 2 (Shrimptons Ck) 200m upstream in May 2006.

Shrimptons Ck recorded the lowest taxa diversity of the five sites, totalling 16 different taxa during the Autumn 2006 sampling events. Shrimptons Ck recorded the lowest dissolved oxygen and pH of all sites for all sampling events.; however, it recorded the lowest Ammonia levels of all sites.

Only 9 taxa were collected during May, 10 during April and 14 during March, and all were considered pollution tolerant taxa (<5 Signal score) except for Acarina (6). There was also an abundance of missing taxa that were expected to be at the site including 3 indicator taxa (Scirtidae, Leptophlebiidae and Leptoceridae). AusRivAS banding for this site ranged from band 'C' severely impaired to Band 'D' extremely impaired.

Possible impacts causing the overall poor ecological health for Shrimptons Ck include poor water quality (low dissolved oxygen, high nutrients), and potential toxicants in stormwater discharges.

5.2.3 Sites 3: Porters Ck

Porters Ck is a highly modified system, with the majority of the creek piped underground. Site 3 was located downstream of the Ryde Council Depot. The creek also receives a large volume of discharge from a pipe of unconfirmed origin upstream of Site 3. Releases from nearby rail works have decreased in recent times which has returned flows to more normal regime, no obvious effects are apparent at this stage.

Site 3 recorded a combined taxa diversity of 24. The O/E50 scores were found to be between 0.71 – 0.84, with bandings of 'C' for March (severely impaired), 'A' for April (reference condition) and 'B'(significantly impaired) during May 2006.

The presence of several indicator taxa including Acarina (6), and Leptoceridae (6) were recorded at site 3, however other indicator taxa such as Leptophlebiidae (8) and Scirtidae (6) which had an expectancy of >50%, were not collected

Figure 11:Site 3 (Porters Ck at the depot) downstream in May 2006

5.2.4 Sites 4: Buffalo Ck

Buffalo Ck borders many residential properties and is highly infested with weed species along the riparian zone of both right and left banks. Visually, site 4 provided a semi-shaded environment with trailing bank vegetation and undercut banks. A presence of red algae or possible iron bacteria was observed during all three sampling events.

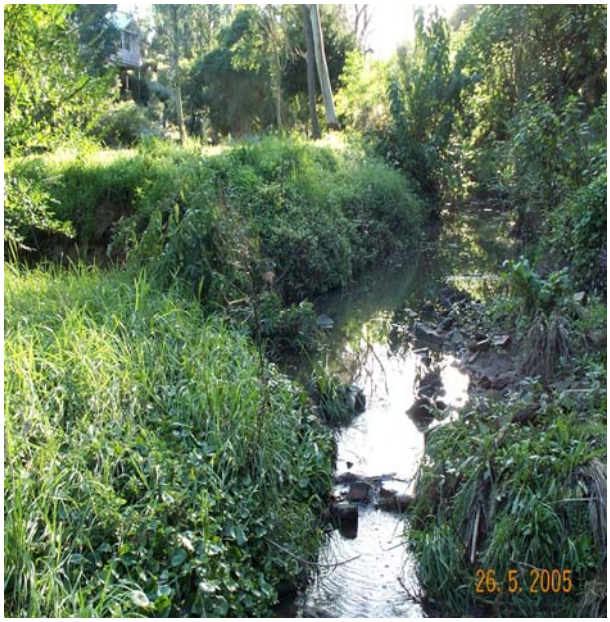


Figure 12:Site 4 (Buffalo Ck) upstream in May 2006

A combined taxa diversity of 28 animals was recorded for site 4. Eight taxa had a >50% probability of occurrence, but were not collected in any samples from the creek during the Autumn 2006 event. These included the indicator taxa Leptophlebiidae (8), Leptoceridae (6), Scirtidae (6) and Acarina (6).

O/E50 scores recorded for site 4 were 0.69 (March), 0.66 (April) and 0.72 (May). with all sampling events recording an AusRivAS banding of 'C' (severely impaired

The results indicate Ck to be in moderate ecological health with generally poor water quality (low dissolved oxygen and high nutrients). The major impacts on this creek include residential runoff scouring flows and point source discharges from industrial drain.

5.2.5 Site 5: Archer Ck

Figure 13:Site 5 (Archer Ck) downstream in March 2006

Archer Ck continues to have construction works on the upstream end of Maze Park, with reconstructed banks using sandstone blocks for stabilisation, and native plant revegetation. Vegetation growth remains steady at this site; however, weeds continue to be quite dense within the in-stream zones, and on-going maintenance may be necessary to prevent weeds spreading. A number of microhabitats were present at this site including macrophyte beds and trailing bank vegetation.

Archer Ck recorded a combined diversity of 20 taxa, with 11 taxa recorded consistently throughout the Autumn 2006 program. This site also recorded consistent AusRivAS banding scores (all Band 'B'), rating the creek as significantly impaired with fewer taxa observed than expected. Four indicator taxa were expected (>50%) at this site but were not collected during the three sampling occasions.

5.3 Conclusion

All sites within the City of Ryde study are indicative of urban creeks, with significant to severe impairment of the ecological health. The main influences on these sites, and the creeks on which they are located, include poor water quality (exceeding recommended ANZECC and ARMCANZ, 2000 guidelines), and poor habitat diversity. Biodiversity and ecosystem health results from the Autumn 2006 sampling program are similar to those obtained in earlier monitoring programs, including the previous sampling program in Spring 2005. However, a comparison of results from Autumn from 2002 to 2005 (Robyn Tuft and Associates and Ecowise) for Terrys Ck, Buffalo Ck and Porters Ck indicated an improvement in the ecological health of these creeks in 2005.

The Autumn 2006 sampling program has demonstrated that the design and methodology adopted for this project are appropriate to achieve the objectives of the City of Ryde program.

6 RECOMMENDATIONS

This program is the fifth of the City of Ryde's Biological/Chemical Water Quality Monitoring Strategy targeting 5 main creek systems and is to be continued twice yearly over a 7 year period. Following the completion of the Autumn 2006 sampling event it is recommended that:

- A water quality monitoring program (including event based sampling) be considered to compliment the bi-annual biological program conducted as part of this study to target potential contaminants at the core sites. A comprehensive water quality dataset would also assist with the interpretation of the biological data,

- Examine influences such as rainfall and flow in relation to water quality results, and

- Consider compiling all historical raw data (where comparable) for assessment with current study data to provide a temporal evaluation of ecological health of the targeted creeks,

7 REFERENCES

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

BioTrack (2001). Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde. Prepared for Ryde City Council.

BioTrack (2002). Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde. Prepared for Ryde City Council.

BioTrack (2004). Post restoration macroinvertebrate sampling of Archer Creek, Ryde. Prepared for Ryde City Council.

Bray, J.R. and Curtis, C.T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* **27**: 325-349.

Chessman, B.C. (2003). New sensitivity grades for Australian River Macroinvertebrates. *Marine and Freshwater Ecology*. **54**: 95-103.

Clarke, KR & Gorley, R. N. (2001). Primer V5: User Manual/Tutorial. Plymouth Marine Laboratory, Plymouth.

Clarke, K.R. & Warwick, R.M. (2001). Change in Marine Communities: An Approach to Statistical Analysis and Interpretation: 2nd Edition. Plymouth Marine Laboratory, Plymouth.

Clifford, H.T. and Stephenson, W. (1975). 'An Introduction to Numerical Classification' Academic Press, New York.

Coysh, J., Nichols, S., Simpson, J., Norris, R., Barmuta, L., Chessman, B. and Blackman, P. (2000). AusRivAS National River Health Program Predictive Model Manual. http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/ (accessed March 2004).

ECOWISE (2004) Biological Monitoring Program for City of Ryde – Spring 2004. Prepared for Ryde City Council.

EHMP (2004). Ecosystem Health Monitoring Program 2002-2003 Annual Technical Report. Moreton Bay Waterways and Catchments, Brisbane.

Gooderham, J. and Tsyrlin, E. (2003). The waterbug book: A guide to the freshwater Macroinvertebrates of Temperate Australia. CSIRO Publishing, Collingwood, VIC.

ISO. (1983). Water Quality: Methods of Biological Sampling - Handnet Sampling of Aquatic Benthic Macroinvertebrates. Draft ISO International Standard.

MRHI (1994). River Bioassessment Manual. National River Processes and Management Program. Monitoring River Health Initiative. Version 1.0. Commonwealth Environment Protection Authority, Canberra, A.C.T., Australia.

Robyn Tuft & Associates (2002). Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2002. Prepared for Lane Cove River Catchment Councils.

Robyn Tuft & Associates (2003a). Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2003. Prepared for Lane Cove River Catchment Councils.

Robyn Tuft & Associates (2003b). Macroinvertebrate Sampling Program Lane Cove River Catchments – Spring 2003. Prepared for Lane Cove River Catchment Councils.

Robyn Tuft & Associates (2004). Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2004. Prepared for Lane Cove River Catchment Councils.

Turak, E., Waddell, N., & Johnstone, G. (2004). New South Wales Australian River Assessment System (AusRivAS) Sampling and Processing Manual - 2004. Department of Environment and Conservation, NSW.

Yandora, K. (1998) Rapid Bioassessment of Benthic Macroinvertebrates illustrates Water Quality in Small Order Streams in a North Carolina Piedmont City. Proceeding from the 1998 NWQMC National Monitoring Conference. http://www.nwqmc.org/98proceedings/Papers/40-YAND.html (accessed August, 2004)

8 APPENDICES

Appendix A: Macroinvertebrate Results during the Autumn 2006 Sampling Program

	Sample date	**9-10 March 2006**					**19-20 April 2006**					**9-10 May 2006**				
	Site Name	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck @ 52 Higginbotham Rd	Archer Ck @ Maze Park	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck @ 52 Higginbotham Rd	Archer Ck @ Maze Park	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck 5 @ 52Higginbotham Rd	Archer Ck @ Maze Park
	Site Code	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge
Order	**Family**															
Acarina	**Acarina**	*	*				*	*	*			*	*			
Amphipoda	**Talitridae**						*			*		*		*		
Bivalvia	**Corbiculidae**	*	*		*			*		*		*	*		*	
Coleoptera	**Elmidae**	*					*									
	Hydrophilidae									*						
	Psephenidae			*												
Crustacea	**Ostracoda**	*	*												*	
	Copepoda				*		*	*				*	*	*	*	
Decapoda	**Atyidae**			*		*			*		*			*		
	Parasticidae		*													
Diptera	**s-f Chironominae**	*			*	*	*	*	*	*	*	*	*	*	*	*
	s-f Tanypodinae	*					*		*		*	*		*	*	*
	s-f Orthocladiinae			*	*		*	*		*					*	
	Ceratopogonidae														*	
	Culicidae					*	*			*					*	*
	Stratiomyidae	*			*	*				*					*	*
	Tipulidae															*
Ephemeroptera	**Baetidae**									*						
Gastropoda	**Hydrobiidae**	*		*	*		*		*			*		*		
	Lymnaeidae	*	*		*						*				*	
	Physidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
	Planorbidae	*	*						*					*		
Hemiptera	**Gerridae**	*			*	*	*		*	*		*				*
	Mesoveliidae									*						

	Sample date	9-10 March 2006					19-20 April 2006					9-10 May 2006				
	Site Name	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck @ 52 Higginbotham Rd	Archer Ck @ Maze Park	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck @ 52 Higginbotham Rd	Archer Ck @ Maze Park	Terrys Ck	Shrimptons Ck	Porters Ck at the depot	Buffalo Ck @ 52 Higginbotham Rd	Archer Ck @ Maze Park
	Site Code	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Habitat	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge
Order	**Family**															
	Notonectidae	*		*	*	*	*		*	*	*	*			*	*
	Pleidae		*													
	Veliidae	*				*	*				*			*		*
Hirudinea	**Glossiphoniidae**	*	*	*	*	*	*	*	*	*	*			*		*
Isopoda	**Oniscidae**				*	*										
Megaloptera	**Corydalidae**	*														
Odonata	**Aeshnidae**	*		*	*				*	*	*			*	*	*
	Epiproctophora	*														
	Coenagrionidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Hemicorduliidae	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Isostictidae	*		*	*		*		*			*		*	*	
	Libellulidae	*	*	*	*	*	*		*	*	*	*	*	*	*	*
	Megapodagrionidae	*		*	*	*	*		*	*	*	*		*	*	*
Oligochaeta	**Oligochaeta**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Plecoptera	**Eustheniidae**			*												
Trichoptera	**Hydroptilidae**	*														
	Leptoceridae			*					*							
Turbellaria	**Dugesiidae**	*	*		*	*	*	*		*	*	*	*		*	*

Appendix B: QA Report

QA Report

For: City of Ryde Autumn Sampling Program 2006
Project No.: QE000037

Site Sample Date	ArchersCk @ Maze park Apr-06	
ID	Original	QA
Chironominae	72	75
Tanypodinae	3	2
Oligochaeta	13	13
Atyidae	1	1
Lymnaeidae	1	2
Physidae	5	4
Notonectidae	1	1
Veliidae	2	2
Glossiphoniidae	6	6
Aeshnidae	11	11
Coengrionidae	7	7
Hemicorduliidae	7	7
Libellulidae	2	3
Megapodagrionidae	7	7
Dugesiidae	4	4
Dugesiidae	2	2

identification error
Count error

Bray Curtis Similarity (%) 2.439

Pass or Fail **PASS**

Appendix C: AusRivAS output – Taxa >50% expected and observed

Taxa observed and were >50% expected to be in the edge samples of the seven sites within the City of Ryde, Autumn 2006. Taxa in bold are indicator taxa.

	Taxon Name	**Acarina**	Atyidae	Hydrophilidae	Veliidae	Gerridae	Notonectidae	Megapodagrionidae	Aeshnidae	**Leptoceridae**
	Signal Score	**6**	3	2	3	4	1	5	4	**6**
Site	**Sampling Event**									
1	March	0.88			0.80	0.76	0.62			
	April	0.89			0.80	0.76	0.61			
	May	0.90			0.83	0.76	0.59			
2	March	0.90								
	April	0.92								
	May	0.89								
3	March		0.62				0.66	0.56	0.56	1.00
	April	0.86	0.62			0.76	0.66	0.56	0.56	1.00
	May		0.62		0.76			0.57	0.57	
4	March					0.73	0.57			
	April			0.55		0.73	0.57			
	May						0.57			
5	March		0.62		0.76	0.76	0.66	0.57		
	April		0.62		0.78		0.64	0.53	0.52	
	May				0.78	0.75	0.64	0.52	0.51	

Appendix D: AusRivAS Output – Taxa >50% expected but not observed

Taxa NOT observed but were >50% expected to be in the edge samples of the five sites within the City of Ryde, Autumn 2006. Taxa in bold are indicator taxa.

	Taxa	**Acarina**	Atyidae	Dytiscidae	Gyrinidae	Hydrophilidae	**Scirtidae**	**Elmidae**	Tanypodinae	Chironominae	**Baetidae**	**Leptophlebiidae**	Veliidae	Gerridae	Notonectidae	Aeshnidae	Cordulilidae	**Leptoceridae**
	Signal Score	**6**	3	2	4	2	**6**	**7**	4	3	**5**	**8**	3	4	1	4	5	**6**
Site	**Sampling Event**																	
1	March		0.73	0.71	0.71	0.60	0.53				0.50	0.98						0.98
	April		0.71	0.73	0.67	0.59	0.56					0.97						0.97
	May		0.79	0.72	0.69	0.69	0.52	0.51			0.53	0.96	0.83					0.96
2	March		0.65	0.78	0.53	0.57	0.65		0.74	0.81		0.92	0.82	0.74	0.58			0.94
	April		0.62	0.83		0.59	0.75		0.77			0.86	0.86	0.71	0.53			0.90
	May		0.63	0.78	0.54	0.55	0.66		0.73			0.92	0.82	0.74	0.59		0.51	0.95
3	March	0.86		0.72	0.70		0.58		0.67	0.81		0.99	0.77	0.76			0.57	
	April			0.72	0.70		0.58					0.99	0.77				0.57	
	May	0.86		0.72	0.71		0.57					1.00		0.76	0.66		0.57	1.00
4	March	0.90	0.62	0.80		0.55	0.69		0.74			0.90	0.83				0.51	0.94
	April	0.90	0.62	0.80			0.70		0.74			0.90	0.83				0.51	0.93
	May	0.90	0.62	0.80		0.55	0.69					0.90	0.83	0.73			0.51	0.94
5	March	0.86		0.72	0.71		0.58		0.67			1.00				0.57	0.57	1.00
	April	0.87		0.74	0.65	0.50	0.61					0.97		0.75			0.56	0.98
	May	0.87	0.62	0.74	0.63	0.50	0.61					0.97					0.55	0.98

Appendix E: SIMPER output – all sites

SIMPER
Similarity Percentages - species contributions

Worksheet

File: T:\Projects\QE000037 City of Ryde BMP\2006 Autumn\Bugs for primer.pri
Sample selection: All
Variable selection: All

Parameters

Standardise data: No
Transform: None
Cut off for low contributions: 90.00%
Factor name: site

Factor groups
Terry's Ck
Shrimpton's Ck
Porter's Ck
Buffalo Ck
Archer's Ck

Group Terry's Ck

Average similarity: 79.87

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gerridae	1.00	5.10	15.80	6.38	6.38
Isostictidae	1.00	5.10	15.80	6.38	12.77
Notonectidae	1.00	5.10	15.80	6.38	19.15
Megapodagrionidae	1.00	5.10	15.80	6.38	25.54
Dugesiidae	1.00	5.10	15.80	6.38	31.92
s-f Chironominae	1.00	5.10	15.80	6.38	38.30
Physidae	1.00	5.10	15.80	6.38	44.69
Coenagrionidae	1.00	5.10	15.80	6.38	51.07
Libellulidae	1.00	5.10	15.80	6.38	57.45
Oligochaeta	1.00	5.10	15.80	6.38	63.84
Hemicorduliidae	1.00	5.10	15.80	6.38	70.22
Acarina	1.00	5.10	15.80	6.38	76.61
Hydrobiidae	1.00	5.10	15.80	6.38	82.99
s-f Tanypodinae	1.00	5.10	15.80	6.38	89.37
Talitridae	0.67	1.80	0.58	2.26	91.63

Group Shrimpton's Ck

Average similarity: 74.53

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Dugesiidae	1.00	9.71	13.19	13.03	13.03
Physidae	1.00	9.71	13.19	13.03	26.06
Oligochaeta	1.00	9.71	13.19	13.03	39.10
Hemicorduliidae	1.00	9.71	13.19	13.03	52.13
Acarina	1.00	9.71	13.19	13.03	65.16
Corbiculidae	1.00	9.71	13.19	13.03	78.19
s-f Chironominae	0.67	3.51	0.58	4.71	82.90
Copepoda	0.67	3.51	0.58	4.71	87.61
Libellulidae	0.67	3.17	0.58	4.26	91.87

Group Porter's Ck

Average similarity: 78.56

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Isostictidae	1.00	6.41	14.15	8.15	8.15
Aeshnidae	1.00	6.41	14.15	8.15	16.31
Glossiphoniidae	1.00	6.41	14.15	8.15	24.46
Megapodagrionidae	1.00	6.41	14.15	8.15	32.61
Physidae	1.00	6.41	14.15	8.15	40.77
Coenagrionidae	1.00	6.41	14.15	8.15	48.92
Libellulidae	1.00	6.41	14.15	8.15	57.07
Oligochaeta	1.00	6.41	14.15	8.15	65.22
Hemicorduliidae	1.00	6.41	14.15	8.15	73.38
Atyidae	1.00	6.41	14.15	8.15	81.53
Hydrobiidae	1.00	6.41	14.15	8.15	89.68
Notonectidae	0.67	2.22	0.58	2.83	92.51

Group Buffalo Ck

Average similarity: 81.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Aeshnidae	1.00	5.46	32.33	6.67	6.67
Notonectidae	1.00	5.46	32.33	6.67	13.35
Megapodagrionidae	1.00	5.46	32.33	6.67	20.02
Dugesiidae	1.00	5.46	32.33	6.67	26.70
s-f Chironominae	1.00	5.46	32.33	6.67	33.37
Physidae	1.00	5.46	32.33	6.67	40.05
Coenagrionidae	1.00	5.46	32.33	6.67	46.72
Libellulidae	1.00	5.46	32.33	6.67	53.40
Oligochaeta	1.00	5.46	32.33	6.67	60.07
Hemicorduliidae	1.00	5.46	32.33	6.67	66.75
s-f Orthocladiinae	1.00	5.46	32.33	6.67	73.42
Stratiomyidae	1.00	5.46	32.33	6.67	80.10
Corbiculidae	1.00	5.46	32.33	6.67	86.77
Gerridae	0.67	1.85	0.58	2.26	89.03
Glossiphoniidae	0.67	1.85	0.58	2.26	91.30

Group Archer's Ck

Average similarity: 82.22

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Notonectidae	1.00	6.67	#######	8.11	8.11
Glossiphoniidae	1.00	6.67	#######	8.11	16.22
Megapodagrionidae	1.00	6.67	#######	8.11	24.32
Dugesiidae	1.00	6.67	#######	8.11	32.43
s-f Chironominae	1.00	6.67	#######	8.11	40.54

Coenagrionidae	1.00	6.67	#######	8.11	48.65
Libellulidae	1.00	6.67	#######	8.11	56.76
Oligochaeta	1.00	6.67	#######	8.11	64.86
Hemicorduliidae	1.00	6.67	#######	8.11	72.97
Veliidae	1.00	6.67	#######	8.11	81.08
Gerridae	0.67	2.22	0.58	2.70	83.78
Aeshnidae	0.67	2.22	0.58	2.70	86.49
Physidae	0.67	2.22	0.58	2.70	89.19
Atyidae	0.67	2.22	0.58	2.70	91.89

Groups Terry's Ck & Shrimpton's Ck

Average dissimilarity = 40.59

Species	Group Terry's Ck Av.Abund	Group Shrimpton's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Gerridae	1.00	0.00	3.36	11.56	8.27	8.27
Isostictidae	1.00	0.00	3.36	11.56	8.27	16.53
Notonectidae	1.00	0.00	3.36	11.56	8.27	24.80
Megapodagrionidae	1.00	0.00	3.36	11.56	8.27	33.06
Hydrobiidae	1.00	0.00	3.36	11.56	8.27	41.33
s-f Tanypodinae	1.00	0.00	3.36	11.56	8.27	49.60
Talitridae	0.67	0.00	2.32	1.32	5.72	55.32
Veliidae	0.67	0.00	2.13	1.33	5.26	60.57
Glossiphoniidae	0.67	0.67	1.54	0.84	3.78	64.36
Ostracoda	0.33	0.33	1.44	0.84	3.54	67.90
Planorbidae	0.33	0.33	1.44	0.84	3.54	71.44
Lymnaeidae	0.33	0.33	1.44	0.84	3.54	74.97
Copepoda	0.67	0.67	1.44	0.84	3.54	78.51
Coenagrionidae	1.00	0.67	1.17	0.66	2.88	81.39
Libellulidae	1.00	0.67	1.13	0.66	2.78	84.17
s-f Orthocladiinae	0.33	0.00	1.10	0.67	2.71	86.88
Culicidae	0.33	0.00	1.10	0.67	2.71	89.60
Corbiculidae	0.67	1.00	1.10	0.67	2.71	92.31

Groups Terry's Ck & Porter's Ck

Average dissimilarity = 28.69

Species	Group Terry's Ck Av.Abund	Group Porter's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Dugesiidae	1.00	0.00	2.85	11.51	9.93	9.93
Atyidae	0.00	1.00	2.85	11.51	9.93	19.86
Aeshnidae	0.33	1.00	1.96	1.32	6.84	26.69
Gerridae	1.00	0.33	1.94	1.32	6.75	33.44
Acarina	1.00	0.33	1.94	1.32	6.75	40.19
Corbiculidae	0.67	0.00	1.91	1.32	6.66	46.85
Talitridae	0.67	0.33	1.62	1.04	5.64	52.50
Copepoda	0.67	0.33	1.62	1.04	5.64	58.14
Planorbidae	0.33	0.67	1.57	1.05	5.48	63.62
Veliidae	0.67	0.33	1.57	1.05	5.46	69.08
s-f Orthocladiinae	0.33	0.33	1.29	0.84	4.49	73.57
s-f Chironominae	1.00	0.67	1.02	0.66	3.57	77.14
s-f Tanypodinae	1.00	0.67	1.02	0.66	3.57	80.71
Glossiphoniidae	0.67	1.00	1.02	0.66	3.57	84.28
Culicidae	0.33	0.00	0.94	0.67	3.27	87.54
Notonectidae	1.00	0.67	0.91	0.67	3.18	90.72

Groups Shrimpton's Ck & Porter's Ck

Average dissimilarity = 52.52

Species	Group Shrimpton's Ck Av.Abund	Group Porter's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	0.00	1.00	3.88	10.39	7.38	7.38
Aeshnidae	0.00	1.00	3.88	10.39	7.38	14.76
Megapodagrionidae	0.00	1.00	3.88	10.39	7.38	22.14
Dugesiidae	1.00	0.00	3.88	10.39	7.38	29.52
Atyidae	0.00	1.00	3.88	10.39	7.38	36.90
Hydrobiidae	0.00	1.00	3.88	10.39	7.38	44.29
Corbiculidae	1.00	0.00	3.88	10.39	7.38	51.67
Notonectidae	0.00	0.67	2.65	1.32	5.05	56.72
Acarina	1.00	0.33	2.65	1.32	5.05	61.78
s-f Tanypodinae	0.00	0.67	2.44	1.33	4.65	66.43
Copepoda	0.67	0.33	2.21	1.04	4.21	70.64
Planorbidae	0.33	0.67	2.12	1.05	4.04	74.68
s-f Chironominae	0.67	0.67	1.75	0.83	3.34	78.02
s-f Orthocladiinae	0.00	0.33	1.43	0.67	2.73	80.74
Glossiphoniidae	0.67	1.00	1.36	0.66	2.59	83.33
Coenagrionidae	0.67	1.00	1.36	0.66	2.59	85.92
Libellulidae	0.67	1.00	1.31	0.66	2.49	88.41
Gerridae	0.00	0.33	1.22	0.67	2.33	90.74

Groups Terry's Ck & Buffalo Ck

Average dissimilarity = 24.69

Species	Group Terry's Ck Av.Abund	Group Buffalo Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Acarina	1.00	0.00	2.64	15.55	10.70	10.70
Aeshnidae	0.33	1.00	1.81	1.33	7.35	18.04
Stratiomyidae	0.33	1.00	1.81	1.33	7.35	25.39
Hydrobiidae	1.00	0.33	1.78	1.33	7.19	32.58
s-f Tanypodinae	1.00	0.33	1.78	1.33	7.19	39.78
s-f Orthocladiinae	0.33	1.00	1.77	1.32	7.17	46.95
Veliidae	0.67	0.00	1.70	1.33	6.87	53.82
Culicidae	0.33	0.67	1.48	1.05	5.98	59.80
Talitridae	0.67	0.33	1.47	1.05	5.96	65.76
Lymnaeidae	0.33	0.67	1.47	1.05	5.96	71.72
Glossiphoniidae	0.67	0.67	1.19	0.84	4.82	76.54
Copepoda	0.67	0.67	1.17	0.84	4.73	81.28
Ostracoda	0.33	0.33	1.15	0.84	4.65	85.93
Isostictidae	1.00	0.67	0.91	0.67	3.69	89.63
Corbiculidae	0.67	1.00	0.87	0.67	3.52	93.15

Groups Shrimpton's Ck & Buffalo Ck

Average dissimilarity = 42.67

Species	Group Shrimpton's Ck Av.Abund	Group Buffalo Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Aeshnidae	0.00	1.00	3.50	17.23	8.20	8.20
Notonectidae	0.00	1.00	3.50	17.23	8.20	16.40
Megapodagrionidae	0.00	1.00	3.50	17.23	8.20	24.60
s-f Orthocladiinae	0.00	1.00	3.50	17.23	8.20	32.80
Stratiomyidae	0.00	1.00	3.50	17.23	8.20	40.99
Acarina	1.00	0.00	3.50	17.23	8.20	49.19
Culicidae	0.00	0.67	2.36	1.33	5.53	54.72
Gerridae	0.00	0.67	2.36	1.33	5.53	60.26
Isostictidae	0.00	0.67	2.28	1.33	5.34	65.59
Lymnaeidae	0.33	0.67	1.94	1.05	4.55	70.14
Glossiphoniidae	0.67	0.67	1.57	0.84	3.67	73.81
Copepoda	0.67	0.67	1.56	0.84	3.65	77.46
Ostracoda	0.33	0.33	1.52	0.84	3.57	81.02
Talitridae	0.00	0.33	1.22	0.67	2.86	83.89
Coenagrionidae	0.67	1.00	1.22	0.67	2.86	86.75
Libellulidae	0.67	1.00	1.18	0.67	2.76	89.51
Hydrobiidae	0.00	0.33	1.14	0.67	2.67	92.18

Groups Porter's Ck & Buffalo Ck

Average dissimilarity = 34.58

Species	Group Porter's Ck Av.Abund	Group Buffalo Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Dugesiidae	0.00	1.00	2.95	14.61	8.54	8.54
Atyidae	1.00	0.00	2.95	14.61	8.54	17.08
Stratiomyidae	0.00	1.00	2.95	14.61	8.54	25.62
Corbiculidae	0.00	1.00	2.95	14.61	8.54	34.16
Culicidae	0.00	0.67	1.99	1.32	5.75	39.91
Hydrobiidae	1.00	0.33	1.99	1.32	5.75	45.66
Lymnaeidae	0.00	0.67	1.93	1.33	5.58	51.24
Planorbidae	0.67	0.00	1.89	1.33	5.46	56.70
s-f Orthocladiinae	0.33	1.00	1.89	1.33	5.46	62.16
Gerridae	0.33	0.67	1.66	1.05	4.81	66.97
Copepoda	0.33	0.67	1.64	1.05	4.74	71.71
s-f Tanypodinae	0.67	0.33	1.62	1.05	4.68	76.39
Talitridae	0.33	0.33	1.31	0.84	3.80	80.19
s-f Chironominae	0.67	1.00	1.06	0.67	3.08	83.27

Isostictidae	1.00	0.67	1.02	0.66	2.96	86.23
Glossiphoniidae	1.00	0.67	0.96	0.67	2.79	89.02
Ostracoda	0.00	0.33	0.96	0.67	2.79	91.81

Groups Terry's Ck & Archer's Ck

Average dissimilarity = 30.42

Species	Group Terry's Ck Av.Abund	Group Archer's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	1.00	0.00	2.89	15.64	9.52	9.52
Acarina	1.00	0.00	2.89	15.64	9.52	19.04
Hydrobiidae	1.00	0.00	2.89	15.64	9.52	28.55
Talitridae	0.67	0.00	1.99	1.33	6.56	35.11
Copepoda	0.67	0.00	1.99	1.33	6.56	41.67
Corbiculidae	0.67	0.00	1.94	1.32	6.39	48.05
Atyidae	0.00	0.67	1.93	1.33	6.35	54.40
Stratiomyidae	0.33	0.67	1.63	1.05	5.36	59.76
Aeshnidae	0.33	0.67	1.63	1.05	5.36	65.12
Culicidae	0.33	0.67	1.61	1.05	5.30	70.42
Lymnaeidae	0.33	0.33	1.27	0.84	4.16	74.58
Glossiphoniidae	0.67	1.00	1.04	0.67	3.42	78.00
Veliidae	0.67	1.00	1.04	0.67	3.42	81.43
Gerridae	1.00	0.67	0.96	0.66	3.17	84.60
Physidae	1.00	0.67	0.96	0.66	3.17	87.77
s-f Tanypodinae	1.00	0.67	0.96	0.66	3.17	90.94

Groups Shrimpton's Ck & Archer's Ck

Average dissimilarity = 49.20

Species	Group Shrimpton's Ck Av.Abund	Group Archer's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Notonectidae	0.00	1.00	3.96	19.48	8.04	8.04
Megapodagrionidae	0.00	1.00	3.96	19.48	8.04	16.09
Veliidae	0.00	1.00	3.96	19.48	8.04	24.13
Acarina	1.00	0.00	3.96	19.48	8.04	32.17
Corbiculidae	1.00	0.00	3.96	19.48	8.04	40.21
Copepoda	0.67	0.00	2.72	1.33	5.53	45.75
Gerridae	0.00	0.67	2.64	1.33	5.36	51.11
Aeshnidae	0.00	0.67	2.64	1.33	5.36	56.47
Atyidae	0.00	0.67	2.64	1.33	5.36	61.83
Culicidae	0.00	0.67	2.64	1.33	5.36	67.19
Stratiomyidae	0.00	0.67	2.64	1.33	5.36	72.56
s-f Tanypodinae	0.00	0.67	2.64	1.33	5.36	77.92
Lymnaeidae	0.33	0.33	1.73	0.84	3.52	81.43
Glossiphoniidae	0.67	1.00	1.39	0.67	2.82	84.26
Coenagrionidae	0.67	1.00	1.39	0.67	2.82	87.08
Libellulidae	0.67	1.00	1.33	0.67	2.71	89.79
Physidae	1.00	0.67	1.32	0.67	2.68	92.47

Groups Porter's Ck & Archer's Ck

Average dissimilarity = 32.74

Species	Group Porter's Ck Av.Abund	Group Archer's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	1.00	0.00	3.27	14.67	10.00	10.00
Dugesiidae	0.00	1.00	3.27	14.67	10.00	20.00
Hydrobiidae	1.00	0.00	3.27	14.67	10.00	30.00
Veliidae	0.33	1.00	2.23	1.32	6.82	36.82
Culicidae	0.00	0.67	2.18	1.33	6.67	43.48
Stratiomyidae	0.00	0.67	2.18	1.33	6.67	50.15
Planorbidae	0.67	0.00	2.08	1.33	6.36	56.52
Gerridae	0.33	0.67	1.84	1.05	5.61	62.12
s-f Tanypodinae	0.67	0.67	1.49	0.84	4.55	66.67
s-f Chironominae	0.67	1.00	1.19	0.67	3.64	70.30
s-f Orthocladiinae	0.33	0.00	1.19	0.67	3.64	73.94
Aeshnidae	1.00	0.67	1.09	0.66	3.33	77.27
Physidae	1.00	0.67	1.09	0.66	3.33	80.61
Atyidae	1.00	0.67	1.09	0.66	3.33	83.94
Lymnaeidae	0.00	0.33	1.09	0.66	3.33	87.27
Notonectidae	0.67	1.00	1.04	0.67	3.18	90.45

Groups Buffalo Ck & Archer's Ck

Average dissimilarity = 27.90

Species	Group Buffalo Ck Av.Abund	Group Archer's Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
s-f Orthocladiinae	1.00	0.00	3.00	32.67	10.76	10.76
Veliidae	0.00	1.00	3.00	32.67	10.76	21.52
Corbiculidae	1.00	0.00	3.00	32.67	10.76	32.28
Atyidae	0.00	0.67	2.00	1.33	7.17	39.46
Isostictidae	0.67	0.00	1.96	1.33	7.03	46.49
Copepoda	0.67	0.00	1.96	1.33	7.03	53.51
s-f Tanypodinae	0.33	0.67	1.67	1.05	6.00	59.52
Lymnaeidae	0.67	0.33	1.65	1.05	5.93	65.45
Gerridae	0.67	0.67	1.33	0.84	4.76	70.20
Culicidae	0.67	0.67	1.33	0.84	4.76	74.96
Talitridae	0.33	0.00	1.04	0.67	3.73	78.70
Aeshnidae	1.00	0.67	1.00	0.67	3.59	82.28
Physidae	1.00	0.67	1.00	0.67	3.59	85.87
Stratiomyidae	1.00	0.67	1.00	0.67	3.59	89.46
Glossiphoniidae	0.67	1.00	0.98	0.67	3.51	92.97

Appendix F: BVSTEP output – all sites

BVSTEP

Biota and/or Environment matching

Similarity Matrix

File: T:\Projects\QE000037 City of Ryde BMP\2006 Autumn\Multivariates\Simmatrix.sid
Data type: Similarities
Sample selection: All

Parameters

Rank correlation method: Spearman
Termination criteria:
rho > 0.95
delta rho < 0.001
Use random selection for starting variables
Number of restarts: 5
Percentage of starting variables: 50

Similarity Matrix Parameters for sample data worksheet:
Analyse between: Samples
Similarity measure: Euclidean distance
Standardise: No
Transform: None

Variables

```
  1 TURBIDITY
  2 MEAN WETTED WIDTH (m)
  3 BEDROCK  %
  4 BOULDER %
  5 COBBLE %
  6 PEBBLE %
  7 GRAVEL %
  8 SAND %
  9 SILT / CLAY%
 10 DETRITUS %
 11 STICKS %
 12 BRANCHES %
 13 LOGS %
 14 ALGAE %
 15 Macrophytes %
 16 OVERHANGING HABITAT %
 17 BLANKETING SILT %
 18 SHADING%
 19 WATER TEMP
 20 CONDUCTIVITY (US/cm-1)
 21 pH
 22 DISSOLVED OXYGEN
 23 %SAT. DISSOLVED OXYGEN
```

Best results

No. Vars	Corr.	Selections
3	**0.568**	**5,11,21**
8	0.562	2,3,5,11,12,15,18,21
5	0.562	2,3,5,11,12