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ENVIRONMENTAL HEALTH OF STREAMS IN THE YARRA RIVER CATCHMENT

Environment Protection Authority
State Government of Victoria

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ABSTRACT

The health of waterways in the Yarra River catchment is largely determined by the effects of land use and other human activities. The freshwater environment changes considerably from the near-pristine forests in the ranges of the upper Yarra, to the diverse agricultural areas in the middle valley, and sprawling residential, commercial and industrial areas in metropolitan Melbourne.

The aim of this study was to highlight management priorities by assessing the environmental health of the Yarra River and its major tributaries, using macroinvertebrate-based rapid bioassessment and physicochemical measurement. Additional aims were to develop and apply Australian River Assessment System (AUSRIVAS) models and to assess compliance of the waterways with objectives set in the State Environment Protection Policy (Waters of Victoria) Schedule F7 – Waters of the Yarra Catchment (WoV Schedule F7) (Government of Victoria 1999). The sampling program was intended to assess the general condition of the catchment's waterways rather than investigate specific point source problems in the Yarra catchment.

Much of the upper catchment of the Yarra River is forested. Foresight has seen that large areas were strictly maintained for many years as water-supply catchment for Melbourne. Erosion impacted noticeably upon aquatic ecology in this area, but generally, these waterways were very healthy, with diverse faunal communities and good water quality.

Lower in the valley, agricultural practices and the effects of regional urban areas disrupted the aquatic ecology more dramatically. Contamination from land runoff, discharges from small regional sewage treatment plants, removal of riparian vegetation and disruption of instream habitat altered water quality and habitat conditions and affected aquatic communities.

In metropolitan Melbourne, the impacts on streams were stronger and more complex. Riparian and instream habitat alteration, urban stormwater systems and complex chemical pollution placed great stress on urban aquatic communities and, in some cases, severely diminished stream health.

Analysis of macroinvertebrate community structure indicated that sites in the Yarra catchment fell into four broad categories – the largely natural upper catchment (13 sites); the rural/urban fringe (including the rural and outer urban tributaries) (13 sites); the inner urban tributaries (19 sites); and the lower and middle reaches of the mainstream Yarra River (7 sites).

Compliance with ecological objectives set in the WoV Schedule F7 (Government of Victoria 1999) was good for sites in the upper catchment, but decreased with increasing proximity to Melbourne. All sites in the catchment failed to satisfy the nitrogen objectives set in the preliminary nutrient guidelines for Victorian inland streams (EPA 1995b), suggesting that refinement of the guidelines may be warranted.

Management priorities highlighted include riparian zone rehabilitation, runoff management, improved management of stormwater and sewerage systems and greater community education to reduce pollution inputs to stormwater systems and streams. AUSRIVAS model outputs were found to be useful indicators of stream health, particularly of habitat effects.

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1. INTRODUCTION

1.1 The Yarra catchment

The Yarra valley is a significant asset to Melbourne. It provides Melbourne's inhabitants with clean water, excellent soils and climate for agriculture and a forested valley for water-harvesting, recreation and timber production. However, land use in and around Melbourne has taken a heavy toll on the health of the Yarra River and its tributaries. In forested areas, erosion from current and past logging operations causes sedimentation of the streams, and water-harvesting impoundments alter aquatic conditions. In agricultural areas, destruction of the riparian zone, sedimentation caused by clearing and tillage, and chemical residues in runoff are common problems. In urban areas, habitat destruction, discharges from sewage treatment plants, pollutants washed from paved landscapes and waste entering stormwater drains are major impacts.

1.2 Monitoring ecological health

Pollution is essentially a biological phenomenon, since its principal effect is on living things (Hynes 1960; Wright *et al.* 1994; Cullen 1990). The complexity of the impacts suffered by aquatic environments means that measurement and characterisation of the biota is crucial to understanding anthropogenic effects on aquatic communities. This realisation has led to the development of biological monitoring of the ecology of streams to complement the more traditional physical and chemical monitoring. Although contributing valuable information about the water conditions at the time of sampling, physicochemical monitoring may fail to account for the variable nature of the aquatic environment. Unless this type of monitoring is continuous, it may not detect occasional changes or intermittent pulses of pollutants. Measurement and characterisation of biological communities can reveal a more complete picture of water quality and habitat degradation because aquatic organisms show an integrated response to environmental factors (Cullen 1990; Rosenberg and Resh 1993), reflecting the prevailing conditions at a site and the accumulation of impacts over time.

Aquatic macroinvertebrates have been used as the biological indicator in this program. A preference for using the macrobenthic community has developed in many countries, as they are an important and relatively well-understood component of the stream fauna (Hellawell 1986). They are particularly useful bioindicators since: they are ubiquitous, abundant and easy to collect; they are relatively immobile and hence representative of local conditions; their lifespans are adequate for providing a record of environmental conditions; and they are differentially sensitive to various pollutants and stresses, thus providing a graded response to a broad spectrum of impacts (Metcalfe 1989).

Many investigations of environmental health have been undertaken in the Yarra catchment and several have involved biological assessment (Campbell *et al.* 1982; Pettigrove 1989; Reed and Newall 1990; Mitchell and Clark 1991; Jones and Ferdinands 1993; EPA 1993; Marchant *et al.* 1994). Campbell *et al.* (1982) found that macroinvertebrate communities in mainstream Yarra River riffles were quite different from riffles in rural tributaries (where stoneflies and mayflies were extremely scarce), and in urban tributary riffles (where these groups were absent). That study also found that riffle communities in urban tributaries were far more stressed than in riffles of rural tributaries or the urban mainstream Yarra River. Pettigrove (1989) reported progressive downstream deterioration of invertebrate communities in the Yarra, indicating increasing anthropogenic disturbance. Both Campbell *et al.* (1982) and Pettigrove (1989) reported nutrient impacts on the fauna at some of the lowland sites. A study of the Plenty River (Reed and Newall 1990), a northern tributary of the Yarra River, found assemblages of diatoms and invertebrates reflecting a river in poor condition due to low flow and organic pollution. In a study of the Merri Creek, another northern tributary of the Yarra, Mitchell and Clark (1991) found a major decline in biological diversity and abundance as the creek flowed through industrial areas in Somerton and Campbellfield. They also found that diatom assemblages tolerant of organic pollution were ubiquitous in Merri Creek.

In 1994, in order to characterise aquatic health in the Yarra system, Metzeling summarised available ecological data for the catchment. These data suggested that the upper Yarra catchment was in near pristine condition, with high species-diversity, though some changes in faunal composition were associated with water-harvesting impoundments. A significant change in aquatic biota was evident with the transition to the agricultural region in the middle Yarra valley. Nutrient inputs, habitat changes and possible toxic inputs were found to lower species richness, causing increasing dominance by a small number of taxa. Urban development lower in the valley was responsible for major deterioration in aquatic biota, caused by further habitat destruction and decline in water quality.

1.3 The current study

This study was largely funded by the Monitoring River Health Initiative (MRHI), part of the National River Health Program (NRHP), a Commonwealth Government project to produce a nationally coordinated approach to monitoring inland waters. A major aim of the program was to develop and implement a standard methodology for monitoring benthic macroinvertebrates in freshwater streams using Rapid Bioassessment (RBA) techniques, thus allowing faster and less expensive evaluation of ecological health. The data accumulated during the program has been used to develop the Australian River Assessment System (AUSRIVAS) predictive computer models for river health assessment. AUSRIVAS consists of mathematical models based on the British River Invertebrate Prediction and Classification System II (RIVPACS) program. The system is modified for different seasons and aquatic habitats, producing models that predict the fauna likely to occur at a site in the absence of stresses such as pollution and habitat alteration. The results of the models can be tailored for a range of users, from community groups and managers to ecologists. On a broader scale, the MRHI program has provided a very important inventory of baseline data on the ecological health of streams nationwide.

The aim of this study was to highlight management priorities by assessing the environmental health of the Yarra River and its major tributaries using macroinvertebrate-based RBA and physicochemical measurement. The sampling program was intended to assess the general condition of the catchment’s waterways rather than investigate specific point source problems in the Yarra catchment. An additional aim was to assess compliance of the waterways with the State Environment Protection Policy (Waters of Victoria) Schedule F7 – Waters of the Yarra Catchment (WoV Schedule F7) (Government of Victoria 1999). Released in June 1999, this document is targeted at restoring environmental quality to an acceptable level and adopting measures to prevent further degradation, while allowing sustainable use of natural resources in the catchment. It divides the catchment into segments and sets objectives for environmental quality indicators specific to these segments. These indicators and objectives are tabulated in appendix I.

1.4 Catchment description

The Yarra valley rises from the Great Dividing Range in the north and the Blue Range and Dandenong Ranges in the east and south. It covers an area of approximately 4 100 km^2, extending 50 km north and 120 km east of Melbourne (figure 1). Rainfall ranges from as low as 500 mm/yr in the west, to over 1 500 mm/yr in the east. Precipitation is greatest in winter and spring (Department of Conservation and Natural Resources 1995).

Land use and geology vary greatly in the Yarra valley. In the Silurian-derived sedimentary hills to the east, the Yarra and nearby tributaries rise in cool temperate rainforests and wet sclerophyll forests, and flow through fertile floodplains of light-grey loam. Further west, in the hills to the north and north-east, the streams rise in dry sclerophyll forests and flow through open woodlands (Society for Growing Australian Plants Maroondah Inc. 1991). West of the Yarra valley is the Maribyrnong catchment. The Maribyrnong River flows into the Yarra River near its mouth where the river is tidal and saline. Rainfall, geology and vegetation types in the Maribyrnong catchment are distinctly different from the Yarra valley; consequently, the Maribyrnong catchment is examined in a separate report in this series.

The diverse land uses in the Yarra valley can currently be divided into three major zones. About 42 per cent of the Yarra catchment is forested. Half of the total waterway length within the basin is located throughout these forests (Chesterfield and Sovitslis 1994). In the east, in the mountains of the Great Dividing Range, substantial areas of the upper catchment are maintained in near-pristine condition. Many of these areas have been maintained as closed water-supply catchments since the turn of the century. In 1995 they were gazetted as the Yarra Ranges National Park. Although some of these areas were previously logged or mined, or had suffered from major bushfire damage, they were closed to public access early this century to maintain a clean water supply. This policy is still enforced and has resulted in the protection of rich stands of forest. The region also has other protected forest areas, such as Kinglake National Park in the north-east, although large areas still support forestry. The O’Shannassy River, in the upper catchment, is scheduled as a Heritage River under the *Heritage Rivers Act 1992*. Its catchment has escaped most of the major recorded bushfires and anthropogenic disturbances, and is an essentially natural area.

The reservoirs built to collect Melbourne’s water supply have a direct impact on the streams in the catchment. About 97% of water extraction from the Yarra catchment is for potable water supply and approximately half of the natural annual flow in the Yarra River remains after water-harvesting (Haydon 1994a). Runoff in the upper catchment is usually 30–35 per cent of rainfall (Haydon 1994b) and groundwater discharge comprises about half the total annual flow in the Yarra River (Shugg and O’Rourke 1994). In addition to the natural water supply in the Yarra basin, water is diverted from the Thomson River in the Thomson catchment via the Thomson–Yarra tunnel.

Further down the valley, in the foothills and on the floodplains, is a large variety of agriculture including nurseries, cut flowers, cropping, orchards, berry farms, market gardening, viticulture, grazing and dairy farming. These land uses affect streams flowing through these middle reaches, most notably through erosion and organic enrichment (Pettigrove 1989). In much of this region, riparian vegetation is distinctly lacking (Chesterfield and Sovitslis 1994) and the benefits of the riparian zone, both as a filter for runoff and as a valuable component of the stream environment, are severely reduced.

Melbourne is one of the most dispersed cities in the world (Duncan 1982). The urban sprawl covers extensive areas of the catchment with impermeable paved surfaces. This leads to very high levels of runoff and hence high pollution loads on streams. After rainfall reaches a small threshold, all rainfall from paved areas becomes runoff (Chiew and McMahon 1997). It is collected by kerbs and drains and transported to urban streams, carrying with it insoluble and soluble pollutants, such as litter and chemical residues. Chemical pollutants, such as brake-dust and oils from roads, combine with spills from industry and from deliberate dumping. Most stream sediments along the length of the basin are affected to some degree by heavy-metal contaminants (such as cadmium, copper, lead and zinc) and organic compounds (such as petroleum hydrocarbons and organo-chlorine pesticides). The trends in levels of these contaminants reflect the increasing urbanisation along the streams (Graesser 1994).

Urban runoff from commercial premises, and from activities such as car washing and hosing of footpaths, continues to pollute urban waterways during dry periods. Consequently, levels of contaminants in urban runoff during these periods can be very high. During wetter periods, pollutants can be diluted by higher stream-flows. However, greater runoff can also effect greater transport of pollutants from urban surfaces (Andoh 1994). Extensive paving in urbanised areas can exacerbate flow spates, causing considerable physical disturbance of aquatic habitat. Wet periods can also result in contamination of stormwater with sewage from emergency relief structures (Andoh 1994; EPA 1997). These structures are designed to alleviate stormwater flooding of the sewerage system by allowing waste to overflow to the stormwater system and hence to streams.

Urbanised areas are not restricted to the metropolitan region. Smaller townships are scattered throughout the rural and forested areas, each with the litter, runoff and chemical pollution associated with residential and commercial areas. Furthermore, these areas either have no sewerage system (relying instead on septic systems that can affect groundwater), or they have sewage treatment plants (STPs) that have direct deleterious effects on the streams into which they discharge (Jones and Ferdinands 1993). In the Yarra catchment, there are 105 premises licensed to discharge waste to the water environment (Robins 1994). Of these, 14 are for regional and local Melbourne Water STPs, with licence to discharge a combined total of 29 684 kL of treated effluent to the water environment each day. The Brushy Creek STP, and the Lilydale STP on Olinda Creek, discharge the greatest volumes (Robins 1994). In addition to the Melbourne Water discharge licences, there are 66 sewage and sullage effluent licences, 18 extractive industries licences, five licences to discharge contaminated/cooling water from manufacturing sites, and two fish-farm licences (Robins 1994).

PF	Yarra R at Banksia St Heidelberg	QH	Diamond Ck at Eltham
PG	Yarra R at Fitzsimmons Lane Templestowe	QI	Diamond Ck at Gipson St Diamond Ck
PH	Yarra R at Burke Rd Ivanhoe	QJ	Diamond Ck at St Andrews
PI	Gardiners Ck at Cato St Kooyong	QK	Merri Ck at Miller St Preston
PJ	Gardiners Ck at Warrigul Rd Chadstone	QO	Merri Ck at Creek Pde Clifton Hill
PK	Gardiners Ck at Station St Box Hill	QV	Merri Ck at Summerhill Rd
PL	Moonee Ponds Ck at Primrose St	QY	Plenty R at Booyan Cres Greensborough
PM	Moonee Ponds Ck at Devereaux St Oak Park		
PN	Moonee Ponds Ck at Bent St		**Upper Catchment Sites**
PO	Koonung Ck at Box Hill North	RI	***Yarra R at Maxwells Rd***
PP	Rufey Ck at Ruffy St Templestowe	RR	***Starvation Ck u/s diversion weir***
PQ	Stringybark Ck at McKillop Rd	RS	***Armstrong Ck East Branch***
PR	Stringybark Ck at Coldstream	RT	***O'Shannessy R u/s Reservoir***
PS	Brushy Ck at Wonga Park	RU	***Alderman Ck***
PT	Bushy Ck at Valda Ave	RV	***McMahon Ck***
PU	Mullum Mullum Ck at Ailsa Crt Ringwood	RW	***Upper Yarra R at Track 12***
PV	Mullum Mullum Ck at Quarry Rd Mitcham	RX	***Yarra R at Big Peninsula Tunnel***
PW	Mullum Mullum Ck at Warandyte	RZ	***Little Yarra R at Lowe Rd***
PX	Watsons Ck at Christmas Hills	SA	***Little Yarra R at Powelltown***
PY	Watsons Ck at Kangaroo Ground	SB	***Cement Ck at Acheron Way***
PZ	Olinda Ck at Silvan	SC	***Watts R at Fernshaw Reserve***
QA	Olinda Ck at Mt Evelyn	SD	***Woori Yallock Ck at Yellingbo***
QB	Olinda Ck Drain at Coldstream	SE	***Cockatoo Ck u/s Cockatoo***

Note: Sites in bold are reference sites used to formulate the AUSRIVAS models

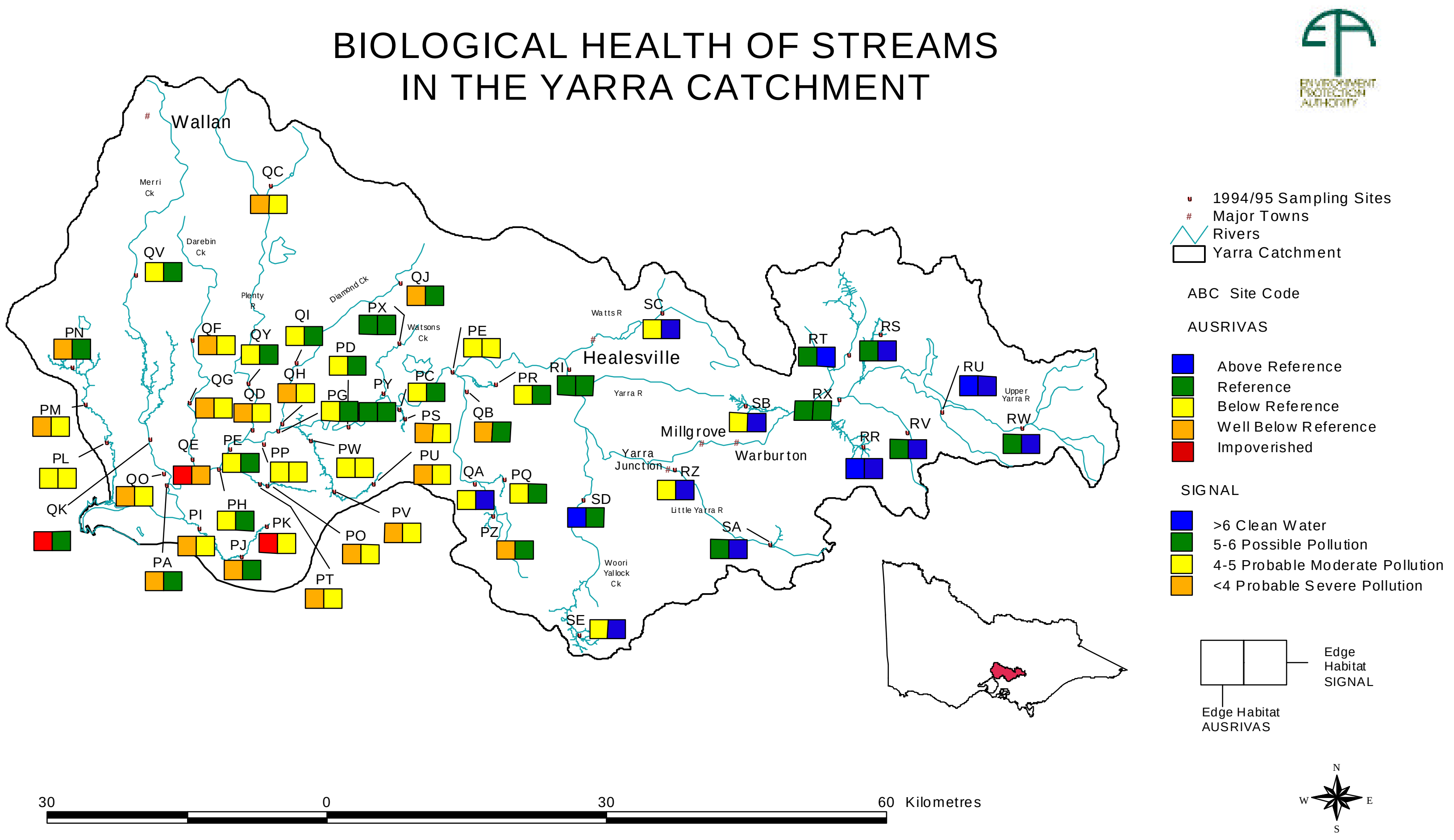

Figure 1: **Map of the Yarra catchment showing site locations with SIGNAL and AUSRIVAS scores. See appendix II for site descriptions.**

2. Methods

2.1 Site selection

Fifty-three sites were selected from the metropolitan areas of Melbourne and the rural and upper catchment regions (figure 1 and table 1). Fourteen rural and upper catchment sites were used as reference sites, with the 39 urban sites designated as test sites. The reference sites are relatively undisturbed sites, chosen to represent, as closely as possible, ideal stream conditions in the Yarra catchment. Data from these sites were used to develop the AUSRIVAS models, against which the test sites were compared in order to estimate their ecological health. The sites exhibit differing degrees of impact, from little-disturbed, forested upland sites, to heavily altered and urbanised lowland sites. Specific site descriptions are contained in appendix II. All sites in the statewide biological monitoring network have been allocated a two-letter alpha code and this system has been used in this report. Macroinvertebrate and physicochemical sampling was conducted in both rural and urban regions during spring 1994 and autumn 1995, to account for seasonal variation in community structure and water quality.

2.2 Biological methods

Where possible, at each site, samples were taken from two distinct aquatic habitats – stream edges, which may include macrophyte (water plant) beds, and riffles. Riffles (areas of shallow, turbulent water running over rocks or other uneven substrate) were not present at all sites and kick samples were not taken where riffles were absent.

Kick-samples were taken by kicking and disturbing the stream bed with a 250 µm-mesh kick net positioned directly downstream, allowing the current to flush dislodged invertebrates into the net. Kick sampling proceeded upstream, covering 10 m of riffle, which could be discontinuous. Sweep sampling of stream edges entailed vigorous sweeping, with a 250 µm-mesh net, through macrophyte beds and backwaters and along areas of edge with slow currents. A composite sample covering 10 m, which could also be discontinuous, was collected in this manner.

Samples were sorted in the field while the animals were still alive. The net contents were spread out in shallow trays and a subsample of animals was picked out over 30 minutes. As broad a range of taxa as possible was collected, while attempting to ensure that numbers of individuals picked were as representative as possible of their abundance in the whole sample. Riffle and edge samples were sorted and preserved separately in 80 per cent ethanol and transported to the laboratory for further processing and identification.

Identifications were made to family level using standard published keys and extensive voucher collections maintained by EPA. Exceptions to these levels of identification were the Oligochaeta and Hirudinea which, for reasons of taxonomic difficulty, were not resolved beyond class, the Hydracarina, which were not resolved beyond order, and Chironomidae larvae, which were only identified to subfamily. Macroinvertebrate data were ordered using a new invertebrate coding system developed by EPA. The system is capable of coding all invertebrates and has been adopted as the national standard for the MRHI program.

Internal and external quality assurance and control systems were followed throughout to ensure the accuracy and consistency of sampling, picking, identification and data entry.

2.3 Physicochemical sampling

Physicochemical variables, measured in the field using portable meters and from water samples returned for laboratory analysis, are listed in table 2.

Table 2: Measured physicochemical water variables

Variable	Abbreviation	Unit
Temperature	TEMP	°C
Electrical Conductivity	EC	µS/cm
pH	pH	pH units
Dissolved Oxygen	DO	mg/l
Turbidity	TURB	NTU
Total Phosphorus	Tot P	mg P/l
Total Kjeldahl Nitrogen	TKN	mg N/l
Nitrate and Nitrite	NO_x	mg N/l
Alkalinity	ALK	mg $CaCO_3$/l
Total Organic Carbon	TOC	mg C/l

2.4 Habitat

Habitat variables were recorded at the time of sampling to include more descriptive assessments of stream quality. Habitat variables used in the analyses include slope, altitude, discharge area upstream of the site, and categorical values pertaining to substrate composition, abundance of filamentous algae, riparian vegetation and river shading.

2.5 Data analysis

Analyses were performed on combined data sets from spring 1994 and autumn 1995, treating the edge and riffle habitats separately.

2.5.1 Multivariate analyses

RBA sample collection techniques do not rigorously measure abundance of taxa and so are generally not sufficiently quantitative to allow inclusion of abundance data in analyses. Invertebrate data were therefore transformed to binary (presence/absence) data. It has been demonstrated that binary data can be as effective as abundance data in determining ecological trends in water quality where analyses at the scale of a whole basin or state are being attempted (Marchant *et al.* 1995; Wright *et al*. 1994). Infrequently occurring taxa are often excluded from analyses as they may cause noise and obscure ecological patterns (Gauch 1982). Analyses for this study were conducted on data masked to remove taxa present at fewer than 10 per cent of sites.

All multivariate analyses were performed using PATN (Belbin 1993). Association matrices were calculated using the Bray–Curtis dissimilarity index, which is widely used in ecology and is considered robust (Clarke 1993). These matrices were then subjected to further analysis for graphical display as dendrograms (clustering) and ordinations (multidimensional scaling).

2.5.1.1 Classification using cluster analysis

Classification methods assign entities, such as species or sites, to groups. The members of each group are more similar to each other than to members of other groups (Gauch 1982). Numerous clustering techniques have been developed for this purpose. In this study, unweighted pair-groups method using arithmetic averaging (UPGMA) was used to determine site groupings based on the presence or absence of taxa. UPGMA is an hierarchical agglomerative clustering technique and is the most frequently used clustering technique, recommended where there is no specific reason for using another technique (Sneath and Sokal 1973). It classifies sites using information on all the taxa, grouping the two most similar entities (sites) into a cluster, then the next most similar, and so on, until all entities are classified. The resulting classification is presented as a dendrogram. Classification is not always the most appropriate technique, since it attempts to find clear breaks in the data that may not be there, ignoring trends or gradients. Trends or gradients are revealed more clearly through ordination, which emphasises the continuous variation in the data (Marchant *et al.* 1994).

2.5.1.2 Ordination

Ordination methods present multidimensional data in a reduced number of dimensions for ease of interpretation. Multidimensional scaling (MDS), one ordination technique, presents biotic relationships as a map, with the distances between sites in the map representing biotic dissimilarity between sites (Clarke 1993). Semi-strong hybrid multidimensional scaling (SSH) was the ordination technique chosen for this study because it is currently considered the most robust method available and it copes with the common situation where the responses of taxa to underlying gradients are unimodal, noisy and skewed (Marchant *et al.* 1994). SSH is described in detail in Belbin (1991). The technique requires that the number of dimensions are specified before the analysis. Two-dimensional ordinations are used here for ease of interpretation. In SSH ordinations, each axis is unweighted and equivalent, thus information is equally represented by each axis; the configuration can be arbitrarily rotated or expanded, but the relative position of samples within the ordination is not arbitrary (Clarke 1993).

2.5.1.3 Correlation of environmental variables and taxa with ordinations

To associate the SSH patterns with environmental features, the environmental data were related to the ordinations using the principal axis correlation (PCC) routine in PATN. This calculates a vector of maximum linear correlation for each variable and plots its direction in the ordination space to depict an environmental trend. The purpose is to determine whether the biological data are responding in any systematic way to the environmental attributes (Belbin 1993). This technique was also used to plot vectors for those taxa with the highest correlations with the ordinations. In order to account for Type I errors, correlations were tested for significance at $p <$ (0.05 divided by the number of environmental variables or taxa for each ordination). Unless otherwise stated, only vectors with significant correlations are displayed on PCC plots.

2.5.2 Biotic indices

Biotic indices attempt to combine data on taxonomic structure of a community into a single, easily interpreted number. Though they are sometimes criticised for their lack of wider application (Washington 1984), their simplicity and ease of interpretation makes biotic indices useful tools for assessing the ecological health of waterways, particularly in association with other analytical techniques such as classification and ordination (Gerritsen 1995).

Biotic indices were calculated using the Stream Invertebrate Grade Number–Average Level (SIGNAL) index developed by Chessman (1995), ratios of observed to expected taxa (O/E) using the AUSRIVAS models (Simpson *et al.* 1997) and the Key Families (families defined as key elements of the stream fauna) and Total RBA Families (the total number of families collected at a site) objectives from the WoV Schedule F7 (Government of Victoria 1999). Objectives for SIGNAL, Key Families and RBA Families are set as ecological objectives in the WoV Schedule F7 and are given in appendix I. These objectives require standard sampling methods using RBA sampling techniques (EPA 1998), with two sampling runs over one year.

2.5.2.1 Key Families

In the WoV Schedule F7 (Government of Victoria 1999), a number of invertebrate families were identified as being important indicators of stream quality. Objectives for the presence of a numerically defined subset of these families were set out for selected segments of the Yarra River system. For instance, for a site in the Aquatic Reserves segment of the Yarra River catchment to satisfy WoV Schedule F7 objectives, it is required that at least 19 of the 24 listed Key Families be present. These objectives were applied to the sites in the relevant Yarra segments identified in the WoV Schedule F7 (Government of Victoria 1999).

2.5.2.2 RBA Families

In addition to the Key Families indices, the total number of families collected by the RBA method (RBA Families) was compared with WoV Schedule F7 objectives (appendix I).

2.5.2.3 SIGNAL Index

The SIGNAL Index (Chessman 1995) was developed in south-eastern Australia and thus has local application. SIGNAL scores are a mean value calculated for each site based on the presence of families of aquatic invertebrates. The SIGNAL Index is best suited as an indicator of organic pollution (Chessman 1995), such as nutrient enrichment. Each family has been allocated a score (1–10) relating to their pollution sensitivity – with a low score indicating pollution-tolerant taxa, and a high score indicating pollution-sensitive taxa. These values are summed and the total divided by the number of families at the site, to give an index of water quality (table 3)**.** In this study, SIGNAL scores have been calculated for family lists compiled from edge samples. Oligochaeta were not identified beyond class in this study. The SIGNAL score for oligochaetes was taken to be 1, as they are generally pollution-tolerant. This allocation is in accordance with calculations used in the preparation of WoV Schedule F7 objectives (EPA 1995a). For Hirudinea, also not identified to family level, an average score of all families in that taxon was calculated. This combined average score (3) was then used in the SIGNAL calculation in place of Chessman's (1995) individual family scores.

Table 3: Key to SIGNAL scores (from Chessman 1995)

SIGNAL score	Water Quality
>6	clean water
5–6	doubtful quality, possible pollution
4–5	probable moderate pollution
<4	probable severe pollution

2.5.2.4 AUSRIVAS observed/expected score

The Australian River Assessment System (AUSRIVAS) is a series of mathematical models based on data collected during the MRHI sampling program. The models were developed using data from reference sites in the rural and upper catchment, chosen to represent little-disturbed streams, then evaluated using data from test sites in the urban areas known to be disturbed.

A site in question is compared to the model based on its physical and chemical characteristics. Using these characteristics, a suite of macroinvertebrates is predicted representing the likely fauna at the site in the absence of disturbance. The summed probabilities of the fauna expected to occur (Expected) is compared to those actually collected (Observed). The Observed/Expected (O/E) score provides a measure of biological impairment of the site. The score can range from zero (none of the predicted taxa were found) to one (all predicted taxa were found); it may also surpass one. A score greater than one may indicate an unexpectedly diverse site or may be the result of mild organic enrichment, allowing greater colonisation. As a simple characterisation of the stream's health, scores from the model can be placed into bands (table 4) representing different levels of biological condition (Simpson *et al.* 1997). AUSRIVAS scores used in this study are calculated from edge samples only.

Table 4: AUSRIVAS O/E score categories – scores and bands shown relate specifically to edge data from Victorian streams for the 1994 and 1995 seasons combined

Band Label	O/E Score	Band Name	Comments
X	≥1.15	richer than reference	• more families found than expected • potential biodiversity hotspot • possible mild organic enrichment
A	0.85–1.14	reference	• index value within range of the central 80 per cent of reference sites
B	0.55–0.84	below reference	• fewer families than expected • potential mild impact on water quality, habitat, or both, resulting in loss of families
C	0.25–0.54	well below reference	• many fewer families than expected • loss of families due to moderate to severe impact on water and/or habitat quality
D	≤0.24	impoverished	• very few families collected • highly degraded • very poor water and/or habitat quality

3. RESULTS

3.1 General faunal characteristics of the catchment

Table 5 shows a summary of all taxa found at each site for both sampling seasons combined. Taxa present at each site are represented by a filled box in the site column. Site descriptions are abbreviated (see appendix II for full details). Sub-family taxa in the Chironomidae (Tanypodinae, Orthocladiinae and Chironominae) are also abbreviated. The distribution of macroinvertebrates in table 5 reflects broad ecological patterns that are not unique to the Yarra catchment but reveal the nature of changes along the length of the valley. For the purpose of illustrating changes in aquatic communities across the catchment, sites are loosely organised from left to right on a geographical basis. The lowland tributary sites in the urban areas of Melbourne are on the left of the table. To the right of these are the mainstream Yarra River sites, which extend from the inner suburbs to the partially urbanised rural fringe east of Melbourne. To the right of these sites are the tributary sites in the rural/urban fringe north and east of Melbourne, with the sites in the upper catchment, east of the city, furthest to the right. The increasing density of filled squares from left to right in the table reflects an increase in taxon richness from the urban sites to the sites higher in the catchment.

In addition to the general trend of increasing taxon richness towards the upland sites, there were several other notable features in the data. For example, at the top of table 5, the distributions of taxa across sites shows that the flatworms (Taxon–code IF61) and molluscs (KG02–KG99) tended to be more common and widespread in the urban lowland areas. Crustaceans (OP01–OV01) had a more variable distribution. Most families of crustaceans in the table show a bias towards lowland sites, whereas the Eusiridae amphipods (OP03) show a preference for upland sites. Beetles (QC09–QC39) and fly larvae (QD01–QDAJ) tended to have cosmopolitan distributions, but were more common in the upland sites, with more sensitive taxa (for example, Ptilodactylidae [QC39], Blephariceridae [QD04], Dixidae [QD06], Athericidae [QD22] and Podonominae [QDAD]) found only at upland sites. Two groups that showed a clear bias towards the lowland sites were the true bugs (Hemiptera) (QH54–QH67) and damselfly nymphs (Zygoptera) (QO02–09).

In the context of this study, one of the most important factors in macroinvertebrate distribution is human activity. Anthropogenic pressures change along the length of the catchment, effecting changes which are evident both in the fauna (table 5) and in the environmental variables (table 6; see also more comprehensive results presented in appendix III). Habitat alteration and poor water quality are two important anthropogenic effects. Taxa with habitat requirements such as shading, low turbidity and abundant detritus input, which are provided for by dense riparian zones and forest surrounds, will be less well-adapted to rural or urban streams. Others are more pollution-tolerant and may be selectively advantaged when poor water quality excludes other taxa.

	Site name abbreviation	Grdnrs@Kyng	Grdnrs@WrglR	Grdnrs@BoxHill	Moone@Prmrs	Moone@Devrx	Moonee@Bent	Konng@BoxHill	Brushy@Wonga	Bushy@Valda	Mullum@Ailsa	Mullum@Quary	Mullum@Wndyt	Plenty@Wwood	Plenty@Vwbnk	Darebin@Frfld	Drbn@Epping	Drebin@Chnies	Merri@MllrSt	Merri@CkPde	Yarra@Dights	Yarra@Wonga	Yarra@Warndt	Yarra@Spadnis	Yarra@Banksia	Yarra@Ftsmns	Yarra@Bourke	Merri@Sumrhill	Plenty@Booyan
	Site code	PI	PJ	PK	PL	PM	PN	PO	PS	PT	PU	PV	PW	QC	QD	QE	QF	QG	QK	QO	PA	PC	PD	PE	PF	PG	PH	QV	QY
Code	Taxon																												
IB01	Hydridae													■	■		■			■									
IB02	Clavidae																	■	■										
IF49	Temnocephalidea			■	■																								
IF61	Dugesiidae	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■
II99	Nematoda				■	■		■	■		■		■		■		■										■		
IJ01	Gordiidae																												
KG02	Hydrobiidae		■		■	■	■		■		■	■	■				■		■		■	■							
KG05	Lymnaeidae								■			■	■		■	■		■	■	■									
KG06	Ancylidae		■	■	■				■		■	■	■							■		■				■	■		
KG07	Planorbidae														■			■				■							
KG08	Physidaa																			■									
KG99	Gastropoda	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
KP01	Hyriidae																												
KP02	Corbiculidae				■	■	■								■			■	■	■	■		■		■				■
KP03	Sphaeriidae															■													
LH01	Glossiphoniidae				■		■		■							■	■			■									
LH03	Richardsonianidae					■																							
LH05	Eropdellidae															■				■									
LH99	Hirudinea		■			■			■	■	■		■	■							■						■		■
LO99	Oligochaeta	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
MM99	Hydracarina					■	■			■	■			■				■		■			■		■	■	■		■
OP01	Talitridae	■	■						■			■							■			■							
OP02	Ceinidae	■	■		■	■	■		■		■	■	■	■	■		■	■				■	■		■			■	■
OP03	Eusiridae																												
OP04	Paracalliopidae																											■	
OP06	Paramelitidae																												
OR18	Janiridae	■		■		■								■	■			■				■			■				
OR25	Oniscidae																										■		
OT01	Atyidae								■						■	■			■		■	■	■	■	■	■	■	■	■
OV01	Parastacidae		■	■	■	■				■	■																		
QC09	Dytiscidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		■			■		■	■		■	■
QC10	Gyrinidae																	■											
QC11	Hydrophillidae				■	■	■	■		■	■	■		■			■			■				■		■		■	
QC13	Hydraenidae													■										■				■	
QC18	Staphylinidae																					■					■		
QC20	Scirtidae													■								■							■
QC34	Elmidae																				■	■	■	■	■	■	■		
QC37	Psephenidae				■	■						■						■				■	■			■			
QC39	Ptilodactylidae																												
QCAN	Curculionidae																					■							
QD01	Tipulidae											■										■	■	■	■	■			
QD04	Blephariceridae																												
QD06	Dixidae																												
QD07	Cilicidae	■	■	■				■		■	■			■	■														■
QD09	Ceratopogonidae										■	■					■											■	■
QD10	Simuliidae				■			■	■			■							■		■	■	■		■	■	■		
QD12	Psychodidae										■																		
QD22	Athericidae																												
QD24	Stratiomyidae								■																	■			

	Site name abbreviation	Ruffey@Ruffey	Olnda@MtEvln	Olinda@Cldstrm	Diamnd@Elthm	Dmnd@Dmnd	Dmnd@StAnds	Stgyk@McKlp	Strgbk@Cldstm	Watson@Xmas	Watsn@KngGd	Lyrebird@Silvan	***Cockatoo***	***Yarra@Maxwels***	***Starvation***	***Armstrong***	***O'Shannessy***	***Alderman***	***McMahon***	***Yarra@Tk12***	***Yarra@BPT***	***LtYarra@Lowe***	***LtYarra@Pwltwn***	***Cement***	***Watts@Frnshw***
	Site code	PP	QA	QB	QH	QI	QJ	PQ	PR	PX	PY	PZ	SE	RI	RR	RS	RT	RU	RV	RW	RX	RZ	SA	SB	SC
Code	Taxon																								
IB01	Hydridae			■			■																		
IB02	Clavidae																								
IF49	Temnocephalidea																								
IF61	Dugesiidae	■			■		■					■	■												
II99	Nematoda			■	■																				
IJ01	Gordiidae											■	■		■	■		■							
KG02	Hydrobiidae		■	■			■	■		■	■		■						■						
KG05	Lymnaeidae																								
KG06	Ancylidae						■	■			■										■				■
KG07	Planorbidae																								
KG08	Physidaa																								
KG99	Gastropoda	■	■	■	■	■	■	■	■	■	■			■	■										
KP01	Hyriidae							■				■	■												
KP02	Corbiculidae				■			■									■								
KP03	Sphaeriidae																								
LH01	Glossiphoniidae	■																							
LH03	Richardsonianidae																								
LH05	Eropdellidae																								
LH99	Hirudinea	■			■	■	■		■																
LO99	Oligochaeta	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■		■	■	■	■	■	■
MM99	Hydracarina	■	■	■			■	■	■	■	■	■			■		■		■	■	■			■	
OP01	Talitridae	■																							
OP02	Ceinidae			■		■	■		■	■	■														
OP03	Eusiridae		■									■			■	■	■	■	■	■		■		■	■
OP04	Paracalliopidae																								
OP06	Paramelitidae			■								■	■												
OR18	Janiridae			■						■															
OR25	Oniscidae																								
OT01	Atyidae	■	■	■	■	■	■		■	■	■			■				■			■				
OV01	Parastacidae		■									■	■											■	
QC09	Dytiscidae	■	■	■		■	■	■		■	■				■	■		■			■		■		■
QC10	Gyrinidae								■	■											■				■
QC11	Hydrophillidae	■	■	■			■	■	■					■	■	■	■	■	■	■	■		■	■	■
QC13	Hydraenidae		■						■		■			■			■					■			
QC18	Staphylinidae																								
QC20	Scirtidae						■	■		■	■		■		■	■	■	■	■		■	■		■	■
QC34	Elmidae	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■
QC37	Psephenidae	■	■			■	■				■	■			■		■		■			■		■	
QC39	Ptilodactylidae											■	■		■	■	■		■	■	■			■	
QCAN	Curculionidae																								
QD01	Tipulidae	■	■				■					■	■	■	■	■	■	■	■	■	■	■	■	■	■
QD04	Blephariceridae														■		■	■	■	■				■	
QD06	Dixidae		■								■		■		■	■	■	■	■	■	■		■	■	
QD07	Cilicidae	■				■	■			■	■														
QD09	Ceratopogonidae	■	■				■			■	■		■					■			■	■			
QD10	Simuliidae	■	■				■		■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	
QD12	Psychodidae	■																	■						
QD22	Athericidae											■			■	■			■		■			■	
QD24	Stratiomyidae		■							■															

Table 5: Summary of taxa present at each site for both seasons combined (taxa presence denoted as filled square)

Code	Taxon	PI	PJ	PK	PL	PM	PN	PO	PS	PT	PU	PV	PW	QC	QD	QE	QF	QG	QK	QO	PA	PC	PD	PE	PF	PG	PH	QV	QY	PP	QA	QB	QH	QI	QJ	PQ	PR	PX	PY	PZ	SE	RI	RR	RS	RT	RU	RV	RW	RX	RZ	SA	SB	SC
QD35	Empididae											■	■										■			■				■									■											■			
QD36	Dolichopodidae																																													■							
QD45	Sciomyzidae																			■																■																	
QD78	Ephydridae				■																■																																
QD89	Muscidae																												■	■																							
QDAB	Chiro,Diamesinae																																																				■
QDAD	Chiro,Podonominae																																												■	■		■					■
QDAE	Chiro,Tany		■					■			■	■	■											■						■	■		■	■		■		■		■	■	■	■	■	■	■			■	■	■		■
QDAF	Chiro,Ortho	■	■		■	■		■	■	■	■	■				■		■	■	■	■	■	■	■	■	■	■	■		■	■			■		■	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■
QDAJ	Chiro,Chiro	■	■	■				■		■	■	■	■	■	■									■					■	■			■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■			■
QE02	Baetidae								■												■	■	■	■	■	■	■	■	■	■	■				■	■	■	■	■		■	■	■		■	■	■	■	■	■	■	■	■
QE03	Oniscigastridae																														■				■							■		■	■	■		■	■	■			■
QE05	Coloburiscidae																					■	■																				■		■	■	■	■	■	■	■	■	■
QE06	Leptophlebiidae												■									■	■		■	■					■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
QE08	Caenidae																				■	■	■	■	■	■	■	■	■																				■				
QH54	Hydrometridae																													■					■		■	■															
QH56	Veliidae			■	■	■	■	■	■	■	■	■	■	■	■		■	■				■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■						■	■	■			■
QH57	Gerridae																								■		■																						■	■			
QH61	Nepidae																							■											■		■																
QH65	Corixidae			■	■	■	■	■	■	■	■	■	■		■			■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■							■		■		
QH66	Naucoridae																											■																									
QH67	Notonectidae		■	■	■		■	■	■	■		■	■		■			■	■			■		■	■	■	■	■	■	■			■	■	■	■	■	■															
QK01	Nannochoristidae																																											■		■							
QL01	Pyralidae																											■									■																
QM01	Corydalidae																						■		■	■	■																		■	■		■	■	■			■
QM02	Sialidae																											■	■					■																			
QN03	Osmylidae																																															■				■	
QN04	Neurorthidae																																										■		■	■	■	■					
QO02	Coenagrionidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■		■	■	■	■	■	■	■		■	■	■			■	■	■														
QO04	Protoneuridae												■		■				■								■		■				■						■														
QO05	Lestidae						■				■																							■	■			■	■														
QO07	Megapodagrionidae											■	■																	■		■	■		■		■	■			■												
QO08	Synlestidae																					■					■				■				■		■	■	■			■							■				
QO09	Amphipterygidae																															■																					
QO12	Aeshnidae				■		■			■	■	■	■	■			■	■				■	■		■	■	■				■	■	■	■			■	■	■	■				■	■	■	■	■	■	■			■
QO13	Gomphidae																						■									■					■											■	■	■			
QO16	Corduliidae		■	■		■	■	■	■				■	■			■	■	■		■	■				■			■		■						■	■				■		■			■		■	■			
QP01	Eustheniidae																																							■			■	■	■	■	■	■	■			■	■
QP02	Austroperlidae																														■													■	■	■		■		■	■	■	■
QP03	Gripopterygidae																					■	■	■	■	■	■		■		■		■	■	■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
QP04	Notonemouridae													■																													■		■	■	■					■	
QT01	Hydrobiosidae																					■	■		■	■	■				■			■	■				■			■	■	■	■	■	■	■	■	■	■	■	■
QT02	Glossosomatidae																					■																		■					■	■	■	■	■	■			■
QT03	Hydroptilidae		■		■			■				■						■								■										■	■		■				■	■							■		
QT04	Philopotamidae																																						■				■		■	■	■		■			■	■
QT06	Hydropsychidae	■			■			■	■			■	■					■	■		■	■	■		■	■	■			■									■	■		■	■		■	■	■	■	■	■	■	■	■
QT08	Ecnomidae				■																	■	■			■	■		■					■	■			■		■					■		■		■				
QT10	Limnephilidae																																															■					
QT13	Tasimiidae																																															■					
QT15	Conoesucidae																										■				■								■			■			■	■	■	■	■	■	■		■
QT17	Helicopsychidae																																											■		■		■					■
QT18	Calocidae																																								■		■	■	■	■	■	■	■	■		■	■
QT19	Helicophidae																																										■		■	■	■	■			■	■	■
QT21	Philorheithridae																														■									■			■	■	■	■	■	■			■		■
QT23	Atriplectididae																									■					■				■				■											■			
QT24	Calamoceratidae																								■			■											■								■		■				■
QT25	Leptoceridae	■	■									■	■					■			■	■	■		■	■	■	■	■		■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Conoesucidae (QT15) and Calocidae (QT18) caddisfly larvae (Trichoptera) were restricted to sites with good water quality and healthy riparian zones (table 5). Families that were more successful in the urban areas, particularly in the lower reaches of the Yarra River, were the Hydropsychidae (QT06) and Ecnomidae (QT08) (table 5). The Leptoceridae caddisfly larvae (QT25) had a broad distribution throughout the catchment (table 5) but were excluded from the very degraded urban sites.

Mayfly nymphs (QE02–QE08) (Ephemeroptera) displayed a pattern of distribution similar to the caddisfly larvae (table 5). The Oniscigastridae (QE03) and Coloburiscidae (QE05) are taxonomically small groups. The few species in these families were restricted to forest areas, whereas the taxonomically richer Leptophlebiidae (QE06) and Baetidae (QE02) inhabited a wider range of sites (table 5).

Certain groups, such as the Oligochaeta (LO99) (worms) and the Hydrobiidae (KG02) (molluscs), were better able to cope with degraded urban stream environments. At sites with severe pollution impacts, molluscs, in particular, were often found in very high numbers. Communities dominated by worms, molluscs and chironomid larvae were typical of sites with severe anthropogenic impacts.

Healthier sites with good water quality and adequate habitat, such as those in the closed upper catchment, had a richer fauna. Taxa such as the Eustheniidae stonefly nymphs (QP01) and the Blephariceridae fly larvae (QD04) were restricted to cooler, mountain streams with clean water and forested catchments. Sites on the mainstream Yarra River and on the tributaries in the rural/urban fringe are between the extremes of the degraded urban tributaries and pristine forest streams. Macroinvertebrate communities at these mainstream and fringe sites reflected the unique conditions that riparian and instream habitats, local land use and water quality have created at each site. Taxa such as Elmidae beetle larvae (QC34) and Gripopterygidae stonefly nymphs (QP03) were typical elements of the moderately sensitive fauna at these sites (table 5).

3.2 Comparison of indicators with WoV Schedule F7 objectives for the Yarra catchment

3.2.1 Ecological objectives

The WoV Schedule F7 (Government of Victoria 1999) sets objectives for indicators of ecological health in the aquatic environment. Used in conjunction with physical and chemical water-quality indicators, these objectives provide a benchmark against which current ecological condition can be measured.

Objectives for three macroinvertebrate indicators of environmental quality – the total number of RBA Families, number of Key Families (defined for each segment), and SIGNAL score – have been established in the WoV Schedule F7 (appendix I). Table 7 shows the biological indicator results for each site and their WoV Schedule F7 segment membership. It should be noted that these results are based on only two sampling events and should be treated with some discretion as they do not constitute statistically significant data.

Sites in the closed catchment fall within the range set for the Aquatic Reserves segment of the WoV Schedule F7. Only East Armstrong Creek (RS) failed to meet the biological objectives for this segment, falling below the proposed levels for the total number of RBA Families and number of Key Families.

Table 6: Selected environmental variables for all Yarra catchment sites (average data from the 1994 and 1995 seasons)

	DO (mg/L)	EC (uS/cm)	pH	turbidity (NTU)	NO2 + NO3 (mg/L)	TKN (mg/L)	Total nitrogen (mg/l)	total P (mg/L)	altitude (m)	mean width (m)	mean substr. reach (phi)	vegetation (category)
Site	**DO**	**EC**	**PH**	**TURB**	**NO_x**	**TKN**	**NO_x + TKN**	**TOTP**	**ALT**	**WIDTH**	**RECHSUB**	**VEGCAT**
RR - Starvation Creek	9.30	37.5	7.4	4.55	0.205	0.45	0.655	0.024	330	4.00	-3.538	4
RS - Armstrong Creek, East Branch	9.80	57.5	7.15	3.60	0.155	0.25	0.405	0.024	340	2.25	-2.705	4
RT - O'Shannessy River	11.20	25.0	7.1	5.05	0.150	0.45	0.600	0.039	430	8.00	-5.263	4
RU - Alderman Creek	11.50	38.5	7.05	1.65	0.160	0.1	0.260	0.010	380	5.00	-5.215	4
RV - McMahon Creek	11.45	41.5	7.15	3.70	0.240	0.3	0.540	0.018	400	4.50	-1.600	4
RW - Yarra River at Track 12	11.60	24.0	7.05	1.10	0.125	-	0.125	0.008	500	5.00	-5.300	4
SB - Cement Creek at Acheron Way	9.25	16.0	7.05	1.35	0.295	0.2	0.495	0.012	650	3.00	-7.125	4
SC - Watts River at Fernshaw Reserve	9.98	27.0	7.4	3.60	0.135	0.5	0.635	0.034	190	8.50	-3.273	3
RX - Yarra River at Big Peninsula Tunnel	8.18	46.5	7.45	3.90	0.145	0.2	0.345	0.010	240	6.50	-3.300	3
RI - Yarra River at Maxwell's Road	8.58	77.5	7.2	11.10	0.205	0.35	0.555	0.048	80	10.00	4.025	3
RZ - Little Yarra River at Lowe's Road	9.60	65.0	7.25	14.50	0.275	0.6	0.875	0.050	110	6.00	-3.610	2
SA - Little Yarra River at Powelltown	9.76	48.0	7.05	3.55	0.285	0.3	0.585	0.017	180	3.50	0.363	3
SD - Woori Yallock Creek at Yellingbo	10.50	102.5	7.15	15.00	0.605	0.35	0.955	0.024	105	5.50	4.525	4
SE - Cockatoo Creek at Cockatoo	10.05	105.0	7	7.25	0.745	0.3	1.045	0.024	200	3.00	0.438	3
PZ - Lyrebird Creek at Silvan	9.65	67.5	6.95	24.50	0.235	0.6	0.835	0.051	215	3.00	7.750	3
PD - Yarra River at Warrandyte	8.25	105.0	7.4	10.25	0.430	0.3	0.730	0.067	30	30.00	1.088	1
PC - Yarra River at Wonga Park	8.00	127.5	7.4	11.50	0.665	0.35	1.015	0.140	50	25.00	-1.013	1
PG - Yarra River at Templestowe	8.70	136.5	7.4	13.50	0.455	0.35	0.805	0.087	20	25.00	0.275	1
PH - Yarra River at Ivanhoe	7.70	150.0	7.1	16.00	0.400	0.65	1.050	0.087	15	28.50	-0.425	1
PF - Yarra River at Heidelberg	7.60	141.0	7.5	14.00	0.455	0.35	0.805	0.091	18	20.50	-4.268	1
PA - Yarra River at Abbottsford	8.40	220.0	7.45	13.50	0.450	0.400	0.850	0.110	12	25.00	-4.100	1
PE - Yarra River at Spadonis Reserve	7.80	95.0	7.4	12.25	0.295	0.65	0.945	0.085	70	22.50	1.488	2
PY - Watsons Creek at Kangaroo Ground	7.85	850.0	7.65	2.30	0.037	0.3	0.337	0.016	50	1.50	0.900	2
PX - Watson's Creek at Christmas Hills	8.60	3425.0	8	10.80	0.027	0.65	0.677	0.023	110	2.00	-6.300	2
PR - Stringybark Creek at Coldstream	8.60	675.0	7.55	17.25	0.730	0.55	1.280	0.024	75	2.50	1.050	2
PQ - Stringybark Creek at Silvan	10.20	412.5	7.7	10.50	2.600	0.35	2.950	0.022	240	1.75	-8.088	2
QJ - Diamond Creek at St Andrews	6.15	450.0	7.2	24.50	0.170	1.85	2.020	0.124	140	3.75	-4.825	2
QA - Olinda Creek at Mount Evelyn	9.05	97.5	7.2	5.75	0.520	0.25	0.770	0.025	130	2.50	-6.050	1
QH - Diamond Creek at Eltham	7.35	540.0	7.3	27.00	0.420	0.9	1.320	0.108	30	3.25	-0.738	1
QI - Diamond creek at Diamond Creek	6.50	640.0	7.25	33.00	0.083	1.1	1.183	0.121	70	3.50	1.475	1
QB - Olinda Creek at Coldstream	4.15	585.0	7.25	8.00	1.750	1.15	2.900	0.225	105	1.75	-5.550	1
PW - Mullum Mullum Creek at Warrandyte	7.65	620.0	7.7	22.50	2.550	0.9	3.450	0.290	40	4.00	-0.300	1
PU - Mullum Mullum Creek at Ringwood	9.80	505.0	8.35	12.90	0.052	1	1.052	0.073	130	2.50	-0.838	1
PV - Mullum Mullum Creek at Mitcham	7.15	725.0	7.45	36.50	1.770	2.25	4.020	0.570	90	1.00	-2.550	1
PT - Bushy Creek at Doncaster	11.75	1350.0	8.5	18.50	0.170	1.05	1.220	0.249	40	3.00	-6.575	1
PS - Brushy Creek at Wonga Park	7.60	432.5	7.25	16.25	10.700	1.85	12.550	7.950	55	4.00	-2.588	2
PP - Ruffey Creek at Templestowe	14.40	950.0	8.85	9.80	0.590	0.75	1.340	0.140	20	3.50	7.850	1
PO - Koonung Creek at Box Hill	7.90	522.5	7.6	39.00	0.215	0.8	1.015	0.082	45	1.75	4.175	1
PL - Moonee Ponds Creek at Essendon	6.30	1225.0	8.2	8.25	0.265	0.95	1.215	0.165	21	5.75	5.600	1
PM - Moonee Ponds Creek at Oak Park	10.25	1500.0	8.15	14.80	0.450	1.1	1.550	0.162	43	2.50	1.055	1
PN - Moonee Ponds Ck at Westmeadows	6.30	1320.0	7.6	33.25	0.071	1.05	1.121	0.171	80	1.50	-2.525	1
PK - Gardiners Creek at Box Hill	6.40	408.5	7.45	28.50	0.400	0.9	1.300	0.088	35	4.00	-5.475	1
PJ - Gardiners Creek at Chadstone	11.15	575.0	9.8	9.50	0.100	0.75	0.850	0.090	25	5.50	-4.125	1
PI - Gardiners Creek at Kooyong	7.35	375.0	7.75	56.00	0.455	0.85	1.305	0.130	15	2.00	-7.088	1
QD - Plenty River at Viewbank	4.10	1325.0	7.35	6.50	0.157	1.05	1.207	0.067	60	5.50	-1.800	1
QY - Plenty River at Greensborough	4.55	725.0	7.6	10.10	0.015	1.25	1.265	0.087	50	3.50	8.000	1
QC - Plenty River at Whittlesea	4.10	800.0	7.2	36.25	0.014	3.1	3.114	0.275	200	2.25	3.638	1
QV - Merri Creek at Craigieburn	7.10	3450.0	8.3	7.45	-	0.85	0.850	0.052	200	6.00	8.300	2
QK - Merri Creek at Coburg	4.78	1250.0	7.8	2.90	0.185	1.15	1.335	0.200	40	8.00	0.325	1
QO - Merri Creek at Northcote	10.20	900.0	7.9	4.40	0.222	0.9	1.122	0.140	20	4.25	0.300	1
QF - Darebin Creek at Epping	6.50	425.0	7.4	4.85	0.369	0.75	1.119	0.070	130	1.75	2.900	1
QG - Darebin Creek at Kingsbury	7.75	1400.0	7.9	6.05	1.478	0.65	2.128	0.087	70	2.00	6.200	1
QE - Darebin Creek at Fairfield	10.00	925.0	8.6	5.65	0.730	1.4	2.130	0.260	40	5.00	-3.163	1

WoV Schedule F7 objectives for environmental quality indicators:

PASS **FAIL** **MARGINAL**

	DO	pH	Total nitrogen	total P
Aquatic Reserves	**N**	**N**	**N**	**N**
Parks and Forests	**>8.0**	**6.5 - 8.5**	**0.2**	**0.03**
Rural Eastern Mainstream	**>6.0**	**6.5 - 8.5**	**0.6**	**0.05**
Rural Eastern Tributaries	**>6.0**	**6.5 - 8.5**	**0.6**	**0.05**
Rural Western	**>6.0**	**6.5 - 8.5**	**0.6**	**0.05**
Urban Mainstream	**>6.0**	**6.5 - 8.5**	**0.9**	**0.08**
Urban Tributaries	**>6.0**	**6.5 - 8.5**	**1.0**	**0.10**

A more complete table of environmental variables is contained in appendix III.

VEGCAT categories:- 1 urban, 2 agriculture/some residential, 3 some forestry/agriculture, 4 native forest.

N = natural background level

Of the four sites in the Parks and Forests segment, Lyrebird Creek (PZ) and Yarra River at Big Peninsula Tunnel (RX) failed to attain the SIGNAL score objective (7) (appendix I), but had scores exceeding 6, indicating clean water. Cement Creek (SB) did not satisfy the WoV Schedule F7 objective for the total RBA Families and Lyrebird Creek (PZ) failed all three objectives.

In the Urban, Rural Western and Rural Eastern segments, no sites complied with all three biological indicators. The two sites in the Rural Western segment failed all three objectives, but Merri Creek at Craigieburn (QV) only narrowly failed to meet the SIGNAL and RBA Families objectives. All sites except Olinda Creek at Coldstream (QB) failed to meet the SIGNAL objective, and all but Diamond Creek at Diamond Creek (QI) failed to satisfy the Key Families objective. Conformance with the total number of RBA Families was better, however, with two of the six mainstream urban sites meeting the objectives and two sites – Ivanhoe (PH) and Heidelberg (PF) – narrowly failing. Only seven of the 23 Urban Tributaries met the RBA Families objective.

3.2.2 Physicochemical objectives

Table 6 shows the physicochemical results for all sites in the catchment. WoV Schedule F7 segment membership for the sites, and objectives for environmental quality indicators, are also shown. Most sites in the catchment conform to the pH and dissolved oxygen water quality objectives. Only sites on Merri Creek (QK) and the Plenty River (QD, QY, QC), which often have low flow, and Olinda Creek at Coldstream (QB), which is downstream of the Lilydale sewage treatment plant, failed to meet dissolved oxygen requirements. Dissolved oxygen concentrations were high in Gardiners Creek at Chadstone (PJ) and pH was also above the maximum limit. Ruffey Creek at Templestowe (PP) and Darebin Creek at Fairfield (QE) also failed to meet pH objectives, although Darebin Creek was only marginally high. These high pH levels coincided with very high dissolved oxygen concentrations (table 6). Compliance with the proposed nutrient objectives, which were developed to concur with the EPA's interim and long-term preliminary nutrient guidelines for Victorian inland streams (EPA 1995b), was much poorer.

The Aquatic Reserves segment falls within the Highlands River Region of the preliminary nutrient guidelines. Recommended maxima for nutrients in this region are 0.200 mg/l total nitrogen and 0.030 mg/l total phosphorus. The O'Shannassy River (RT) failed to meet the target for phosphorus concentrations and all sites in the segment, except the Yarra River at Track 12 (RW), failed to comply with the nitrogen guideline as defined for the Highlands River Region. However, the recommended objective for nutrients in this segment of the WoV Schedule F7 is 'natural background levels'. Further interpretation of these results will assist in determination of these levels and assessment of compliance.

The Parks and Forests segment of the WoV Schedule F7 largely falls within the Southern Foothills Region of the guidelines (recommended maxima 0.200 mg/l total nitrogen and 0.030 mg/l total phosphorus). All sites in this segment failed to meet the guideline for nitrogen. Two sites met the target for phosphorus (SB and RX); the remaining two (SC and PZ) failed only narrowly.

One-quarter of sites in the Rural Eastern Waterways segment complied with the objective for nitrogen (table 6). Levels in Watsons Creek at Christmas Hills (PX) were only marginally high. Compliance with the phosphorus objectives was much better, with 10 of the 12 sites having phosphorus concentrations below the recommended maximum, whereas levels in the Yarra River at Spadonis Reserve were marginally high. Both sites in the Rural Western Waterways segment (QC and QV) failed to comply with either nutrient objective.

The urban tributaries fall largely within the preliminary nutrient guidelines' Southern Foothills River Region (0.030 mg/l phosphorus and 0.200 mg/l nitrogen). Although the physical and geographical characteristics of the urban tributaries are similar to those of the Southern Foothills waterways, concentrations in the urban tributaries, not surprisingly, far exceed the guidelines recommended for these waterways. As a first step, the WoV Schedule F7 suggests objectives for the urban tributaries of 0.100 mg/l for total phosphorus and 1.000 mg/l for total nitrogen. Most sites still fail to comply with these objectives (table 6). This is recognised in the WoV Schedule F7, but in 1995 these levels were considered attainable in the next 10 years (EPA 1995a). Compliance with the objective for nitrogen was poorer than for phosphorus, with only one site – Gardiners Creek at Chadstone (PJ) – meeting the nitrogen objective, whereas eight sites met the phosphorus objective (table 6). Total nitrogen concentrations at Mullum Mullum Creek at Ringwood (PU) and Koonung Creek at Box Hill (PO) were only marginally above objectives.

The mainstream Yarra River largely falls within the Southern Lowland Rivers Region. Nutrient targets for this region in the preliminary nutrient guidelines are 0.050 mg/l phosphorus and 0.600 mg/l nitrogen. However, currently the urban mainstream Yarra River is far from complying with the guidelines for Southern Lowland Rivers. Once again, as a first step, the WoV Schedule F7 objectives have been raised for these sites to 0.080 mg/l phosphorus and 0.900 mg/l nitrogen until 2005. After a review of the schedule, the guidelines for the Southern Lowland Rivers Region should replace these targets (EPA 1995a). Four of the six sites in the urban mainstream Yarra River meet the nitrogen objectives, whereas only one site, in Warrandyte (PD), meets the phosphorus objective. The sites at Templestowe (PG) and Ivanhoe (PH) narrowly fail to meet the phosphorus objective.

3.3 Multivariate analysis of aquatic communities

In the following multivariate analyses, the UPGMA dendrogram and SSH ordination are displayed together with the PCC plots for taxa and environmental factors for ease of interpretation. Analyses over the whole Yarra catchment for each sample type will be followed by separate analyses for the urban and upper regions, as defined in figure 1 and appendix II.

3.3.1 The Yarra catchment as a whole – riffles

The UPGMA classification (figure 2a) distinguishes three main groups – sites in the upper Yarra catchment, sites on the urban mainstream Yarra River and rural/urban fringe tributaries, and sites on urban tributaries. These groups are also separate in the SSH ordination (figure 2b). There are two outlying sites – Stringybark Creek at McKillop Road, Silvan (PQ) and Mullum Mullum Creek at Warrandyte (PW). Streams in the upper Yarra, the rural/urban fringe tributaries and the mainstream Yarra River were more similar to each other than to the more degraded urban tributaries (figure 2a).

A strong altitudinal gradient was revealed in the ordination (figure 2b) and this trend is reflected in the environmental factors PCC (figure 2d), which shows the six highest correlated environmental factor vectors. The positive correlation of the vegetation category (VEGCAT) and altitude vectors with the higher, forested sites reflects the changing land use in the catchment. Alkalinity and pH are positively correlated with sites in the metropolitan area. Electrical conductivity (EC) and temperature are also positively correlated with the more urban sites.

Table 5 shows that sites in the upper catchment group have higher taxonomic richness than sites in the other two groups, although molluscs (KG02–KP03), worms (LH01–LO99), true bugs (QH54–QH67) and damselfly nymphs (QO02–QO08) are uncommon in the upper sites. The group of urban sites have fewer taxa, with a higher proportion of molluscs, worms and damselfly nymphs, whereas sites in the mainstream Yarra River and rural/urban tributaries have macroinvertebrate communities with intermediate taxon richness but with differing community structures between the mainstream and tributary sites.

Two sites did not fit the general pattern of separation of urban from upper sites. Cockatoo Creek (SE) was the only site from the rural/upper catchment not in the upper Yarra group. This site, although outside the main metropolitan area of Melbourne, is affected by local urban runoff around Cockatoo and is more like a rural/urban fringe tributary. In comparison, Lyrebird Creek at Silvan (PZ) was a relatively unimpaired site compared with others in the urban catchment.

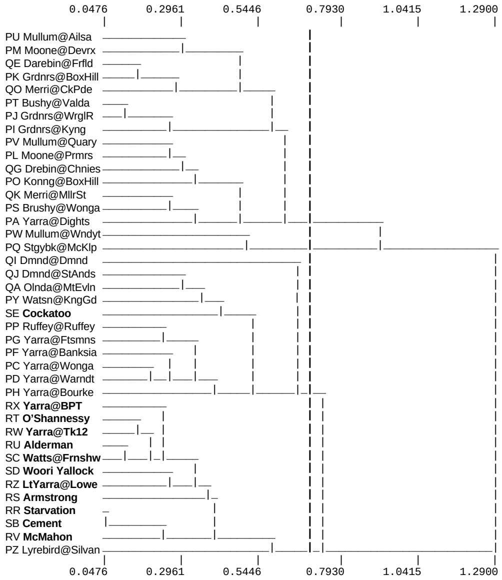

Figure 2a UPGMA classification of all riffle sites in the Yarra catchment

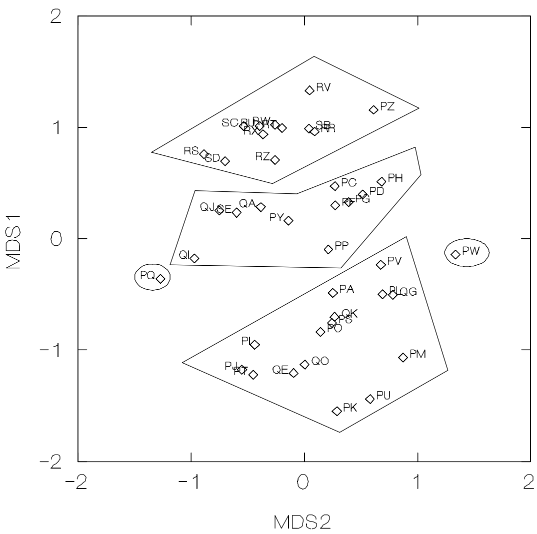

Figure 2b SSH ordination of all riffle sites in the Yarra catchment (Stress = 0.200)

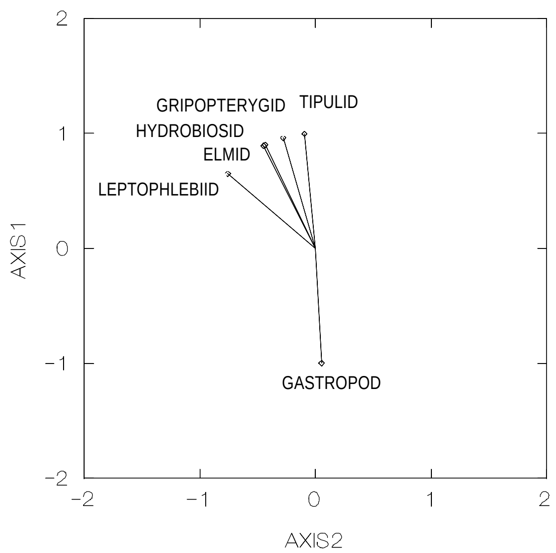

Figure 2c 2-dimensional PCC for taxa in all riffles in the Yarra catchment

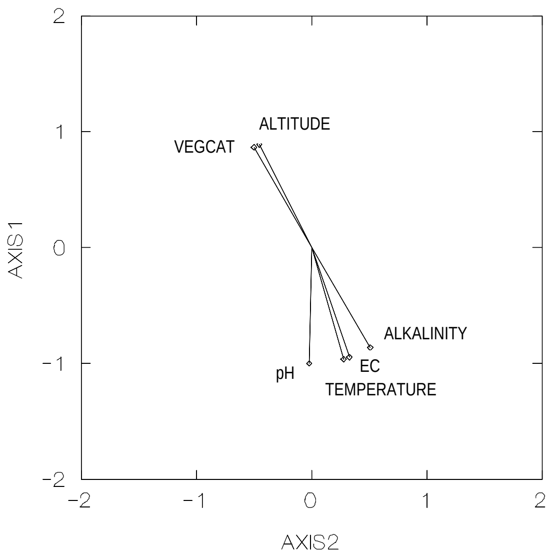

Figure 2d 2-dimensional PCC for environmental factors in all riffles in the Yarra catchment

Table 7: Biotic indices for all sites in the Yarra catchment. Sites have been placed within segments defined in the WoV Schedule F7 (SIGNAL and AUSRIVAS O/E scores are based on edge samples only)

Site	Families O/E	O/E Band	SIGNAL score	SIGNAL Band	Total RBA Families	Total SEPP key families
RR - Starvation Creek	1.15	X	7.0	A	30	19
RS - Armstrong Creek, East Branch	1.14	A	7.2	A	27	15
RT - O'Shannessy Creek	1.14	A	7.1	A	35	22
RU - Alderman Creek	1.26	X	7.3	A	36	22
RV - McMahon Creek	0.97	A	7.1	A	34	22
RW - Yarra River at Track 12	1.03	A	7.2	A	34	20
SB - Cement Creek at Acheron Way	0.76	B	7.2	A	28	19
SC - Watts River at Fernshaw Reserve	0.83	B	7.0	A	31	20
RX - Yarra River at Big Peninsula Tunnel	1.14	A	6.4	B	38	17
RI - Yarra River at Maxwell's Road	0.91	A	5.9	B	19	10
RZ - Little Yarra River at Lowe's Road	0.78	B	6.5	A	30	15
SA - Little Yarra River at Powelltown	1.01	A	6.6	A	22	12
SD - Woori Yallock Creek at Yellingbo	1.15	X	5.9	B	26	15
SE - Cockatoo Creek at Cockatoo	0.77	B	6.0	A	22	8
PZ - Lyrebird Creek at Silvan	0.38	C	6.3	B	21	12
PD - Yarra River at Warrandyte	0.72	B	5.5	B	25	15
PC - Yarra River at Wonga Park	0.59	B	5.6	B	32	15
PG - Yarra River at Templestowe	0.73	B	5.3	B	30	14
PH - Yarra River at Ivanhoe	0.78	B	5.2	B	26	12
PF - Yarra River at Heidelberg	0.82	B	5.4	B	26	14
PA - Yarra River at Abbottsford	0.36	C	4.8	B	17	9
PE - Yarra River at Spadonis Reserve	0.61	B	4.9	C	16	6
PY - Watsons Creek at Kangaroo Ground	0.97	A	6.2	B	33	15
PX - Watson's Creek at Christmas Hills	0.90	A	5.4	B	26	9
PR - Stringybark Creek at Coldstream	0.80	B	5.4	B	23	7
PQ - Stringybark Creek at Silvan	0.64	B	5.4	B	17	6
QJ - Diamond Creek at St Andrews	0.50	C	5.6	B	33	13
QA - Olinda Creek at Mount Evelyn	0.82	B	6.3	A	31	13
QH - Diamond Creek at Eltham	0.54	C	4.9	C	15	7
QI - Diamond creek at Diamond Creek	0.79	B	5.3	B	20	12
QB - Olinda Creek at Coldstream	0.54	C	5.5	B	17	8
PW - Mullum Mullum Creek at Warrandyte	0.61	B	5.0	C	21	8
PU - Mullum Mullum Creek at Ringwood	0.43	C	4.6	C	17	6
PV - Mullum Mullum Creek at Mitcham	0.54	C	4.8	C	23	9
PT - Bushy Creek at Doncaster	0.35	C	4.3	C	12	3
PS - Brushy Creek at Wonga Park	0.48	C	4.3	C	19	7
PP - Ruffey Creek at Templestowe	0.62	B	4.5	C	23	8
PO - Koonung Creek at Box Hill	0.35	C	4.5	C	13	4
PL - Moonee Ponds Creek at Essendon	0.43	C	4.6	C	22	8
PM - Moonee Ponds Creek at Oak Park	0.48	C	4.6	C	16	6
PN - Moonee Ponds Creek at Essendon	0.66	B	4.9	B	15	6
PK - Gardiners Creek at Box Hill	0.11	D	4.6	C	12	2
PJ - Gardiners Creek at Chadstone	0.49	C	4.9	B	13	5
PI - Gardiners creek at Kooyong	0.28	C	4.3	C	9	4
QD - Plenty River at Viewbank	0.48	C	4.3	C	16	4
QY - Plenty River at Greensborough	0.74	B	5.0	B	23	10
QC - Plenty River at Whittlesea	0.27	C	4.9	C	16	5
QV - Merri Creek at Craigieburn	0.68	B	5.3	B	19	7
QK - Merri Creek at Coburg	0.22	D	4.8	B	12	5
QO - Merri Creek at Northcote	0.26	C	4.0	C	13	3
QF - Darebin Creek at Epping	0.35	C	4.7	C	13	6
QG - Darebin Creek at Kingsbury	0.49	C	4.7	C	20	8
QE - Darebin Creek at Fairfield	0.14	D	3.3	D	7	1

WoV Schedule F7 objectives for biological indicators:		PASS	FAIL	MARGINAL	
	Aquatic Reserves	7.0		30	19
	Parks and Forests	7.0		30	17
	Rural Eastern m'strm	6.5		27	17
	Rural Eastern tribs	6.5		27	16
	Rural Western	5.5		20	10
	Urban m'strm	6.0		26	16
	Urban tribs	5.5		20	12

The clear segregation of Lyrebird Creek (PZ) from other urban sites (figures 2a and 2b) reflects the effects of water quality differences (SIGNAL score = 6·29) and forest land use on the aquatic fauna. However, despite the forested catchment and reasonably good water quality (table 6), its O/E score of 0.38 (table 7) suggests a highly degraded site. Although the site is not pristine, it is not highly degraded. This discrepancy suggests a potential weakness in the AUSRIVAS model.

3.3.2 Riffles in the upper Yarra

Clear trends are evident in the analysis of riffles in the upper Yarra catchment and these compare well to the analyses of riffles over the whole catchment. The UPGMA dendrogram (figure 3a) distinguishes two main groups, with two outlying sites – Cockatoo Creek (SE) and East Armstrong Creek (RS). These groups are also separate in the SSH ordination (figure 3b).

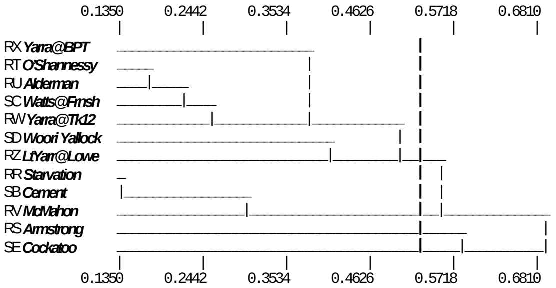

Figure 3a UPGMA classification of upper Yarra riffles

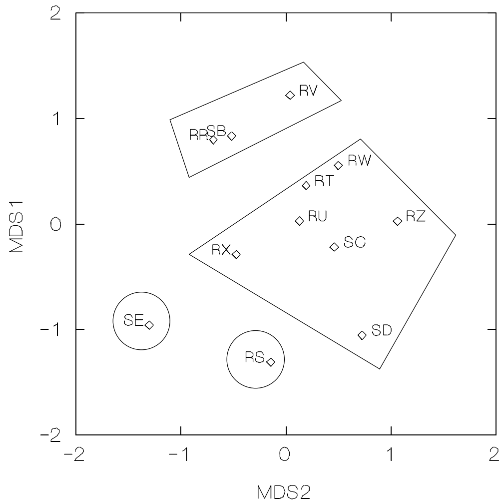

Figure 3b SSH ordination of upper Yarra riffles (Stress = 0.190)

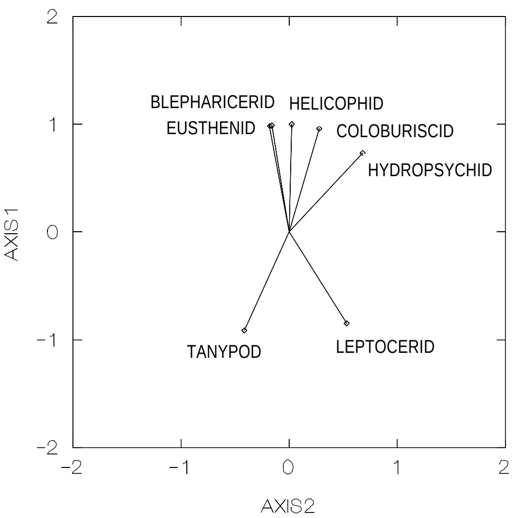

Figure 3c 2-dimensional PCC for taxa in upper Yarra riffles

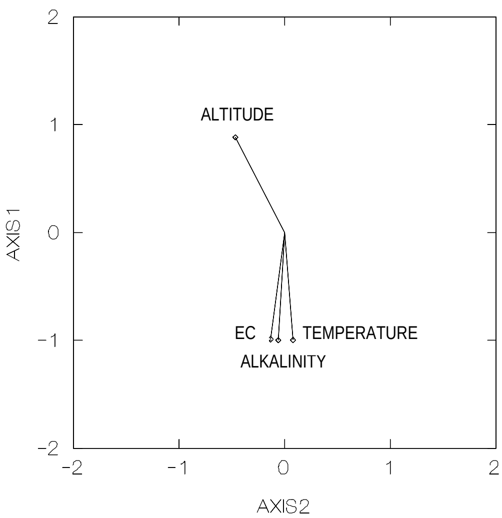

Figure 3d 2-dimensional PCC for environmental factors in upper Yarra riffles

The distribution of sites in the ordination (figure 3b) suggests a trend separating sites by altitude that corresponds with a gradient in SIGNAL score (table 7). The correlation of the altitude vector in the environmental PCC (figure 3d) and the vectors for Blephariceridae (QD04), Helicophidae (QT19), Coloburiscidae (QE05) and Eustheniidae (QP01) in the taxa PCC (figure 3c) also supports the altitudinal trend. These families were found at forested upper catchment sites with good water quality and are commonly associated with fast, turbulent currents (Colless and McAlpine 1991; Neboiss 1991; Peters and Campbell 1991; and Hynes 1978) which are typical of sites in the upper catchment.

The two outlying sites – the East branch of Armstrong Creek (RS) and Cockatoo Creek (SE) – lie at the bottom of the ordination. Both are small, shallow streams (table 6). East Armstrong Creek had a substrate composed mostly of small cobbles, pebbles and smaller fractions, possibly resulting from erosion upstream in its catchment. Cockatoo Creek had a substrate apparently affected by periodic sediment deposition and scouring, caused by stormwater runoff from local roadside drains (table 6, appendix II). The vector for the mean substratum for the reach (phi, not plotted), from the PCC for environmental factors, supports substrate as a factor separating East Armstrong Creek and Cockatoo Creek from the main body of sites. Despite its lower overall correlation value (0.5851), reach phi has a very strong negative correlation with MDS axis 1 (-0.9923), which is the main axis separating these two sites from the others in the upper catchment. This axis also strongly delineates Woori Yallock Creek (SD) (which has a clay- dominated substrate) from the main group of sites.

3.3.3 Riffles in the urban region

Two large site groups are apparent in the UPGMA classification of urban riffles (figure 4a). One group contains all of the outer urban tributaries and mainstream Yarra River sites except Dights Falls (PA), while the other group contains the tributary sites in urban Melbourne, plus the Yarra River at Dights Falls. Two sites lie outside these two main groups – Mullum Mullum Creek at Warrandyte (PW), in the Urban segment of the WoV Schedule F7, and Stringybark Creek at McKillop Road (PQ), in the Rural Eastern segment. The UPGMA classification groups these outlying sites together, but the SSH ordination (figure 4b) separates them strongly on axis 1. This placement was investigated using different data-masking and different numbers of axes in the ordinations. None of these ordinations grouped these sites close to one another; consequently, the analyses are not presented here.

The PCC for taxa (figure 4c) shows strong positive correlation of the vectors for Elmid beetles (QC34) and Gripopterygidae stonefly nymphs (QP03) with sites to the right of MDS 2. There is also a somewhat lower, but still substantial, positive correlation of the vectors for Leptophlebiidae mayfly nymphs (QE06) and Tipulidae fly larvae (QD01), with this gradient separating the main groups.

Sites on the mainstream Yarra River and outer urban tributaries group on the right-hand side of the ordination (figure 4b). The mainstream sites cluster tightly within this group, reflecting their homogeneous nature relative to the overall range of sites. Figure 5 shows a substantially greater mean number of taxa for the group of sites in the mainstream Yarra and outer urban tributaries than is evident at sites in the group of urban tributaries. There is also a considerable difference between SIGNAL scores for the two groups (figure 6), illustrating the poorer water quality in the urban tributaries. This is supported by the strong positive correlation of the vector for unidentified gastropods (KG99) with the group of urban tributary sites (figure 4c). Most of the individuals making up the unidentified gastropods in the data are introduced *Physa* sp. or *Physastra* sp., which are pollution-tolerant (and hence have low SIGNAL scores) and can dominate at sites where pollution stresses have caused diversity to be lowered (Hynes 1960).

The convergence of the alkalinity, electrical conductivity (EC) and pH vectors (figure 4d) with the separation of sites within each group along axis 1 suggests water quality is having an influence on group separation. However, none of the correlations in the PCC for environmental parameters is significant and neither the SIGNAL scores nor the O/E scores support a water quality gradient in this direction (table 7).

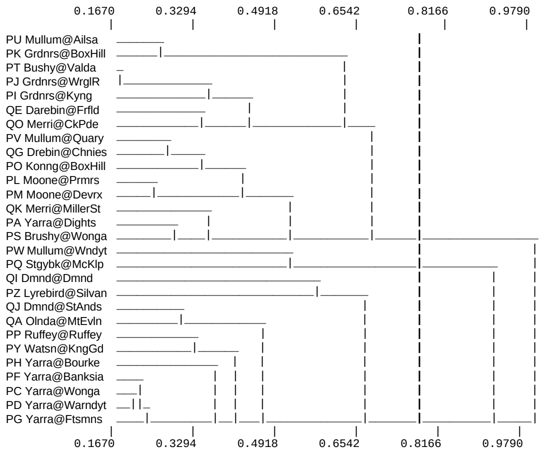

Figure 4a **UPGMA classification of urban Yarra riffles**

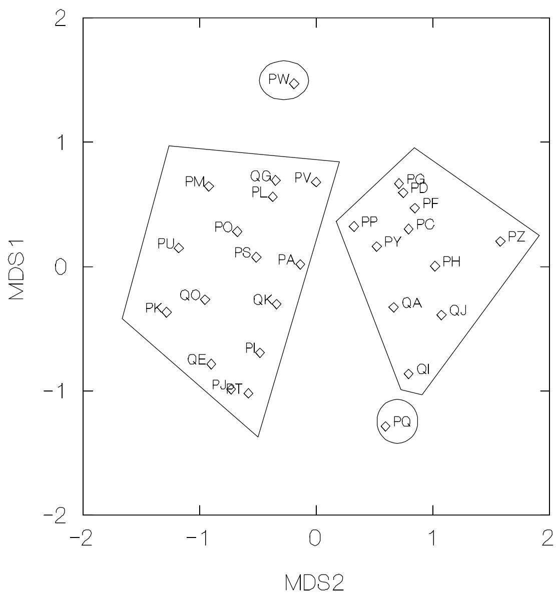

Figure 4b **SSH ordination of urban Yarra riffles (Stress = 0.232)**

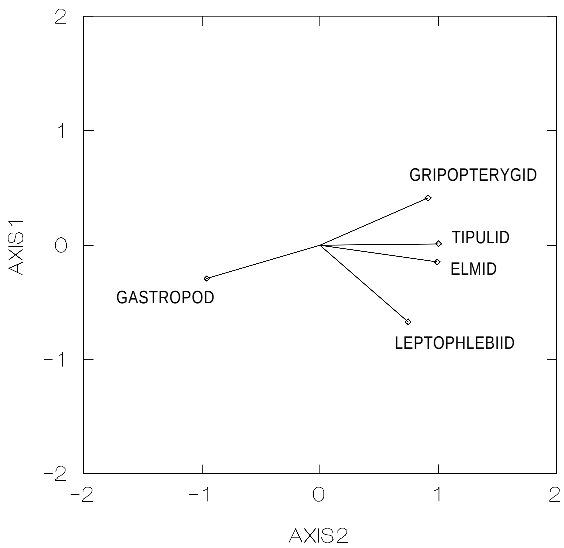

Figure 4c **2-dimensional PCC for taxa in urban Yarra riffles**

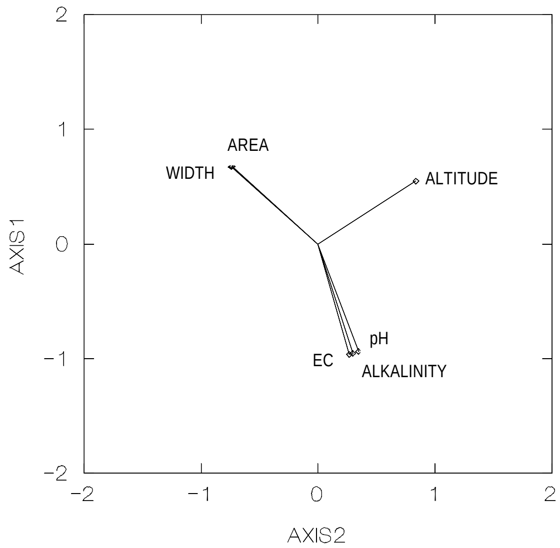

Figure 4d **2-dimensional PCC for environmental factors in urban Yarra riffles (No significant correlations)**

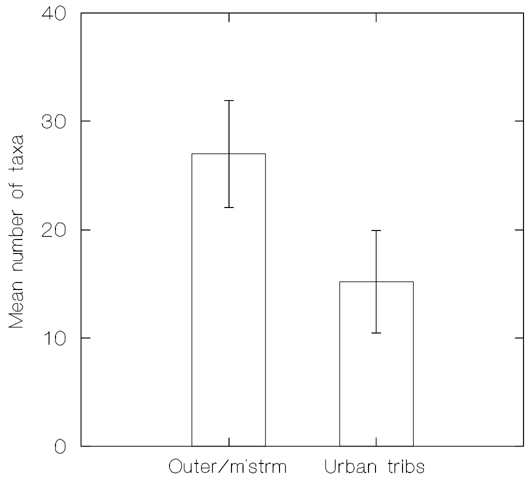

Figure 5 Mean number of taxa for UPGMA/ SSH groups

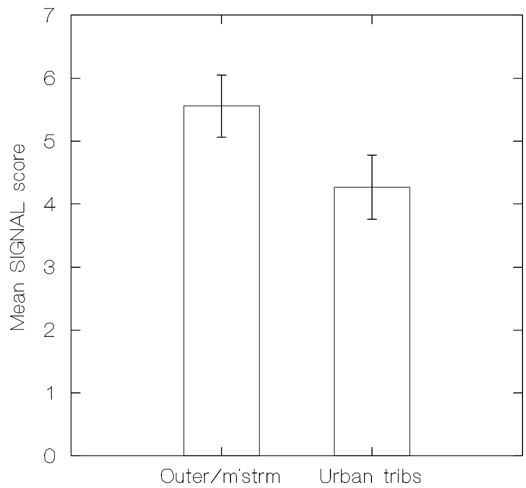

Figure 6 Mean SIGNAL score for UPGMA/ SSH groups

The outlying sites – Mullum Mullum Creek at Warrandyte (PW) and Stringybark Creek at McKillop Road (PQ) – had the highest nitrate and nitrite (NO_x) levels of all sites except Brushy Creek at Wonga Park (PS), which is downstream of the Brushy Creek sewage treatment facility. Concentrations of NO_x in Mullum Mullum Creek at Warrandyte (PW), Stringybark Creek at McKillop Road (PQ) and Brushy Creek at Wonga Park (PS) were 2.55, 2.6 and 10 mg/l, respectively (table 6). These readings are averages for the two samples but levels were very similar on each sampling occasion. Concentrations of NO_x at these sites are an order of magnitude greater than readings at most other sites in the catchment, with only Mullum Mullum Creek at Ailsa Court (PV) (1.77 mg/l), Olinda Creek drain at Coldstream (QB) (1.75 mg/l) and Darebin Creek at Chenies Road (QG) (1.48 mg/l) having comparably high readings (table 6). Despite the high NO_x readings, the O/E scores predicted by the AUSRIVAS model for Mullum Mullum Creek (PW) (0.61) and Stringybark Creek (PQ) (0.64) (table 7), and the SIGNAL scores of 5.00 and 5.35 respectively (table 7), show that the sites, while clearly affected, are relatively healthy in comparison with similar nearby sites. The UPGMA classification (figure 4a) shows that Stringybark Creek (PQ) and Mullum Mullum Creek (PW) differ markedly from sites in the two main groups but are also quite different from one another. Elmidae beetles (QC34) were found in Stringybark Creek at McKillop Road (PQ) but not in Mullum Mullum Creek at Warrandyte (PW). In the PCC for taxa, this family has a high positive correlation (0.91) with the trend separating PQ from other sites in the ordination, including PW (figures 4b and 4c).

3.3.4 The Yarra catchment as a whole – Edges

A notable difference between analyses of the riffles and edges for the whole Yarra catchment is the number of site groups. While the riffle analysis separates the sites into three main groups, the edge analysis divides them into two large, strongly dissimilar groups with smaller internal groupings. In the UPGMA classification (figure 7a), there is a clear distinction between sites in the urban zone and those in the upper catchment. These groups are also separate in the SSH ordination (figure 7b).

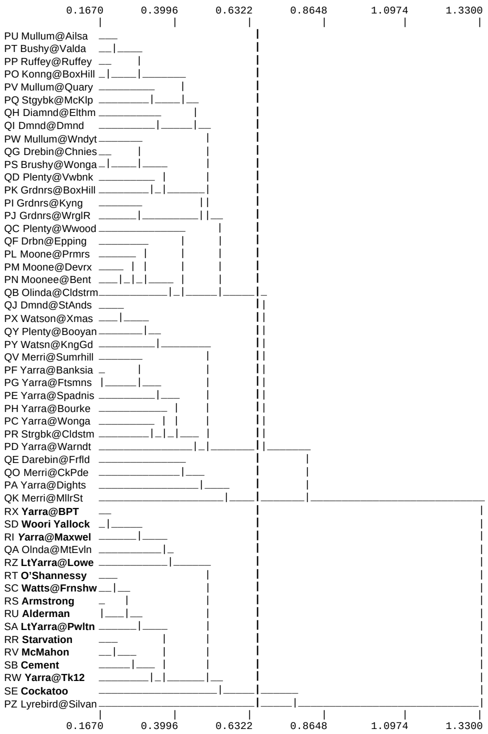

Figure 7a UPGMA classification of all edges in the Yarra catchment

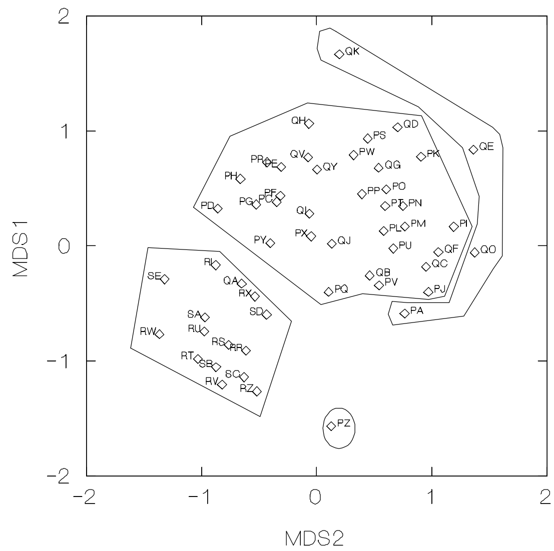

Figure 7b SSH ordination of all edges in the Yarra catchment (Stress = 0.238)

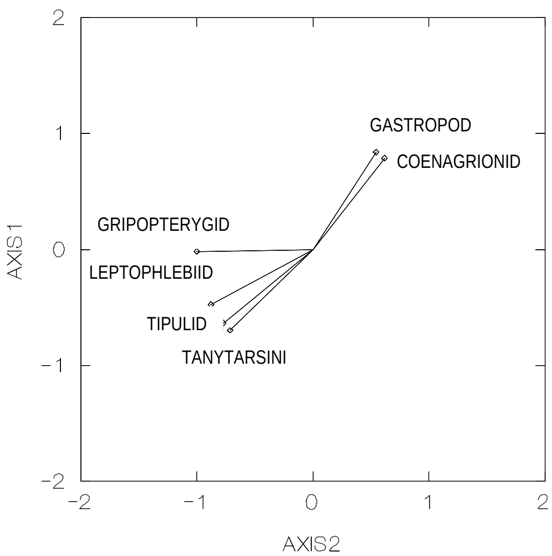

Figure 7c 2-dimensional PCC for taxa in all Yarra edges

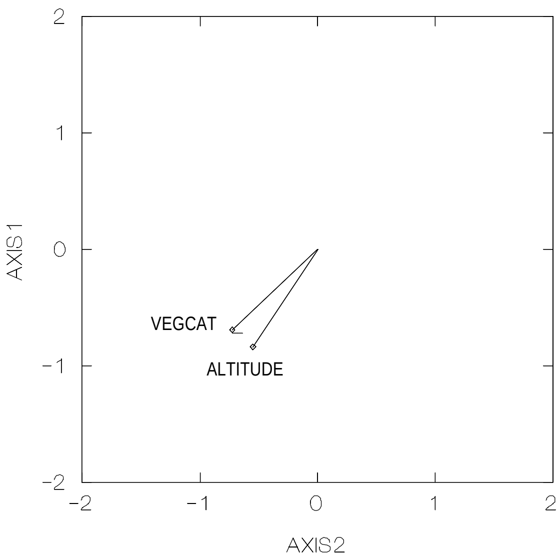

Figure 7d 2-dimensional PCC for environmental factors in all Yarra edges

Two urban test sites – Olinda Creek at Mount Evelyn (QA) and Lyrebird Creek at Silvan (PZ) – stand apart from the urban zone. Olinda Creek at Mount Evelyn (QA) groups with the upper catchment sites, while Lyrebird Creek (PZ) is an outlier from the upper catchment group (figure 7b).

Figure 8 shows PCCs for O/E score and SIGNAL score with the SSH ordination of the edge habitats (figure 7b). Both indices show strong positive correlation with the gradient separating relatively undisturbed, forested sites in the upper catchment from the urban tributaries. The direction of the vectors coincides with the altitudinal and vegetation category gradient apparent in the ordination (figure 7b) and the PCC for environmental factors (figure 7d). Vectors for pollution-tolerant taxa, such as gastropods and Coenagrionidae damselfly nymphs, and moderately tolerant taxa, such as Gripopterygidae stonefly nymphs and Leptophlebiidae mayfly nymphs (figure 7c), reflect the decline in biotic indices from the upper catchment to the urban areas.

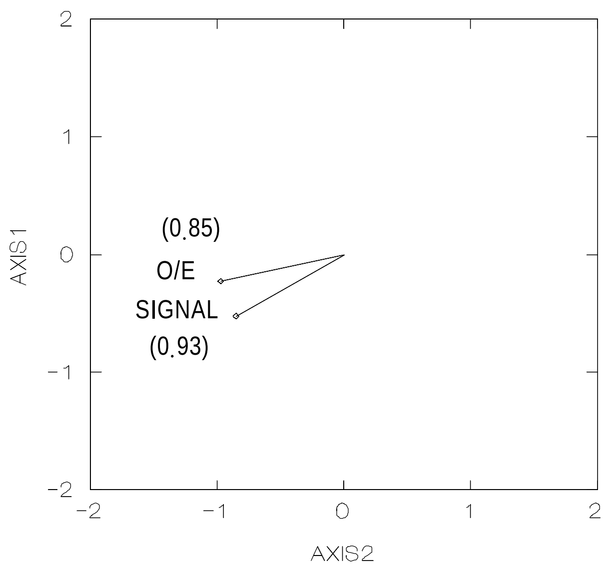

Figure 8 2-dimensional PCC of O/E and SIGNAL scores

3.3.5 Edges in the upper Yarra

The UPGMA classification of the edge data for the upper catchment distinguishes two groups of sites with one outlier (figure 9a). These groups are also evident in the SSH ordination (figure 9b). There is an apparent altitudinal gradient separating sites in the ordination, which is correlated with altitude, shade, temperature and turbidity in the PCC for environmental factors (figure 9d). The shade, temperature and turbidity variables are closely linked with altitude because of land-use patterns in the catchment and because of natural geographic variation.

The smaller of the two UPGMA groups is composed of sites where the riparian habitat has suffered noticeable disturbance. Sites in the larger group are in forest environments, many within the closed water-supply catchment. Only Watts River at Fernshaw Reserve (SC) and Little Yarra River at Powelltown (SA) are not entirely surrounded by protected forest (see site descriptions, appendix II). The site on the Yarra River at Big Peninsular Tunnel (RX) is the only site in the smaller group not associated with cleared land or urban disturbance, or both. It is within the recently gazetted Yarra Ranges National Park, but has suffered considerable disturbance in the past. The site is immediately downstream of a gold-mining tunnel cut through a ridge (the peninsula) and is now a very popular swimming hole. These combined impacts have reduced the riparian vegetation and caused erosion of the banks in some areas.

Sites in the smaller group supported macroinvertebrate communities having elements more commonly found in streams at lower altitudes and with slower currents (table 5). Taxa characteristic of this group were members of the Hemiptera (water bugs) (QH56 and QH65), Synlestidae (QO08) and Corduliidae (QO16) dragonfly nymphs, and an Atyidae shrimp (OT01). Sites in the larger group supported faunal communities typical of higher-gradient streams, including Ptilodactylidae beetle larvae (QC39), Blephariceridae fly larvae (QD04), Helicophidae caddisfly nymphs (QT19), and Eustheniidae (QP01) and Austroperlidae (QP02) stonefly nymphs.

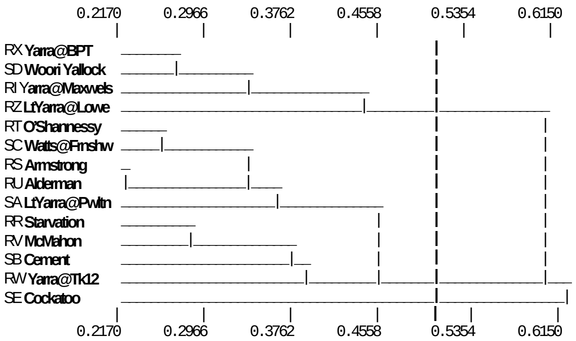

Figure 9a UPGMA classification of upper Yarra edges

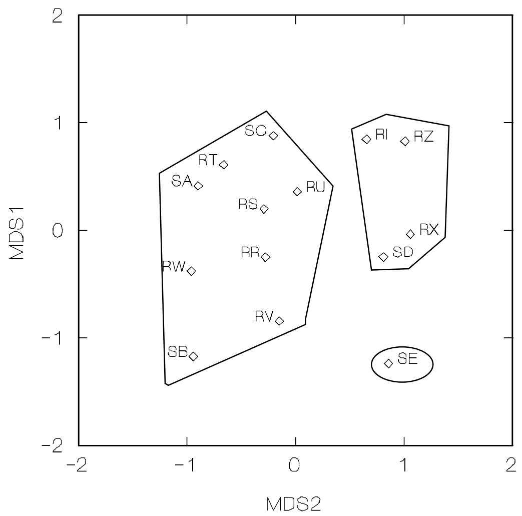

Figure 9b SSH ordination of upper Yarra edges (Stress = 0.240)

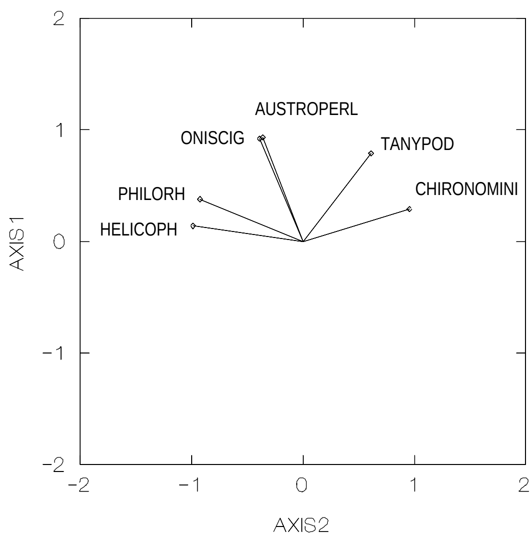

Figure 9c 2-dimensional PCC for taxa in upper Yarra edges

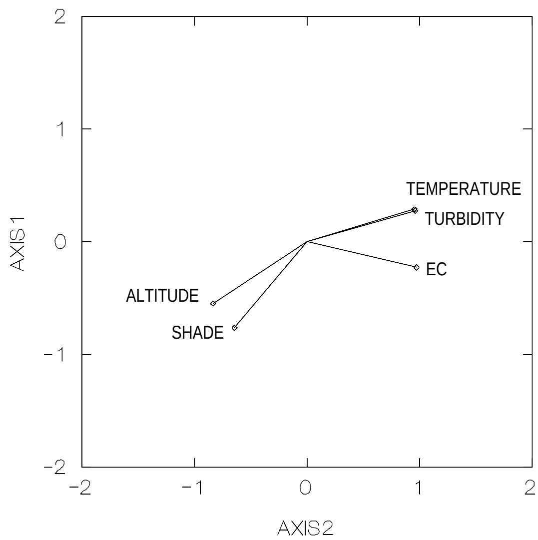

Figure 9d 2-dimensional PCC for environmental factors in upper Yarra edges

The positioning of East Armstrong Creek (RS) in the edge analysis contrasts with its position in the riffle analyses. Whereas East Armstrong Creek was an outlier in the riffle analyses, the site groups with the main body of sites when edge data alone is analysed (figures 10a and 10b). Cockatoo Creek (SE) remains an outlier.

3.3.6 Edges in the urban region

Analyses of edge communities in the urban region were characterised by high stress values in the SSH ordination (figure 10b) and poor correlations using the PCC routines (figures 10c and 10d). A three-dimensional SSH solution returned a high stress value of 0.249, compared to 0.279 for the two-dimensional SSH, and was too noisy to be interpreted, with few or no clear groups. On this basis, it was decided to proceed with the higher-stress, two-dimensional solution. Because of the higher stress levels, these analyses should be treated cautiously.

The PCC for taxa (figure 10c) shows positive correlations of vectors for moderately tolerant mayfly (Baetidae, Leptophlebiidae), caddisfly (Leptoceridae), stonefly (Grypopterygidae) and beetle (Elmidae) families with the lower right region of the SSH ordination (figure 10b). This region of the ordination includes tributary sites of relatively high taxon-richness and all the mainstream Yarra River sites except Dights Falls (PA), confirming the similarity of the mainstream sites. Although groups are less distinct than in the riffle analysis (figure 4b), they have the same basic site membership, with two large groups from the UPGMA classification (figure 10a) largely separate in the ordination – one composed of the outer urban tributaries and mainstream Yarra River sites, the other containing most of the remaining urban tributary sites. A smaller, looser group, composed of sites on Darebin (QE) and Merri Creeks (QO, QK) in the Northcote area, and on the Yarra River at Dights Falls (PA), skirts the urban tributary group in the top right-hand corner of the ordination. There is also a distinct outlier in the classification – Lyrebird Creek at Silvan (PZ) – which is at the bottom of the ordination.

Stringybark Creek at McKillop Road (PQ) is grouped with tributary sites of lower taxon-richness in the UPGMA classification in figure 10a, but, in the ordination, overlaps with the group with higher taxon-richness (figure 10b). Correlated with this overlap, and separating Stringybark Creek at McKillop Road from other sites in the less taxon-rich group (including Mullum Mullum Creek at Warrandyte), is the vector for Elmid beetle larvae (figure 10c). As noted in the analysis of riffles in the urban region (section 3.7), this family was found at McKillop Road but not at the Mullum Mullum Creek site in Warrandyte.

The PCC for environmental factors (figure 10d) showed no significant correlations with the ordination and no clear trends.

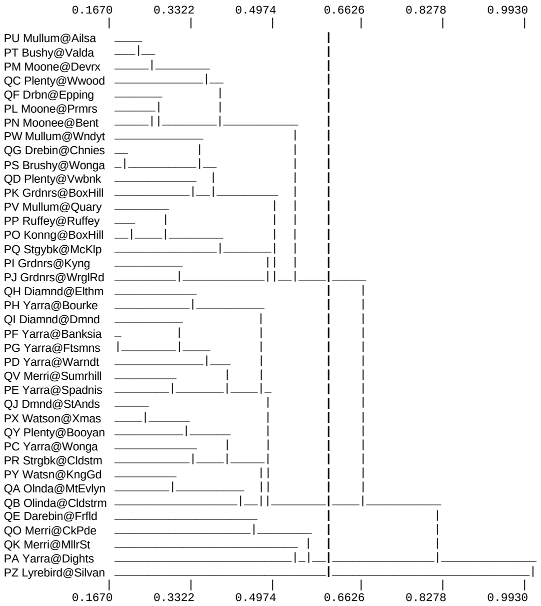

Figure 10a UPGMA classification of urban Yarra edges

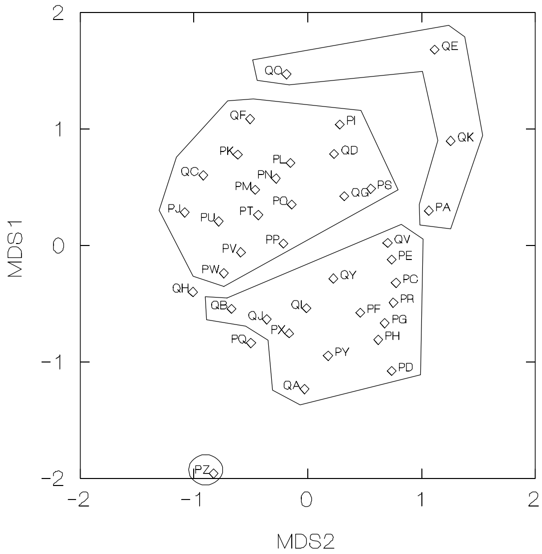

Figure 10b SSH ordination of urban Yarra edges (Stress = 0.279)

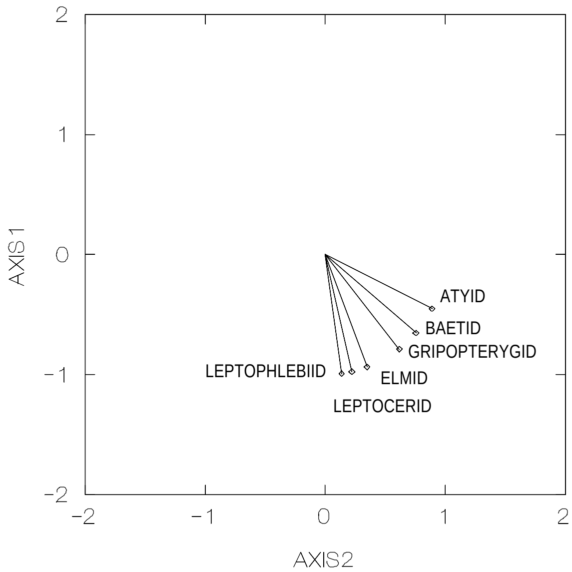

Figure 10c 2-dimensional PCC for taxa in urban Yarra edges

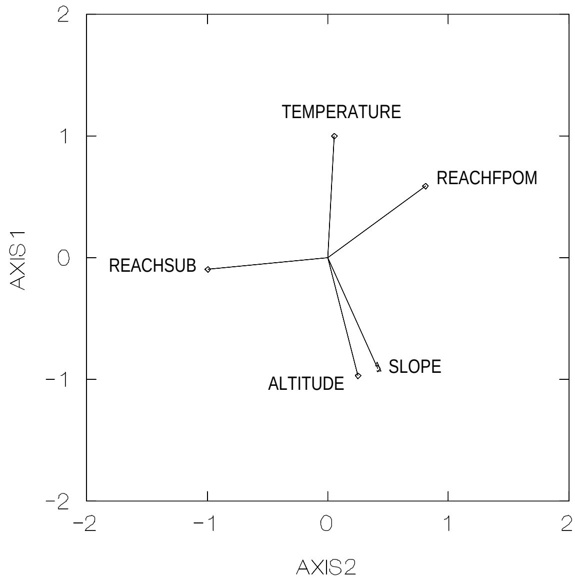

Figure 10d 2-dimensional PCC for environmental factors in urban Yarra edges (no significant correlations)

4. DISCUSSION

4.1 Site categories

Analysis of macroinvertebrate community structure indicates that sites in the Yarra catchment fall into four broad categories – the largely natural upper catchment (13 sites); the urban fringe (including the rural and outer urban tributaries) (13 sites); the inner urban tributaries (19 sites); and the lower and middle reaches of the mainstream Yarra River (7 sites).

Six of the 13 sites in the upper catchment group are in near-pristine environments, due to the restriction of human activity in the closed water-supply areas. The remaining seven sites have generally healthy riparian zones, as well as forest-oriented land uses which have less impact upon streams than land uses in the rural or urban regions.

All 13 sites in the rural/urban fringe group are on small tributaries of the Yarra River. Five sites in the group can be considered rural, with mainly agricultural land uses. The remaining eight sites are within Melbourne's outer suburbs. In these low-density residential areas, some native vegetation has been retained, particularly along waterways, and paved surfaces are not as extensive as in the denser urban areas. However, roadside drains in these outer areas are often gravel and can carry high levels of sediment into streams.

The seven mainstream Yarra River sites occur in the middle and lower reaches, where the river is considerably larger than its tributaries. Water quality at these sites is sustained by the large volume of good-quality water flowing down from higher in the catchment. Riparian vegetation is generally good at the urban mainstream sites as a consequence of active maintenance of the Yarra River's recreational and aesthetic values in the urban area. The Yarra River at Spadonis Reserve (PE), however, suffers from a lack of riparian vegetation, a feature common to this agricultural area of the catchment.

Sites in the urban group are on tributaries well inside the urban region and are subject to the many stresses a large city imposes upon its waterways. Higher levels of stormwater runoff are characteristic of the extensive impermeable surfaces. In wet weather, stormwater runoff produces extreme flow-peaks in the urban waterways and carries high loads of soluble and insoluble pollutants. Leaks from ageing or damaged sewers and from emergency relief structures on overloaded sewerage systems also contribute pollution to the stormwater system and hence to streams (EPA 1997).

4.2 Patterns of impact and ecological change in the catchment

Despite the perception of strong gradients in the PCC analyses for environmental factors, the urban sites are not as clearly segregated nor do they display such evident trends, as sites in the upper catchment. This difficulty in resolving patterns in the multivariate analyses reflects the complexity of the various impacts affecting urban streams.

Patterns of anthropogenic impact across the Yarra catchment are also somewhat obscured by natural patterns of water chemistry and habitat change. Natural changes downstream in the physical and chemical properties of the water (such as temperature, dissolved oxygen and accumulated ions), and changes in environmental features (such as shading, substrate and current), coincide with increasing urbanisation and anthropogenic impact, both of which become more severe as sites get closer to the Melbourne metropolitan area.

Some effects of human activities are evident from the general trends in water quality (table 6). The levels of electrical conductivity, turbidity and nutrients (nitrogen and phosphorus) increase with proximity to the metropolitan area. These indicators naturally increase along a stream's length but can also be affected by human activities. As runoff transports sediment into streams, turbidity, electrical conductivity and nutrient concentrations increase, and will continue to increase downstream as more sediments enter the waterway. These effects can be exacerbated if natural erosion and runoff patterns are altered by activities such as land-clearing, alteration of riparian habitat, and stormwater contamination from urban areas. In contrast to the increases in these indicators, vegetation category and dissolved oxygen decrease with proximity to the metropolitan area (table 6). Vegetation category provides a broad measure of land use in the local area of a site. The decline in the value of this indicator reflects human alteration of the catchment landscape. As changes to the landscape induce greater erosion and contamination of runoff, changes in the inorganic chemistry of the waterway and direct effects on the biology of the stream are reflected in the increasing demand which biological and chemical decay processes place upon oxygen levels in the water.

Biotic indices can be used to explore past natural patterns of change. For example, Growns *et al*. (1995) have shown that the SIGNAL index is essentially independent of natural distribution patterns. In particular, they found that SIGNAL is sensitive to organic pollution but not to altitude. When determining O/E scores using AUSRIVAS, environmental features are integral to the process of calculating model outputs for each test site. Test sites are compared with reference sites having similar environmental variables. Sites of similar stream order at comparable altitudes can have very different O/E and SIGNAL scores, depending on anthropogenic impacts. Hence, correlations between altitude/geography-related variables and O/E or SIGNAL are most likely to reflect real variation in anthropogenic disturbance.

4.2.1 The upper catchment

In the upper catchment group, 10 sites have O/E scores at or above 'reference' conditions. Six of these sites, including two of the three sites with 'higher than reference' scores, are in the closed aquatic reserves and are in near-pristine condition. The third site with a score above reference – Woori Yallock Creek at Yellingbo (SD) – is in the Yellingbo State Nature Reserve on the outskirts of Yellingbo, but is downstream of cleared agricultural areas. The high O/E score for this site is probably due to mild organic enrichment, which can increase faunal abundance and diversity (Hynes 1960). The SIGNAL score (5.92) for this site also suggests mild pollution.

Four sites in the original group of upper catchment reference sites – Cement Creek at Acheron Way (SB), Watts River at Fernshaw Reserve (SC), Little Yarra at Lowes Road (RZ), and Cockatoo Creek at Cockatoo (SE) – have O/E scores below reference.

Where it was sampled, Cement Creek (SB) is in near-pristine condition and the 'below reference' O/E score is a reflection of the habitat at the site. The site is a very steep cascade consisting, essentially, of a series of waterfalls separated by turbulent pools. The strong, turbulent flow and associated scouring results in a substrate composed almost entirely of large boulders. These features severely restrict the habitat available to the edge fauna. This is a natural condition and the low O/E score does not reflect human impact. This is supported by the SIGNAL score of 6.29, indicating good water quality.

Watts River at Fernshaw Reserve is bounded on one bank by a well-established and well-maintained roadside picnic ground. The site is otherwise surrounded by the Yarra Ranges National Park. The O/E score for the site is only marginally below reference conditions, reflecting a relatively healthy environment. However, habitat conditions may be compromised by disturbance within the adjacent park, particularly the differing habitat conditions associated with the presence of exotic vegetation. Compared with Australian native trees, the different leaf types and leaf-fall patterns of these exotic trees may make them less suitable as riparian vegetation by altering riparian and stream habitat conditions. Activities such as lawn maintenance may also have an effect.

The Little Yarra at Lowes Road site is not far upstream of Yarra Junction. Riparian vegetation is somewhat degraded at the site and surrounding land use is largely dominated by agriculture. The below reference score for this site reflects the effects of anthropogenic impacts, such as agricultural runoff and riparian habitat degradation.

Although Cockatoo Creek (SE) falls within the bounds of the upper catchment, analyses classify the site as urban fringe. The site is surrounded by local urbanisation and suffers from urban stormwater runoff. A large proportion of this runoff comes from gravel roads and drains; as a consequence the substrate at the site was smothered by sand and gravel carried into the stream by stormwater. The riffle substrate had a mean substrate particle-size approximating very small pebbles. The taxa PCC for the upper Yarra riffle ordination (figure 3c) shows strong negative correlation of Coloburiscidae (QE05) with the separation of Cockatoo Creek. Coloburiscidae mayfly nymphs, which were commonly found at rocky sites in the upper catchment, were not found at Cockatoo Creek (table 5). Nymphs in this family have spinose gills which appear to help anchor them beneath rocks in swift currents and the family shows a strong preference for large, stable, rocky substrates (Peters and Campbell 1991), which were not present in the sand and gravel-dominated substrate at this site. Backwaters and slow-flow areas were also very scarce at the site and the stream was highly incised, resulting in poor-quality edge habitat. The environmental PCC for the upper Yarra edges (figure 9d) did not show any factors significantly correlated with the positioning of Cockatoo Creek. However, the mayfly family Oniscigastridae (QE03), which was not present at Cockatoo Creek, shows a strong negative correlation in the taxa PCC (figure 9c) with the gradient separating the site from others in the upper catchment. Oniscigastridae nymphs are commonly associated with silty, slow-flowing streams (Peters and Campbell 1991) and their absence may reflect the paucity of slow-flowing and backwater areas at this site.

4.2.2 The rural/urban fringe

Lyrebird Creek at Silvan (PZ) was originally sampled as a member of the urban test-site group. The O/E score for Lyrebird Creek (0.38) suggests a macroinvertebrate community ‘well below reference’ (table 4). This score compares poorly with the scores for Olinda Creek at Mount Evelyn (QA) (O/E 0.82) and Watsons Creek at Kangaroo Ground (PY) (O/E 0.97), which had the next best SIGNAL scores in the test-site group (table 7) but were perceived to be slightly more degraded than Lyrebird Creek due to rural and urban development in their catchment areas. In the analysis of riffles at sites in the urban catchment, Lyrebird Creek at Silvan (PZ) grouped fairly closely with the outer urban sites (figure 4b). Using edge samples, however, the site is a distinct outlier (figure 10b). Lyrebird Creek is on the outskirts of Melbourne and the catchment upstream of the site is entirely State Forest. Land use is not characteristically urban, but the site still shows evidence of human impacts. The SIGNAL score of 5.67 suggests possible pollution. High levels of sedimentation (phi 0.275) and turbidity (24.5 NTU) (table 6) are probably caused by runoff from gravel roads and drains throughout the surrounding forest. The results of the edge and riffle analyses suggest that the edge fauna is affected less by these impacts than is riffle fauna, particularly with regard to the smothering of habitat by sediment. Edge substrate is often dominated by finer sediment particles, whereas riffles in these upland streams are usually scoured of much of their finer sediments by higher water velocities. This impact can be seen in the differences in faunal composition between Lyrebird Creek and other sites in the WoV Schedule F7 Parks and Forests segment (table 5). Notable differences include the absence from Lyrebird Creek of Coloburiscidae (QE05), Hydrobiosidae (QT01) and Philopotamidae (QT04) – families which were common at other higher altitude forest sites in the catchment. The presence of Gordiidae (IJ01), which are considered moderately sensitive to water quality (Chessman 1995), and families such as Ecnomidae (QT08) and Hydropsychidae (QT06), common at lower, slow-flowing sites, also suggests that this site has an unusual habitat.

Habitat differences reflected in the faunal communities may not be readily apparent from the recorded environmental variables. If the environmental factors used in the model are insufficient to distinguish the unusual nature of the site, expected taxa will not correspond with those observed and the result will be a low O/E score. However, the suite of macroinvertebrates predicted by the AUSRIVAS models to occur at Lyrebird Creek appears reasonable, given the environmental conditions at the site, and it seems that the site has a genuinely unusual fauna.

Lyrebird Creek is a tributary of Olinda Creek. In a study of Olinda Creek, Jones and Ferdinands (1993) found that this same site differed markedly from others on Olinda Creek and that stream conditions at the site, particularly in the pools, were unusually silty and slow-flowing, allowing only species tolerant of these conditions to survive. The results from this study support their conclusion, with a healthier macroinvertebrate community along the edge than in the riffle, possibly because the macroinvertebrates in the riffle community are affected more by sedimentation. This result highlights the requirement with AUSRIVAS, as with all indices and derived measures of this sort, for informed scrutiny of the outputs. In this case, an unexpected complement of families has been collected from Lyrebird Creek, reflected in the low number of SEPP key families and AUSRIVAS-predicted families collected in proportion to the total number of families.

A notable result in the rural/urban fringe is the outlying positions of Stringybark Creek at McKillop Road (PQ) and Mullum Mullum Creek at Warrandyte (PW) in figures 3b and 5b. Whereas the UPGMA classifications (figures 3a and 5a) portray these sites as more similar to one another than to others in the analyses, the SSH ordinations separate them to opposite sides of the plots (figures 3b and 5b).

All ordination methods are a compromise and there is no guarantee that the rank similarities in species composition can be accurately presented in a reduced number of dimensions (Clarke 1993). The distance between these two sites in the dendrograms indicates that they have differing community compositions, but the separation of the sites to opposing sides of the ordination plots may result from the ordination technique struggling to produce an accurate representation of their relative positions in the reduced number of dimensions. The sites, although supporting different faunal communities, may be more similar than is depicted in the ordinations. The faunal differences between these two sites and others in the rural/urban fringe most likely relate to differences in nutrient levels and habitat, whereas faunal differences between Stringybark Creek at McKillop Road and Mullum Mullum Creek at Warrandyte may be related to differences in the aquatic flora in response to the levels of particular nutrients.

Nutrient results (table 6) show that, although concentrations of NO_x at the Warrandyte and McKillop Road sites were similar, TKN and TP concentrations were much lower at the McKillop Road site, which had extensive beds of *Phragmites* sp. The elevated levels of NO_x in relation to other nutrients at the McKillop Road site is unusual and it is possible that septic or fertiliser leachate or natural groundwater is raising inorganic nitrogen concentrations in the stream (Tiller and Newall[1], pers. comm., 1996). Little is known about safe concentrations of nitrate for aquatic life (Camargo and Ward 1995) but these nutrient levels are unlikely to directly affect stream fauna. Although organic enrichment can eliminate some taxa (Campbell *et al*. 1982), the influence is likely to be indirect, by affecting stream flora. The extent of the *Phragmites* sp. beds at the McKillop Road site limits the edge habitat to one main type. This is likely to affect macroinvertebrate community composition relative to Mullum Mullum Creek at Warrandyte as well as other sites in the outer urban area.

4.2.3 The urban mainstream Yarra River

In the Yarra River between Maxwells Road (RI) and Spadonis Reserve (PE), there is a decline in O/E scores from reference to below reference conditions, which is mirrored in the SIGNAL scores. This decline coincides with the transition from the forested areas, higher in the catchment, to the main agricultural region of the Yarra valley. The severely degraded riparian zones in the agricultural middle-Yarra valley limit edge habitat and reduce macroinvertebrate richness. However, the O/E and SIGNAL scores show that once the Yarra River has passed from the agricultural region into the urban fringe at Wonga Park (PC), faunal richness increases. This phenomenon probably reflects changes in the state of the riparian zone and edge habitat along the Yarra River. Although some downstream recovery in water quality is possible as chemical and biological processes in the river reduce concentrations of excess nutrients, generally there is a gradual decline in water quality along a river’s length as anthropogenic impacts increase. In this case, despite increased nutrient concentrations (table 6), improvements in the riparian zone downstream of the agricultural area have brought improvements in the aquatic habitat and a positive response from macroinvertebrate communities.

Protection of the banks of parts of the lower Yarra River as a recreational asset has resulted in moderate to good riparian vegetation and waterway condition along many of its urban reaches (Chesterfield and Sovitslis 1994), which has benefited edge habitat and macroinvertebrate communities. However, landscape modifications to the Yarra River at Dights Falls (PA), including instream disturbance associated with the construction of a fish ladder and a kayak training-course, have caused severe habitat disturbance. The urban mainstream Yarra River is the only watercourse of its size and type in the catchment and it is not unexpected that the mainstream sites should group closely. However, the Yarra River at Dights Falls groups with tributary sites with poorer water quality. Darebin Creek, Merri Creek and Alexander Parade Main Drain flow into the Yarra River just upstream of Dights Falls and it is likely that the poor water quality from these sources is having a detrimental effect on water quality at Dights Falls. However, the water quality measurements and SIGNAL results for the site do not reflect the scale of the decline in macroinvertebrate richness. The O/E score shows a decline that is more comparable to the observed reduction in taxa numbers and suggests that impacts on the fauna at the site result from a combination of poor habitat and poor water quality.

4.2.4 The urban tributaries

Water quality impacts were very important in the urban tributaries – whereas water quality in the mainstream Yarra River benefits from relatively clean water flowing down from the protected catchments, the urban and rural/urban fringe tributaries do not have this advantage.

[1] David Tiller and Peter Newall (Freshwater Sciences, EPA, Melbourne).

In some cases, the health of urban tributaries does improve as they pass from rural areas into the suburbs, as was the case for the mainstream Yarra. For example, O/E and SIGNAL scores (table 7) show that macroinvertebrate community structure in the Plenty River (QC, QD, QY) improves between Whittlesea (QC) and Greensborough (QY) as the river enters the metropolitan area, but deteriorates again at Viewbank (QD), which is a remnant rural area. These changes probably result from differences in riparian and aquatic habitat. Degraded riparian zones in these rural areas can limit habitat and macroinvertebrate colonisation, compared to outer urban areas, where the riparian zone is often maintained in streamside parks. Smaller tributaries may also sometimes be stressed by low oxygen levels caused by intermittent stream flows, particularly near their source. An example is Diamond Creek (QH, QI, QJ) at St Andrews (QJ) in the rural/urban fringe, which had standing pools but no flow in autumn 1995. The average results from 1994 and 1995 (table 7) show that the O/E and SIGNAL scores at this forested upper site were lower than at the sites in the outer suburbs (QH and QI).

However, invertebrate communities only recover for a short distance, if at all, after streams pass into the outer urban areas. Further into built-up areas poor water quality appears to become the limiting factor. The condition of the riparian zone and edge habitat can fluctuate markedly along the length of urban tributaries. Relatively healthy reaches protected in strip parks contrast with reaches of poor edge habitat dominated by exotic vegetation and artificially simplified habitats. But the urban tributaries derive much or all of their flow from urban catchments and water quality steadily deteriorates along all the urban streams. Pollutants washed from the streets combine with chemicals from commercial and residential premises illegally entering stormwater; these toxic inputs can reduce water quality to a level where stream fauna cannot recover (EPA 1993), regardless of improvements in habitat.

Three sites in the catchment – Gardiners Creek at Box Hill (PK), Darebin Creek at Fairfield (QE) and Merri Creek at Coburg (QK) – have O/E scores indicating the macroinvertebrate communities to be impoverished (table 7). All three are urban streams.

Gardiners Creek rises from Blackburn Lake in the eastern suburb of Blackburn. The creek's total flow is derived from urban water sources, most of which are contaminated to some extent (EPA 2000). The O/E score for the site at Box Hill, in the upper reaches of Gardiners Creek, is poorer than those in the lower reaches. This may reflect a lack of habitat and intermittent flow due to the small size of the creek at this point, but most likely also signifies considerable pollution.

Merri and Darebin Creeks rise in agricultural areas north of Melbourne. Lack of riparian vegetation, together with direct stock access to the stream in these areas, means sediment and nutrients can enter these streams relatively unimpeded. Industry in Melbourne's northern suburbs has also been shown to cause major declines in community diversity in Merri Creek; heavy metal contamination was considered an important factor in this deterioration (Mitchell and Clarke 1991). Furthermore, industrial pollution entering Darebin Creek via the Bell Street Main Drain, which also serves northern industrial and residential areas, has a continuous detrimental effect on the ecology of Darebin Creek (EPA 1993).

Habitat along the edges of urban waterways may also suffer severe disturbance. For example, both Gardiners Creek at Kooyong (PI) and Bushy Creek at Doncaster (PT) have been converted to concrete channels, thereby eliminating almost all habitat; and freeway construction along Koonung Creek in Box Hill (PO) has caused very high levels of sedimentation and periodic scouring of the creek-bed by stormwater. The biotic indices show that these disturbances are greatly affecting macroinvertebrate communities at these sites (table 7).

This overall decline in biological conditions evident in the biotic indices reflects Pettigrove's (1989) findings of considerable deterioration in the fauna downstream along the Yarra River. Pettigrove attributed this decline to changes in water quality, organic enrichment and physical habitat characteristics. Decreases in the number of taxa downstream were considered unusually large, suggesting that the decline was not due to physical changes alone. Furthermore, Campbell *et al.* (1982) found that riffle communities in tributaries of the Yarra River were far more stressed than rural or mainstream urban Yarra River riffle communities, the tributaries showing a clear pattern of degradation from upstream rural sites to downstream urban-influenced sites.

This study has illustrated a clear downstream decline in the ecological health of streams in the Yarra catchment. The most apparent are the rapid decline in riparian and instream habitat associated with land use changes downstream of the well-forested upper catchment, and the rapid decline associated with water quality degradation in the urban tributaries. The protection of large areas of forest in the upper Yarra valley results in an abrupt change in land use in the middle Yarra valley. Agriculture quickly becomes the dominant land use downstream of Healesville, causing degradation of streamside vegetation and increases in the quantities of contaminated runoff. However, pollutants in this area are considerably less than those in the urban tributaries, or those entering the Yarra River in the urban areas, where tributaries and urban drains are more numerous. This leads to a distinct 'fringe area', with less urban influence, but considerable agricultural impact. These effects of the division of land use in the Yarra catchment separate the tributaries and the mainstream Yarra River into areas with distinct major impacts on the aquatic environment.

4.3 Major impacts in the Yarra catchment

Biological analyses suggest that land use and the condition and extent of the riparian zone are strongly influential in group separation within the Yarra catchment, delineating sites within and outside the forested, agricultural and urban areas. In the PCC analysis for environmental factors across the whole catchment (figures 3d and 8d), vegetation category is the environmental variable most significantly correlated with the separation of the urban and upper catchment sites. This environmental factor influences both water quality and riparian habitat and takes into account the extent of exotic flora in the riparian vegetation. The ratio of native to exotic vegetation can be indicative of the state of conservation of the riparian zone and may also affect the suitability of the edge habitat for some taxa, through variations in the type and seasonality of allochthanous inputs and alterations to bank structure (Department of Water Resources 1989).

The quality of aquatic habitat is closely linked to riparian vegetation (Cummins 1993). The type of vegetation along the banks can strongly influence stream morphology, including width and cross-sectional shape, by binding bank material and preventing slumping (Campbell *et al*. 1982). Vegetation type also affects the extent of trailing bank vegetation, interception of sediment from runoff, water temperature and primary production through shading, and deposition of allochthanous organic material. Much of the biotic energy that drives stream communities comes from outside the stream, so it is likely that litter from a mixed woodland will produce a more continuous supply of food than the litter from a pure stand (Hynes 1975). Reed *et al*. (1994) have shown that a stream flowing through pasture, when shaded with an artificial canopy, is similar to a forest site for grazing macroinvertebrates. However, the same site continues to behave as a pasture site for shredders (animals which feed by shredding coarse plant matter) when shaded, because a food source suitable for shredders is not provided by the pasture riparian vegetation. Caddisfly larvae (Trichoptera) in the family Calocidae (QT18) and many of the Conoesucidae (QT15) are associated with forest streams with good water quality and healthy riparian zones that provide high levels of allochthanous inputs (Neboiss 1991; Chessman 1986). These families were restricted to sites which supply these requirements (table 5). Families that were more successful in the urban areas were the Hydropsychidae (QT06) and Ecnomidae (QT08). Members of these families may be collectors or predators, or have diverse omnivorous diets, so their food sources are not so restricted (Neboiss 1991; Chessman 1986). These groups were particularly common in the lower reaches of the Yarra River (table 5). Their prevalence there may be due to tolerance of higher water temperatures and turbidity levels or a response to an influx of partially processed detritus from upstream, reflecting observations made by Vannote *et al.* (1980) and Cummins (1986) of downstream communities capitalising on inefficiencies in the processing of detritus by communities upstream.

Riparian vegetation can contribute large woody debris, branches or whole trees to the stream. This debris can form a major structural component of the stream morphology, changing its profile by forming dams of debris and sediment which may form pools on their downstream side. These structures comprise important habitat and can increase the complexity of the pattern of currents, creating more complex habitat structure and presumably increasing overall biological diversity (Campbell *et al.* 1982). They also serve as a link between terrestrial and aquatic systems (Hilderbrand *et al*. 1997) and, in streams with unstable substrates, may be the only stable surface for colonisation.

Degradation of the riparian zone often leads to edge habitat destruction and loss of the natural contaminant buffer (Campbell 1993). This impact is common in rural areas of the Yarra valley where the natural riparian vegetation has been completely altered or removed in many places. This study and others (Campbell *et al.* 1982; Fitzpatrick 1986) have shown that agricultural activity in the upper Yarra catchment can cause deterioration in water and environmental quality. Practices such as channelisation and reduction of vegetation cover can destroy habitat and alter the hydraulics of the floodplain, making erosion of the waterway more likely (Chesterfield and Sovitslis 1994). Waterway erosion tends to be more localised than widespread in the Yarra valley and many streams could be enhanced by improvements to riparian vegetation (Chesterfield and Sovitslis 1994). Strategies such as the Middle Yarra concept plan (Department of Conservation and Environment 1991) advocate riparian conservation areas to be as wide as possible, with a general minimum of 20 m and exclusion of grazing from streamsides.

However, protection of the stream environment is a major challenge. Remedies, such as fencing and revegetation of both sides of our waterways could cost tens of millions of dollars. Possible remedies can only be addressed by well-conceived strategies together with support from landholders and local communities (Chesterfield and Sovitslis 1994). Furthermore, while management of local and riparian conditions will provide benefits, diffuse pollution sources (such as soil erosion) are likely to require catchment-scale strategies (Allan *et al*. 1997). Ultimately, environmentally sensitive land use is of prime importance. Alteration of methods of fertiliser and biocide application, and adoption of soil conservation techniques such as minimum tillage, present benefits to farmers and to streams, through reductions in soil and chemical losses due to runoff. These kinds of strategies may involve changing age-old practices and will require comprehensive education and extension programs (Osborne and Kovacic 1993).

In the urban streams, the impacts of degradation of the riparian zone are often compounded by instream habitat simplification, which, in extreme cases, may extend to conversion of the stream to a concrete stormwater drain. This type of habitat simplification removes almost all aquatic habitat, eliminates allochthanous inputs, and removes natural flow-control features, contributing to strong, rapidly-fluctuating flows which further stress aquatic communities. Historically, the desire to reduce the likelihood of flooding has encouraged this type of unsustainable urban stormwater system design. Traditionally engineered systems are designed to remove water quickly, rather than transport it slowly, allowing time for infiltration into the soil (Anon. 1990). These systems also ignore the fact that urban runoff water is a valuable resource, not to be squandered in an arid country like Australia (Anon. 1990).

Extensive pollution-control engineering technology is already available (Anon. 1988; Anon. 1990). Implementation is the next step. Urban stormwater management requires reductions in flow quantity and improvement in quality (Andoh 1994). It is possible to address both, while simultaneously improving habitat and amenity. Works which involve re-establishment of natural habitat and flow conditions, and the development of flow- and pollutant-reducing wetlands, flow retardation basins, filter strips and grass swale stormwater floodways, provide some answers to these problems (Anon. 1988; Anon. 1990; New South Wales EPA 1997). More careful design and management of urban stormwater systems holds the potential to dramatically improve urban stream ecology, while providing improved flow and pollution management, water re-use for irrigation of parklands, and considerable aesthetic gains.

Complication of physical degradation of the stream habitat by chemical and organic pollution is a particular problem in urban areas. In some urban waterways, the overriding environmental problem is chemical pollution, the result of industrial spills and dumping, leaking or overloaded sewers, and contaminated runoff from paved areas. Educating the community about the consequences of waterway pollution (and the best means of avoiding it) is arguably the most important step in reducing pollution of our waterways. Prevention is better than cure. High profile litter reduction strategies, clean-up days and community drain-stencilling programs (whereby stormwater drains are marked with information about the destination of water and pollutants) are excellent examples of community education and involvement in stream protection. Providing the community with adequate, accessible and affordable waste reduction, re-use, recycling and disposal measures is also a logical necessity. An agreement between EPA, Melbourne Water and local government is presently exploring approaches that could be adopted to improve urban stormwater management.

4.4 Compliance with Waters of Victoria Schedule F7 objectives

Results for this study display very low compliance with biological indicator objectives set in the WoV Schedule F7. Accordance with physicochemical objectives, however, was considerably better. Notable exceptions were dissolved oxygen concentrations in Merri Creek (QK), Plenty River (QC, QD, QY) and Olinda Creek at Coldstream (QB), and high pH levels in Gardiners Creek at Chadstone (PJ), Ruffey Creek at Templestowe (PP) and Darebin Creek at Fairfield (QE). Low DO levels in the northern tributaries are commonly associated with low flows, which are typical of the area (EPA 1995a). The low DO concentration in Olinda Creek at Coldstream, however, probably reflects high biochemical oxygen demand in effluent from the Lilydale sewage treatment plant. It may also be exacerbated by flow-regime alterations and low oxygen levels in Lilydale Lake and deep pools downstream (Jones and Ferdinands 1993). Elevated pH levels coincided in each case with very high dissolved oxygen concentrations, suggesting high photosynthetic activity may have depressed CO_2 concentrations, thereby increasing pH (Wetzel 1983). Nutrient concentrations, particularly total nitrogen, were mostly much higher than objectives set in the SEPP or the preliminary nutrient guidelines for the state.

Most sites in the near-pristine Aquatic Reserve segment failed to comply with the Highlands River Region nitrogen guidelines. Similarly, all sites in the Parks and Forests segment exceeded the nitrogen guideline for the Southern Foothills Region. Available data for development of the preliminary nutrient objectives were limited and did not include the upper Yarra region (Tiller[2], pers. comm., 1996). The authors of the guidelines stress that they are preliminary and represent a working document to stimulate discussion and ongoing refinement (EPA 1995b). These poor results in relatively healthy, well-protected

[2] D. Tiller (Freshwater Sciences, EPA, Melbourne).

forests suggest that the guidelines may require further refinement, while also raising the possibility that disruption in the aquatic reserves is having a detrimental effect on water quality.

Waterways in the Aquatic Reserves may be responding to higher-than-expected concentrations of nitrogen in the surrounding environment. The nutrient guidelines were created for base-flow conditions. Under these conditions, nitrogen concentrations, particularly NO_x, may increase, relative to phosphorus concentrations, in response to the high proportion of groundwater in base-flows. However, parts of the closed catchment suffer from erosion impacts caused by past logging and extreme bushfires, while logging continues in the catchments of Armstrong, McMahon, Starvation and Cement creeks. Disturbances such as water impoundments and erosion from gravel access tracks and drains are also having detrimental effects and these impacts are likely to endure as they are integral to the beneficial use of the closed catchment.

Considering the level of environmental protection afforded the Aquatic Reserves, nutrient levels in most areas may be the best that can presently be expected. Despite non-compliance with preliminary nutrient guidelines, most parts of the closed catchment area are among the best-preserved areas in the state and are in excellent condition in comparison with other parts of the Yarra catchment. No sign of excessive algal growth was evident at Aquatic Reserves sites during this study. Nevertheless, results for the closed catchment point to localised problems (for example, East Armstrong Creek). On balance, it seems reasonable to assume that nutrient concentrations at sites in the Aquatic Reserves approximate currently obtainable natural background levels. This is not to say that there is not local disturbance or that water quality and aquatic ecology are currently satisfactory for maintenance of ecosystem integrity.

Both the Rural Eastern and Rural Western SEPP segments fall within the Southern Plains River Region of the preliminary nutrient guidelines. Sites in these segments displayed poor compliance with the total nitrogen objective, but somewhat better compliance with phosphorus targets (table 6). In general, the high nutrient concentrations in streams in the Rural Eastern segment reflect poor agricultural practices in their catchment (EPA 1995a). This is also the case for streams in the Rural Western segment, but these waterways have the additional effect of low flows, which are typical of the area (EPA 1995a).

Nutrient concentrations at the urban mainstream sites display a different pattern of compliance from others in the catchment. Most Yarra catchment sites fail to meet nitrogen targets more often than phosphorus targets. However, four of the six sites in the urban mainstream Yarra meet the nitrogen objectives, whereas only one site, in Warrandyte (PD), meets the phosphorus objective. This most likely reflects the high turbidity levels in the lower reaches of the mainstream Yarra (table 6). Phosphorus bound to sediment particles in these more turbid waters probably contributes to the higher relative concentrations of phosphorus and the poorer compliance for this objective. The current objectives for these lowland mainstream sites are interim targets only. Sites on the urban mainstream Yarra are well within reach of the current objectives and need to progress in the longer term to the Southern Lowlands River Region guidelines in order to have the required level of environmental protection (EPA 1995a).

Presently, most of the urban tributaries far exceed interim nutrient objectives. As is the case with the mainstream Yarra River sites, these interim objectives are not considered environmentally sustainable, but represent realistic first-step targets for nutrient reduction strategies (EPA 1995b). This step is required to halt deterioration in urban tributaries and set a trend of improvement. The extremely high nutrient concentrations in most of the urban tributaries necessitate research and development into nutrient reduction strategies before any reassessment of the guidelines for this region (EPA 1995b).

The results for the biological and physicochemical objectives – particularly at sites which failed to meet more than one objective – indicate that conditions are poorer than is considered suitable for maintenance of a healthy aquatic ecosystem, because water quality is below a level that can be expected to sustain biological integrity of the aquatic communities over time.

5. CONCLUSIONS AND RECOMMENDATIONS

A healthy riparian zone is particularly beneficial to aquatic macroinvertebrate communities. The condition of the riparian zone ultimately affects the whole stream ecosystem and can be an extremely important asset of the terrestrial ecosystem. The results of this study show strong promise for improving aquatic health through improvement of riparian habitat. Rehabilitation and protection of riparian habitat in urban and rural areas is of ecological, economic, aesthetic and recreational benefit, and is an essential management priority.

Sedimentation is a common problem in the middle Yarra valley and parts of the upper catchment. Runoff from cleared and tilled areas, and from gravel roads and drains, must be better managed to prevent sediment reaching the stream environment.

Poorly functioning sewerage and stormwater systems have considerable detrimental effects on stream ecology throughout the catchment. Substantial gains can be made through effective management of these systems to reduce the detrimental effects of both their nominal and peak-flow performance, and enable increased environmental protection.

Many rehabilitation and protection measures can be aided by proper community education. Ultimately, the protection of our streams and rivers is dependent on the community. While treatment controls aimed at removing existing pollutants or repairing existing damage can make substantial gains, practices that prevent pollution from occurring are fundamental to environmental protection. Control of the sources of pollution relies on understanding the causes and detrimental effects of pollution and providing the community with the necessary information on how best to passively and actively avoid contamination and degradation of our waterways in the first place.

Analyses in this study have shown differences between sample types in both results and confidence of findings. Multivariate analyses based on edge samples produced more stress and lower correlations than analyses based on riffle fauna. These findings reflect those of Growns *et al.* (1997) of more pronounced differences between reference and polluted sites using SIGNAL scores based on RBA riffle samples than based on edge sample data. The differences in this study may be a result of greater variation in the edge habitat compared with the better-delineated riffle habitat, or it may reflect differences in the macroinvertebrate community structure between the two habitats. Habitat along the edge, as defined by the RBA method for this study, potentially offers a broader range of niches than exists in the riffles. It also has more direct association with the terrestrial environment. Macroinvertebrates from the edge habitat may be more varied and more cosmopolitan as a result. While riffles are not always available at desired study sites, particularly in lowland rivers, they may discriminate better between sites where this habitat type is present. The potential for increasing resolution between sites warrants further investigation and comparison of the ability of different sample types to resolve sites.

A considerable proportion of the degradation in environmental quality in the Yarra catchment, particularly in the Yarra River, is occurring in the agricultural middle Yarra valley (Campbell *et* al. 1982; Pettigrove 1989; Chesterfield and Sovitslis 1994). Riparian habitat destruction and erosion are major causes of this decline. Fortunately, there are some ready solutions to both problems. Further investigation of the extent of the problems, of the effects of these impacts on downstream reaches, and of the potential for restoration of the aquatic environment through rehabilitation of the riparian zone and through erosion control measures, is essential.

Generally, the biotic index results suggest that the AUSRIVAS O/E score may be more sensitive to habitat changes than is SIGNAL. SIGNAL is particularly sensitive to organic pollution (Growns *et al.* 1995) and represents changes in water quality well, while the O/E score appears to better account for variation in habitat quality. While still in their infancy, the AUSRIVAS models show great potential for assessment of habitat quality effects as well as water quality effects. Investigation of the models' strengths and weaknesses is now required.

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APPENDIX I: STATE ENVIRONMENT PROTECTION POLICY ENVIRONMENTAL QUALITY INDICATORS AND OBJECTIVES

Table 1: Objectives for Ecological Indicators of Environmental Quality

SEGMENTS	Aquatic Reserves	Parks and Forests	Rural Eastern Waterways	Rural Western Waterways	Urban Waterways	Upper Estuary	Yarra Port
Invertebrate community							
SIGNAL Index Score	7.0	7.0	6.5	5.5	6.0[a] / 5.5[b]		
Minimum number of Families[c]	30	30	27	20	26[a] / 20[b]		
Key Families (*listed in table 2*)	*List 1*		*List 2*		*List 3*		
No. present	19	17	17[a] / 16[b]	10	16[a] / 12[b]		
Fish (presence)[d]							
Freshwater Blackfish *Gadopsis marmoratus*	✓	✓	✓	✓	✓		
Tupong *Pseudaphritis urvillii*	✓[e]	✓	✓	✓	✓	✓	✓
Grayling *Prototroctes mareana*	✓[e]	✓	✓	✓	✓	✓	✓
Spotted Galaxias *Galaxias truttaceous*	✓[e]	✓	✓	✓	✓	✓	✓
Common Galaxias *G. maculatus*	✓[e]	✓	✓	✓	✓	✓	✓

For the purposes of table 1:

(i) the objectives have been determined using the Rapid Bioassessment Method approved by the Authority, require data combined from two sampling occasions (one each in autumn and spring) and, where possible, require the sampling of two habitats (riffles and edge/macrophytes);

(ii) the letters superscripted after the levels of certain indicators in table 3 have the following meanings:

'a' means the value is the objective for the Yarra River mainstream;

'b' means the value is the objective for the tributaries of the Yarra River;

'c' means the taxonomic level of Family excluding families of Acarina, Oligochaeta, Platyhelminthes (Tricladida and Temnocephalidea), Cnidaria, Collembola, Ostracoda, Copepoda, Cladocera, Hirudinea, Polychaeta, Nematoda, Nematomorpha or Porifera;

'd' means in streams of appropriate size and within the natural range of the species;

'e' means except in waters upstream of the Upper Yarra, Maroondah and Tourourrong Reservoirs;

(iii) 'List 1' is a reference to the key families of invertebrates in the Aquatic Reserves segment and the Parks and Forests segment, specified in table 2;

(iv) 'List 2' is a reference to the key families of invertebrates in the Rural Eastern Waterways segment and the Rural Western Waterways segment, specified in table 2;

(v) 'List 3' is a reference to the key families of invertebrates in the Urban Waterways segment, specified in table 2.

Table 2 : Lists of key families for segments of this schedule

	List 1 **Aquatic Reserves Segment & Parks and Forest Segment**	**List 2** **Rural Eastern Waterways Segment and Rural Western Waterways Segment**	**List 3** **Urban Waterways Segment**
Stoneflies	Gripopterygidae	Gripopterygidae	Gripopterygidae
	Austroperlidae	Austroperlidae	
	Eustheniidae		
	Notonemouridae		
Mayflies	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae
	Baetidae	Baetidae	Baetidae
	Coloburiscidae	Caenidae	Caenidae
		Coloburiscidae	
Dragonflies	Aeshnidae	Aeshnidae	Aeshnidae
		Lestidae/Synlestidae/Corduliidae	Lestidae/Synlestidae/Corduliidae
			Megapodagrionidae
			Any other family of Odonata
True flies	Athericidae	Athericidae	
	Blephariceridae		
Caddis flies	Leptoceridae	Leptoceridae	Leptoceridae
	Philorheithridae	Philorheithridae	Ecnomidae
	Helicopsychidae	Glossosomatidae	Hydrobiosidae
	Glossosomatidae	Calocidae	Hydropsychidae
	Hydrobiosidae	Calamoceratidae	Calamoceratidae
	Philopotamidae	Hydrobiosidae	
	Hydropsychidae	Hydropsychidae	
	Calocidae	Ecnomidae	
	Helicophidae	Atriplectididae	
	Conoesucidae	Conoesucidae	
Beetles	Elmidae	Elmidae	Elmidae
	Ptilodactilidae	Ptilodactylidae	Hydrophilidae
	Scirtidae	Hydrophilidae	Psephenidae
		Hydrochidae	
Amphipods	Eusiridae	Ceinidae/Eusiridae	Ceinidae/Eusiridae
Shrimps		Atyidae	Atyidae
Snails/Bivalves		Hydrobiidae/Corbiculidae	Hydrobiidae/Corbiculidae
TOTAL	24	26	19

APPENDIX II: SITE LOCATIONS AND DESCRIPTIONS

URBAN SITES

Yarra River at Dights Falls, Yarra Bend Park, Abbotsford (PA)

Melway 2D B6 Lat. 37.7989 Long. 144.9998

Site is on the lower reaches, just above the tidal influence, where the river is approximately 30 m wide. Riffle substrate is an artificial boulder and cobble riffle, together with a fish-ladder, immediately downstream of a weir that was used for water extraction earlier this century. Edge habitat is comprised of large boulders placed on a deep bend to reduce erosion, and immediately adjacent to a kayak training-course. No riparian trees or shrubs; only trailing grasses.

Yarra River at Whittons Reserve, Wonga Park (PC)

Melway 24 K6 Lat. 37.7195 Long. 145.2833

Site is a recreation reserve with a largely natural, upstream reach, popular for rafting. The river is approximately 25 m wide, with a deep riffle and sandy, heavily trafficked banks. Edge habitat is disturbed by anglers, swimmers and rafters. Riffle has a substantial flow, with ample area for sampling. Adequate riparian zone, mostly of eucalypts and shrubs.

Yarra River at Warrandyte (PD)

Melway 23 F11 Lat. 37.7384 Long. 145.2205

Site is at a popular swimming area in the centre of Warrandyte. Grassy banks reinforced with boulders. The 30 m wide, deep riffle has a strong, fast current. Little riparian vegetation other than grasses on the bank (sampled). Surrounding land use is residential and commercial. Immediately adjacent is a gravel carpark.

Yarra River at Spadonis Reserve, Coldstream (PE)

Melway 274 E8 Lat. 37.6808 Long. 145.3472

Site on a 25 m wide, sweeping bend in a recreation reserve popular for fishing and canoeing. Sandy, grass-covered banks with few riparian trees or shrubs. Deep, relatively slow-flowing run with no riffle. Surrounding land use is primarily agricultural.

Yarra River at Banksia Street, Heidelberg (PF)

Melway 32 C5 Lat. 37.7619 Long. 145.0762

Site on a fast-flowing run with gravel/pebble banks forming a gentle, 25 m wide riffle. Riparian zone of medium-sized eucalypts and willows, with some shrubby understorey. Edge mostly pebbly banks, with trailing willow branches and roots. Surrounding land use is mostly commercial and open recreation areas.

Yarra River at Fitzsimon's Lane, Templestowe (PG)

Melway 21 G12 Lat. 37.7425 Long. 145.1352

Site at a kayak-launching place in a recreation reserve. The river is approximately 25 m wide, with sandy edges eroded on one bank by kayaker traffic. Relatively small, fast-flowing riffle of large cobbles, boulders and bedrock. Some trees in riparian zone, but mostly grassy banks. Surrounding land use is mostly recreational, with residential areas beyond.

Yarra River at Burke Road, Ivanhoe (PH)

Melway 31 K11 Lat. 37.7828 Long. 145.0627

Site is approximately 30 m wide, with a deep run and no riffle. Banks have good riparian vegetation of *Eucalyptus* and *Acacia* with a shrubby understorey and trailing roots and branches. Shading is good for a wide, lowland river. Immediate surroundings are recreational, with wide buffer strips adjacent to residential areas.

Gardiners Creek at Cato Street, Kooyong (PI)

Melway 59 E4 Lat. 37.8446 Long. 145.0390

Site is a concrete-sided urban stormwater drain with a bluestone bottom, situated between the South-Eastern Arterial Road and a bitumen carpark. Base-flow is approximately 2 m wide at the bottom of the 15 m wide channel. Riparian zone is entirely grass, with no contact between the vegetation and water, and no shading. Surrounding land use is commercial, industrial and residential.

Gardiners Creek at Warrigal Road, Chadstone (PJ)

Melway 60 G12 Lat. 37.8734 Long. 145.0904

Site is a 6 m-wide stream in a residential/commercial area with a golf course on one bank for part of the reach. Artificial riffle area of large boulders and cobbles, with a great deal of trapped litter and debris, including shopping trolleys. Few trees or shrubs in riparian zone. Mostly grasses and larger weeds, such as fennel and thistle. Edge habitat is mostly trailing grasses among artificially placed boulders for erosion control. Immediately upstream of the site, the creek is a concrete channel.

Gardiners Creek at Station Street, Box Hill (PK)

Melway 61 C4 Lat. 37.8424 Long. 145.1210

Site is a 4 m wide, deeply incised stream, in residential surroundings, with a golf course on one bank immediately upstream. Riparian vegetation is mostly grass, with scattered small trees. Substrate is clay, gravel and sand, with scattered cobbles and boulders and some litter. Land use is primarily residential.

Moonee Ponds Creek at Primrose Street, Essendon (PL)

Melway 28 K3 Lat. 37.7543 Long. 144.9270

Site is a 6 m wide stream in urban residential surrounds. Litter is widespread throughout the site. Banks are steep and covered with grass. Edge habitat is mainly trailing grasses and *Phragmites*. The riffle is composed of artificially placed boulders.

Moonee Ponds Creek at Devereaux Street, Oak Park (PM)

Melway 16 D5 Lat. 37.7155 Long. 144.9013

Site is a 2 m wide stream within a suburban park. There is little riparian vegetation and shading is limited. Substrate is dominated by gravel. Banks are covered with grass; edge habitat is trailing grasses and *Phragmites*. The site is adjacent to a new housing development.

Moonee Ponds Creek at Bent Street, Westmeadows (PN)

Melway 5 K6 Lat. 37.6763 Long. 144.8846

Site is a 1.5 m wide stream, in a park between a residential area and a local shopping centre. The banks are steep. Habitat is a slow-flowing run through extensive *Phragmites* beds. Riparian vegetation is mostly grass and *Phragmites*. Substrate is sand and silt. Shading is limited primarily to that provided by the stands of emergent water plants and some scattered mature eucalypts.

Koonung Creek at Elizabeth Street, Box Hill North (PO)

Melway 47 D4 Lat. 37.8004 Long. 145.1227

Site is adjacent to and downstream of earthworks for the construction of an extension to the Eastern Freeway. On the opposite bank is a park and playing fields. The local land use is residential. Riparian vegetation is limited to grasses and a few wattles and willows, with little shading of the stream. Substrate is dominated by cobble and pebble, with heavy deposits of gravel, sand and silt from the nearby earthworks. Banks on the earthworks side are degraded and suffering substantial erosion. Habitat is limited by willow root-mats, with exposed banks affected by periodic silt deposition followed by stormwater scouring. The stream channel changes location and width to some extent according to frequency of rainfall and associated scouring.

Ruffey Creek at Ruffey Street, Templestowe (PP)

Melway 33 C4 Lat. 37.7567 Long. 145.1173

Site is 3–6 m wide, with modified banks. Riparian vegetation is limited to grass and a few scattered shrubs. Substrate is dominated by gravel with pebbles, cobble, sand and occasional boulders. Litter is scattered throughout the site. Shading at midday is effectively non-existent. Land use is residential.

Stringybark Creek at McKillop Road, Silvan (PQ)

Melway 120 J2 Lat. 37.7932 Long. 145.4105

Site is a slow, 2 m wide run, with a small riffle area flowing through extensive *Phragmites* beds. Surrounding land use is mostly agricultural with low-density, unsewered housing upstream. Banks from which the edge sample was taken are entirely covered with emergent water plants. Substrate is mostly pebble and gravel, with some silt deposition. Shade is provided by emergent water plants.

Stringybark Creek at St Hubert’s Road, Coldstream (PR)

Melway 275 E11 Lat. 37.6934 Long. 145.3995

Site is approximately 2.5 m wide, in a grazing area and surrounded by paddocks. A slow run flows through a deep channel, with some *Phragmites* beds and patches of *Triglochin*. Erosion is apparent on the grassy, clay banks. Substrate is clay and silt. Riparian vegetation is almost entirely grass, typical of grazed areas, although steep banks preclude stock access to the water at the site. Shading at noon is limited to the water plants.

Brushy Creek at Homestead Road, Wonga Park (PS)

Melway 279 B9 Lat. 37.7298 Long. 145.2902

Site is 4 m wide, downstream of a local sewage treatment plant and in a grazing area. Riparian vegetation is composed of tea-tree and hawthorn shrubs, with a few small eucalypts. Shade is very limited. Banks are heavily affected by stock access with some grass and *Juncus*. Edge substrate is mostly silt and sand with patchy *Triglochin*. Riffle substrate is a shifting gravel and sand bar. A gravel road crossing the site causes noticeable dust deposits on surrounding vegetation.

Bushy Creek at Valda Avenue, Doncaster (PT)

Melway 47 B3 Lat. 37.7979 Long. 145.1131

Site is in parklands, surrounded by residential areas. Stream is 2–3 m wide, with steep banks and moderate shading. Riparian vegetation is mostly grass and blackberry canes, with scattered trees. Several small riffles separate small pools. Earthworks for freeway construction come within 20 m of the stream and pose a threat of sediment runoff.

Mullum Mullum Creek at Ailsa Court, Ringwood (PU)

Melway 50 C3 Lat. 37.7981 Long. 145.2023

Site is a small, 1 m-wide creek, in a park adjacent to a playing field. There is extensive litter within the site, including shopping trolleys. Housing encroaches closely on the stream. Substrate is cobble, with heavy silt deposits. Banks are covered with grass and *Ranunculus*. Shading is very limited.

Mullum Mullum Creek at Quarry Road, Mitcham (PV)

Melway 49 B6 Lat. 37.8059 Long. 145.2511

Site is a 2.5 m-wide stream, set in a corridor of mainly native vegetation, with some onionweed on the banks. The area is a local recreation area, with a walking track following the stream. The site is well shaded by trees in the riparian zone. Substrate is mostly gravel and cobble.

Mullum Mullum Creek at Warrandyte Road, Warrandyte (PW)

Melway 34 F3 Lat. 37.7523 Long. 145.1749

Site is at the end of a corridor of mostly native riparian vegetation. Shading of the 4 m wide stream is good upstream, but patchy in the riffle and absent where edges were sampled. Edge sample taken from open, grassed area downstream of the corridor of trees, where trailing bank-vegetation is more prevalent. Riffle sample taken downstream of bridge in a small riffle with some shading from small wattles and eucalypts. Substrate is sand, silt and clay in the swept area, and bedrock cobble and boulder in the riffle. Local land use is mainly residential and recreational.

Watson's Creek at Clintons Road, Christmas Hills (PX)

Melway 265 A11 Lat. 37.6510 Long. 145.2826

Site is in a semi-residential native forest area. Riparian zone of small eucalypt and wattle trees, with some shrubby understorey. Very shallow pebbly riffle. Edge substrate is mostly sand and silt. Banks are gently sloping clay, sand and pebble, with some bare areas evident. This site is a Country Fire Authority waterpoint.

Watson's Creek at Henley Road, Kangaroo Ground (PY)

Melway 24 F1 Lat. 37.7034 Long. 145.2633

Site is on a stream about 1.5 m wide, in a deep gully. Land use is mostly grazing. Riparian vegetation comprises eucalypts and wattles, with grasses and some ferns on the water's edge. Banks are slightly undercut, with some trailing bank-vegetation. Riffle is mostly pebbles, with some cobbles, gravel and sand. *Triglochin* is common but dispersed. Shading is good.

Lyrebird Creek at Olinda Creek Road, Silvan (PZ)

Melway 120 F12 Lat. 37.8315 Long. 145.3966

Site is in Olinda State Forest on a stream approximately 3 m wide. Surrounding land use is entirely native forest. Riparian vegetation includes eucalypts, wattles and ferny understorey. Edge substrate is mostly gravel and sand. The shallow riffle has a substrate of mostly pebbles, with some cobble and gravel. The site is well-shaded, with detritus and some rubbish in the water.

Olinda Creek at York road, Mt Evelyn (QA)

Melway 120 A3 Lat. 37.7974 Long. 145.3744

Site is at a small roadside reserve. The 2.5 m-wide creek flows out of slightly degraded native riparian vegetation into an open grassy area with high, steep banks. The edge samples were taken partially from within the shady riparian zone and partially from the open grassed area with trailing grasses. Edge substrate is mostly sand and silt, with some cobble. The riffle is within the shaded riparian area, with a substrate of cobble and pebble, and some sand. Land use is recreational, with residential areas nearby.

Olinda Creek Drain at Macintyre Lane, Coldstream (QB)

Melway 280 J1 Lat. 37.7007 Long. 145.3653

Site is on a very deeply cut, 2–3 m-wide, earthen-banked drain. Riparian vegetation is mostly willow and wattle with extensive blackberry understorey. There is no riffle, only a moderately fast-flowing run. The edge habitat is mostly willow roots and trailing blackberry, with patches of *Triglochin*. Surrounding land is used for agriculture.

Plenty River at Wildwood Road, Whittlesea (QC)

Melway 246 J1 Lat. 37.4865 Long. 145.1258

Site is a 2–3 m wide stream, in a rural area, with a narrow corridor of riparian vegetation. Substrate is clay and silt. Banks are covered with grass, and edge habitat is mainly root mats. Adjacent land use is primarily grazing.

Plenty River at Henty road, Viewbank (QD)

Melway 20 K12 Lat. 37.7411 Long. 145.1035

Site is on a 6 m-wide run, in a remnant agricultural area surrounded by Melbourne's northern suburbs. The narrow riparian zone is mainly exotic oaks and willows, with patchy groundcover from exotic species. Shading is moderate to good. Substrate is clay and silt, with no riffle. Edge habitat is mainly root mats and trailing vegetation on partially exposed banks.

Darebin Creek at Abercorne Avenue, Fairfield (QE)

Melway 31 C8 Lat. 37.7724 Long. 145.0306

Site is in a medium-density urban area, on a 5 m wide, turbulent stream. Banks are high and wide. Trapped litter is very apparent on surrounding boulders and willows. Riparian vegetation is almost exclusively willows, with patchy grass for groundcover. Substrate is dominated by volcanic boulders and cobbles, with some pebbles and gravel. Edge habitat is willow roots. Adjacent land use is residential, with heavy stormwater impact from local upstream commercial and industrial areas.

Darebin Creek at McDonalds Road, Epping (QF)

Melway 182 C10 Lat. 37.6471 Long. 145.0305

Site is in an outer-suburban residential area, on a 2 m wide stream within a much wider channel. Riparian zone is mostly grasses and thistle, with a few small basket willows. Shading is poor. Banks are gently sloping, and litter is prevalent. Riffle substrate is mostly volcanic boulders, cobbles and pebbles. Edge substrate is cobble, sand and silt, with habitat composed mainly of *Phragmites* sp. beds and some *Juncus* sp.

Darebin Creek at Chenies Road, Reservoir (QG)

Melway 19 C4 Lat. 37.7133 Long. 145.0276

Site is a 2 m-wide, earthen-banked channel with steeply sloping sides in residential surroundings. There are no shrubs or trees in the riparian zone, and shading is absent. Banks are covered with grass and larger weed species. Edge habitat is *Phragmites* sp., *Juncus* sp. and trailing grasses. Riffle area is small and composed of boulders and cobbles surrounded by sand.

Diamond Creek at Eltham Lower Park, Eltham (QH)

Melway 21 H10 Lat. 37.7345 Long. 145.1404

Site is on a 3.5 m-wide stream, in outer suburbs, bounded on one side by low-density housing and on the other by Eltham Lower Park. Land use is residential and recreational. Banks are steeply sloping, with understorey of eucalypt, willow and wattle trees, as well as sparse tea-tree. Edge substrate is exposed bedrock reefs, clay and some pebbles, with sparse trailing bank-vegetation and *Juncus*. Shading is moderate.

Diamond Creek at Gipson Street, Diamond Creek (QI)

Melway 12 B5 Lat. 37.6718 Long. 145.1574

Site is on a 3.5 m wide stream in a wide, flood-prone reach, spanned by a 200 m bridge. Edge habitat was sampled upstream of a small concrete water-gauging weir. Riffle habitat sampled downstream of weir in short cobble and boulder riffle. Riparian vegetation is mostly native, with eucalypt and wattle overstorey and shrubby understorey. A wide, grassy, flood-prone recreation area is adjacent. Shading is moderate to good. Banks are mostly clay. Land use is recreational and low-density residential.

Diamond Creek at Mittons Bridge, St Andrews (QJ)

Melway 250 G8 Lat. 37.5880 Long. 145.2829

Site is on a 4 m wide stream on the outskirts of St Andrews, in forested surrounds. Riparian vegetation includes *Eucalyptus*, *Acacia* and *Pomaderris,* with smaller, shrubby understorey. Substrate in the reach is dominated by bedrock, boulder and cobble, with some pebbles and gravel. Edge habitat is scattered *Juncus* and *Triglochin* sp., with some leaf packs. Banks are steep but stable. Land use is native forest and low-density residential.

Merri Creek at Cole Crescent, East Coburg (QK)

Melway 30 A2 Lat. 37.7519 Long. 144.9795

Site is an 8 m wide stream, with grass-covered clay banks and small, shrubby riparian zone of eucalypt and wattle. Land use is recreational and medium-density residential, with heavy stormwater and litter loads. Shading is moderate to good. Substrate is cobbles, pebbles and gravel, surrounded by clay.

Merri Creek at Creek Parade, Clifton Hill (QO)

Melway 30 E12 Lat. 37.7869 Long. 144.9959

Site is a 4–5 m wide, turbulent stream, in a medium- to high-density urban area, with heavy stormwater influence. Trapped litter is very apparent on surrounding boulders and willows. Riparian vegetation is almost exclusively willows. Substrate is dominated by volcanic boulders and cobbles, with some pebbles and gravel. Edge habitat is willow root-mats. Adjacent land use is residential and recreational.

Merri Creek at Summerhill Road, Craigieburn (QV)

Melway 387 H2 Lat. 37.5737 Long. 144.9526

Site is on a 6 m-wide stream with slow, almost stagnant, pools in a dry, degraded agricultural area north of Melbourne. Riparian zone is mostly grass, with a few eucalypts and shrubby tea-trees. Edge habitat is mainly *Phragmites* beds and scattered pockets of *Juncus*. Large amounts of submerged, feathery water plants are present. Substrate is anaerobic silt and clay, with steep, rocky banks. Shade is sparse.

Plenty River at Booyan Crescent, Greensborough (QY)

Melway 10 J10 Lat. 37.6928 Long. 145.0991

Site is on a 3.5 m-wide stream, bounded on one side by native riparian vegetation and forest, and on the other by a narrow riparian zone and a grassy playground. Local land use is recreational and residential. Water is slow-moving, and well-shaded by eucalypts, with some shrubby understorey. Substrate and banks are clay and silt. Edge habitat is mainly root mats, with some trailing bank-vegetation and undercutting.

UPPER CATCHMENT SITES

Yarra River at Maxwell's Road, Healesville (RI)

Melway 277 G7 Lat. 37.6774 Long. 145.4885

Site is a very deep run on a 10–15 m wide bend. Banks are steep, with exposed clay in many areas. Edge habitat is limited, with sparse trailing vegetation and poor bank structure. Riparian zone is mostly wattle, with some eucalypts and blackberry vines. Substrate is clay, silt and sand. Local land use is mostly agricultural and some native forest. Shading is moderate.

Starvation Creek, upstream of the diversion weir on Road 17 (RR)

ESMAP 686 J8 Lat. 37.7562 Long. 145.8483

Site is a 4–5 m-wide stream inside the closed water-supply catchment within the Yarra Ranges National Park. Surrounding land is native forest, with gravel access tracks. Riparian vegetation is regrowth *Eucalyptus* and *Acacia*, with some *Pomaderris* and a ferny understorey. The creek is well-shaded; detritus is extensive. Riffle substrate is dominated by cobble and pebble. Edge substrate is mostly sand and gravel, with trailing bank-vegetation and leaf packs trapped by snags. Banks are moderately steep and somewhat unstable. Site was disturbed by bridge construction after first sampling.

Armstrong Creek, East Branch on East Armstrong Road (RS)

ESMAP 653 J8 Lat. 37.6389 Long. 145.8671

Site is a 2 m wide stream within the closed catchment in the Yarra Ranges National Park. The site is separated into two habitat types by a road crossing. Upstream of the road is a shallow riffle, dominated by small cobbles and pebbles, with noticeable silt deposition. Downstream of the road is a pool, fringed by maidenhair ferns, with a substrate of silt, and some cobbles and pebbles. The creek is well shaded by regrowth riparian vegetation of *Eucalyptus*, *Acacia* and *Pomaderris* – it has a ferny understorey. Land use is entirely native forest.

O'Shannassy River, upstream of O'Shannassy Reservoir (RT)

ESMAP 653 G10 Lat. 37.6604 Long. 145.8293

Site is an 8 m wide, turbulent stream within the closed catchment in the Yarra Ranges National Park. The river is dominated by a wide riffle. Riffle substrate is mainly boulders with cobbles between. Edge substrate is the same, with some trailing bank-vegetation and leaf packs trapped by snags. The river is well-shaded along the banks. Land use is entirely native forest.

Alderman Creek, upstream of Upper Yarra Reservoir on Road 32 (RU)

ESMAP 687 G8 Lat. 37.7279 Long. 145.9429

Site is in the Yarra Ranges National Park, in the closed catchment. The site is at a gauging station which has a small artificial weir. Substrate in the 2–3 m wide riffle is cobble and boulder, with quite heavy sand and silt deposition. Edge substrate is mostly sand and silt in a 3 m wide pool formed by the weir. Edge habitat comprises undercut banks and trailing bank vegetation. The creek is well-shaded by regrowth riparian vegetation of *Eucalyptus*, *Acacia* and *Pomaderris*, and has a ferny understorey. Land use is entirely native forest.

McMahon Creek on Road 5 (RV)

ESMAP 687 D6 Lat. 37.7409 Long. 145.9013

Site is on a 4–5 m wide stream in the closed catchment in the Yarra Ranges National Park. Heavy sand deposition is evident throughout the site. Edge substrate is mostly sand surrounding boulders and large cobbles, with undercut soil banks. Riffle substrate is shifting sand/gravel bars, and cobbles and boulders surrounded by sand and gravel. The creek is well-shaded by riparian vegetation of *Eucalyptus*, *Acacia* and *Pomaderris* and has a ferny understorey. Land use is entirely native forest.

Upper Yarra River at Track 12 (RW)

ESMAP 688 H5 Lat. 37.7355 Long. 146.0408

Site is a 5 m wide, turbulent stream in the closed catchment in the Yarra Ranges National Park. The riffle substrate is composed of boulders and cobbles surrounded by some sand and gravel. Edge substrate is similar, with some silt deposition. Edge habitat is mainly leaf packs trapped by coarse, woody debris, with some trailing bank-vegetation. Banks are mostly rocky. Shade covers about half of the river at midday. Riparian vegetation is *Eucalyptus*, *Acacia* and *Pomaderris*, with a ferny understorey. Land use is entirely native forest.

Yarra River at Big Peninsula Tunnel (RX)

ESMAP 686 F2 Lat. 37.7073 Long. 145.8180

Site is within the Yarra Ranges National Park, has public access and is a popular swimming hole. Site is immediately downstream of a tunnel that was cut through the rock peninsula to aid gold mining. Substrate in the reach is dominated by boulder and cobble. The edge sample was taken partially from extensive sedge beds, downstream of a 15 m wide pool in full sun, and partially from shaded undercut banks with trailing bank-vegetation. The turbulent riffle is 5 m wide and dominated by cobbles and boulders. Riparian vegetation is native grasses and sedges in the slower pool area, with *Eucalyptus* and *Acacia*-dominated forest in the rest of the site. Land use is recreational and native forest.

Little Yarra River at Lowe Road, Yarra Junction (RZ)

Melway 288 F7 Lat. 37.7829 Long. 145.6191

Site is just upstream of Yarra Junction. It is bounded on one side by roadside vegetation, and on the other by grazing land. Stock access is not apparent. The river is 6 m wide and moderately well-shaded by small eucalypts and wattles, with an understorey of shrubs, ferns and introduced grasses. The substrate in the small riffle is mostly cobble, with some pebbles and boulders. The edge substrate is similar, with habitat of trailing bank-vegetation. Banks are stable, with extensive grass cover.

Little Yarra River at Powelltown NRE office (SA)

ESMAP 713 J7 Lat. 37.8604 Long. 145.7425

Site is a 3·5 m wide stream immediately behind the Natural Resources and Environment office in Powelltown. Land use is well-developed regrowth native forest on one bank, and residential on the other, with a narrow riparian zone of degraded native vegetation and an adjacent grassy area. Substrate in the reach is dominated by shifting sand. Edge habitat is undercut soil banks with extensive trailing bank-vegetation. Banks are stabilised by ferns, with some slight erosion caused by anglers. Shading is moderate.

Cement Creek at Acheron Way, Mt Donna Buang (SB)

ESMAP 685 G3 Lat. 37.7146 Long. 145.7041

Site is at a sightseeing area near the Mt Donna Buang turnoff from the Acheron Way. The habitat at this site is quite distinctive. It is composed almost entirely of fast-flowing water falling over large boulders, in a long, gentle 2–3 m wide series of waterfalls. Edge habitat is very limited, with only a few leaf-packs in pools formed behind larger boulders, and virtually no trailing bank-vegetation. Boulders form the banks. Riparian vegetation is beech myrtle and ferns. Land use is native vegetation, with sightseeing paths.

Watts River at Fernshaw Reserve, Black Spur (SC)

ESMAP 651 G6 Lat. 37.6178 Long. 145.6023

Site is an 8–9 m wide turbulent stream, adjacent to Fernshaw Reserve on the Maroondah Highway. On one bank, land use is native forest, in the closed water-supply catchment in the Yarra Ranges National Park. On the other bank is an established roadside park, with mature introduced deciduous trees, barbecues and toilets. Riparian vegetation is a mixture of deciduous exotics and eucalypts, tree ferns and other native understorey species. The riffle is large, with a substrate dominated by boulders, cobbles and pebbles. The edge has a similar substrate, with leaf-packs trapped by coarse, woody debris and some trailing bank-vegetation. The site is well-shaded.

Woori Yallock Creek at Parslow Bridge, Yellingbo (SD)

ESMAP 711 I2 Lat. 37.8135 Long. 145.5077

Site is in degraded native forest of eucalypts and wattles, in the Yellingbo State Wildlife Reserve on the outskirts of Yellingbo. The 5–6 m wide stream is moderately well-shaded by larger eucalypts, but has very little understorey. Steep clay banks provide some trailing grass habitat, with patches of *Triglochin* providing more. Substrate is mostly clay, with some pebbles, gravel and sand. Surrounding land use is agricultural and residential, but with some native forest in the reserve.

Cockatoo Creek at Brisbane Road, Cockatoo (SE)

ESMAP 739 I4 Lat. 37.9551 Long. 145.5032

Site is a 3 m wide creek in low-density residential Cockatoo. Riparian vegetation is mainly eucalypt, wattle and blackberry, with moderate shading. Riffle substrate is cobble, surrounded by gravel, sand and heavy silt deposits. Substrate along the edges is almost entirely silt. Banks are eroded and incised, and edge habitat is limited to sparse trailing bank-vegetation. Stormwater from the surrounding gravel roads and drains is a major factor in siltation, evident from deposition in and around drains entering the site.

APPENDIX III: SUMMARY TABLE OF MAJOR PHYSICAL AND CHEMICAL PARAMETERS

		TEMP	DO	EC	PH	TURB	CURR	ALKAL	NO_x	TKN	TOTP	SLOPE	ALT
PA	Yarra@Dights	19.5	8.4	220	7.45	13.5000	0.554	32.5	0.45	0.400	0.110	8	12
PC	Yarra@Wonga	18.5	8	127.5	7.4	11.5	0.9515	17.5	0.665	0.35	0.14	2	50
PD	Yarra@Warndyt	18.5	8.25	105	7.4	10.25	1.149	14.5	0.43	0.3	0.067	1.2	30
PE	Yarra@Coldstrm	19	7.8	95	7.4	12.25	-	14	0.295	0.65	0.085	0.5	70
PF	Yarra@Heidelberg	19.75	7.6	141	7.5	14	0.6235	20	0.455	0.35	0.091	0.3	18
PG	Yarra@Tmplstwe	19.5	8.7	136.5	7.4	13.5	0.6075	19.5	0.455	0.35	0.087	0.3	20
PH	Yarra@Ivanhoe	19.5	7.7	150	7.1	16	-	19	0.4	0.65	0.0865	0.3	15
PI	GardinersKooyng	19	7.35	375	7.75	56	0.828	53	0.455	0.85	0.13	1.5	15
PJ	Gardnrs@Chadstn	24	11.15	575	9.8	9.5	0.409	53.5	0.1	0.75	0.09	2.9	25
PK	Gardnrs@BoxHill	18.5	6.4	408.5	7.45	28.5	0.28	60.5	0.4	0.9	0.0875	2.9	35
PL	Moonee@Essndn	18.5	6.3	1225	8.2	8.25	0.41	195	0.265	0.95	0.165	4.4	21
PM	Moonee@Deveraux	16.5	10.25	1500	8.15	14.8	0.31	240	0.45	1.1	0.162	5	43
PN	Moonee@Bent	14.5	6.3	1320	7.6	33.25	-	155	0.071	1.05	0.1705	5	80
PO	Koonung@Box Hill	17.75	7.9	522.5	7.6	39	0.346	65	0.215	0.8	0.0815	10	45
PP	Ruffey@Tmplstwe	22.5	14.4	950	8.85	9.8	0.28	87.5	0.59	0.75	0.14	20	20
PQ	Strngybk@Silvan	18.5	10.2	412.5	7.7	10.5	0.06	54.5	2.6	0.35	0.022	20	240
PR	StrngybkC'stream	18	8.6	675	7.55	17.25	-	70.5	0.73	0.55	0.024	0.9	75
PS	Brushy@Wonga Pk	20	7.6	432.5	7.25	16.25	0.411	51.5	10.7	1.85	7.95	3.6	55
PT	Bushy@Doncaster	17	11.75	1350	8.5	18.5	0.1655	109	0.17	1.05	0.249	20	40
PU	Mullum@Quarry Rd	18.5	9.8	505	8.35	12.9	0.4025	72.5	0.0515	1	0.073	8	130
PV	Mullum@Ailsa Ct	19	7.15	725	7.45	36.5	0.13	60.5	1.77	2.25	0.57	10	90
PW	Mullum@Warndyte	16	7.65	620	7.7	22.5	0.35	78	2.55	0.9	0.29	5	40
PX	Watsons@Xmas	18.5	8.6	3425	8	10.8	-	235	0.027	0.65	0.0225	6.7	110
PY	Watsons@Kng Gnd	18	7.85	850	7.65	2.3	0.327	89.5	0.0365	0.3	0.016	6.7	50
PZ	Lyrebird@Silvan	13.9	9.65	67.5	6.95	24.5	0.6	8.5	0.235	0.6	0.0505	13.3	215
QA	Olinda@Mt Evln	15	9.05	97.5	7.2	5.75	0.623	18	0.52	0.25	0.025	10	130
QB	OlindaDrn@Cldstrm	17.5	4.15	585	7.25	8	-	86	1.75	1.15	0.225	1.5	105
QC	Plenty@Wildwood	17	4.1	800	7.2	36.25	-	119	0.014	3.1	0.275	10	200
QD	Plenty@Viewbank	18	4.1	1325	7.35	6.5	-	120	0.1565	1.05	0.067	3.3	60
QE	Darebin@Fairfield	17.5	10	925	8.6	5.65	0.5255	135	0.73	1.4	0.26	6.7	40
QF	Darebin@Epping	17	6.5	425	7.4	4.85	-	103.5	0.369	0.75	0.07	10	130
QG	Darebin@Chenies	20	7.75	1400	7.9	6.05	0.3195	210	1.478	0.65	0.0865	3.6	70
QH	Diamond@Eltham	15.5	7.35	540	7.3	27	-	71	0.42	0.9	0.108	3	30
QI	Diamond@Diamond	17	6.5	640	7.25	33	0.26	57.5	0.0825	1.1	0.1205	4	70
QJ	Diamnd@StAndrws	14	6.15	450	7.2	24.5	0.2	52	0.17	1.85	0.124	11	140
QK	Merri@Coburg	19	4.775	1250	7.8	2.9	0.393	200	0.185	1.15	0.2	2.9	40
QO	Merri@CkPde	17.25	10.2	900	7.9	4.4	0.398	155	0.2215	0.9	0.14	4	20
QV	Merri@Cragieburn	17	7.1	3450	8.3	7.45	-	405	-	0.85	0.0515	3.7	200
QY	Plenty@Grnsbrgh	16.5	4.55	725	7.6	10.1	-	103	0.015	1.25	0.0865	4	50
RI	Yarra@Maxwells	17.3	8.575	77.5	7.2	11.1	-	12	0.205	0.35	0.0475	0.5	80
RR	Starvation Ck	13.25	9.3	37.5	7.4	4.55	0.668	7	0.205	0.45	0.0235	20	330
RS	Armstrong Ck East	14.45	9.8	57.5	7.15	3.6	0.1895	15	0.155	0.25	0.0235	13	340
RT	O'Shannessy R	13.75	11.2	25	7.1	5.05	0.895	5.5	0.15	0.45	0.0385	13	430
RU	Alderman Ck	13.5	11.5	38.5	7.05	1.65	0.4265	9	0.16	0.1	0.01	20	380
RV	McMahon Ck	13.25	11.45	41.5	7.15	3.7	0.8015	7.5	0.24	0.3	0.018	20	400
RW	Yarra@Track 12	12.5	11.6	24	7.05	1.1	0.567	6	0.125	-	0.0075	25	500
RX	Yarra@BPT	16.3	8.175	46.5	7.45	3.9	0.6015	11	0.145	0.2	0.01	5	240
RZ	LtYarra@Lowe	15.7	9.6	65	7.25	14.5	0.768	9	0.275	0.6	0.05	4	110
SA	LtYarra@Powltn	14	9.755	48	7.05	3.55	-	8.5	0.285	0.3	0.0165	6.7	180
SB	Cement Ck	11	9.25	16	7.05	1.35	0.3605	4	0.295	0.2	0.012	100	650
SC	Watts@Fernshaw	15.4	9.975	27	7.4	3.6	0.6535	5	0.135	0.5	0.0335	10	190
SD	WooriYlck@Ylngbo	16.5	10.5	102.5	7.15	15	0.368	15.5	0.605	0.35	0.0235	1.4	105
SE	Cockatoo Ck	17	10.05	105	7	7.25	0.378	12.5	0.745	0.3	0.024	6.7	200

Note: Shaded sites are reference sites used to formulate the AUSRIVAS models.

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site	discharge area upstream of site	mean width (m)	mean depth riffle (cm)	mean substratum reach (phi)	mean substratum riffle (phi)	vegetation (category)	shading category	macrophyte no. of taxa	reach filament. algae category	reach CPOM	reach FPOM
	AREA	WIDTH	DEPTH	RECHSUB	RIFSUB	VEGCAT	SHADE	PLANTSP	RECHALGA	RECHCPOM	RECHFPOM
Yarra@Dights	3609.080	25	47	-7.088	-7.088	1	1	1	1	2	2
Yarra@Wonga	2299.528	25	38.5	-4.125	-5.750	1	1	2	0	1	1
Yarra@Warndyt	2369.104	30	39.5	-5.475	-5.475	1	2	1	0	1	1
Yarra@Coldstrm	2166.863	22.5	-	5.600	-	2	1	2	0	1	1
Yarra@Heidelberg	2939.269	20.5	44.5	1.055	-4.350	1	2	1	1	1	1
Yarra@Tmplstwe	2542.453	25	42.5	-2.525	-5.688	1	1	1	1	2	2
Yarra@Ivanhoe	3210.495	28.5	-	4.175	-	1	2	1	1	2	2
GardinersKooyng	26.533	2	25	-2.588	-3.163	1	1	1	0	1	2
Gardnrs@Chadstn	43.042	5.5	16.5	-6.575	-5.775	1	1	1	2	2	2
Gardnrs@BoxHill	21.226	4	13	-0.838	-6.500	1	3	1	0	1	1
Moonee@Essndn	117.925	5.75	15.5	-2.550	-4.215	1	1	2	1	2	2
Moonee@Deveraux	79.009	2.5	24	-0.300	-1.450	1	1	2	1	2	2
Moonee@Bent	43.632	1.5	-	3.638	-	1	3	2	2	3	3
Koonung@Box Hill	6.486	1.75	8.5	-1.800	-1.768	1	4	0	0	1	1
Ruffey@Tmplstwe	14.741	3.5	7	-3.163	-5.675	1	1	3	2	1	1
Strngybk@Silvan	5.307	1.75	13	2.900	-2.650	2	4	1	1	2	1
StrngybkC'stream	48.349	2.5	-	6.200	-	2	2	2	0	2	2
Brushy@Wonga Pk	13.561	4	11	0.325	-0.625	2	2	3	1	1	2
Bushy@Doncaster	0.590	3	9	0.300	-4.038	1	2	0	1	2	3
Mullum@Quarry Rd	8.255	2.5	9.5	-4.100	-2.516	1	2	1	1	2	1
Mullum@Ailsa Ct	5.896	1	6	-1.013	-0.325	1	2	2	0	2	2
Mullum@Warndyte	29.481	4	19	1.088	-5.750	1	2	1	1	2	2
Watsons@Xmas	34.198	2	10	1.488	-4.600	2	3	2	1	3	1
Watsons@Kng Gnd	50.118	1.5	11	-4.268	-5.425	2	3	3	1	2	1
Lyrebird@Silvan	7.075	3	7	0.275	-3.880	3	5	1	0	2	3
Olinda@Mt Evln	17.689	2.5	14	-0.425	-4.713	1	4	2	0	2	1
OlindaDrn@Cldstrm	48.939	1.75	-	8.300	-	1	2	2	0	2	2
Plenty@Wildwood	61.910	2.25	-	8.000	-	1	4	0	1	3	3
Plenty@Viewbank	998.231	5.5	-	7.850	-	1	3	2	0	3	3
Darebin@Fairfield	162.146	5	22	-6.050	-6.613	1	5	1	3	2	2
Darebin@Epping	70.165	1.75	-	-5.550	-	1	3	5	1	3	3
Darebin@Chenies	102.594	2	22.5	-0.738	-5.575	1	1	3	4	1	2
Diamond@Eltham	841.981	3.25	-	1.475	-	1	2	1	0	2	2
Diamond@Diamond	825.472	3.5	25	-4.825	-6.900	1	3	1	1	3	2
Diamnd@StAndrws	31.250	3.75	20	-8.088	8.025	2	4	1	0	3	2
Merri@Coburg	267.099	8	23	1.050	-7.100	1	2	3	2	3	3
Merri@CkPde	324.292	4.25	25.5	-6.300	-5.600	1	5	1	1	3	3
Merri@Cragieburn	202.241	6	-	0.900	-	2	2	4	2	2	3
Plenty@Grnsbrgh	890.330	3.5	-	7.750	-	1	4	2	0	3	2
Yarra@Maxwells	1709.906	10	-	4.025	-	3	2	1	0	2	1
Starvation Ck	29.481	4	18	-3.538	-4.325	4	4	1	0	2	2
Armstrong Ck East	11.792	2.25	21	-2.705	-3.420	4	5	0	0	3	2
O'Shannessy R	77.830	8	36	-5.263	-6.100	4	2	0	0	2	1
Alderman Ck	25.943	5	20.5	-5.215	-5.440	4	4	0	0	2	2
McMahon Ck	24.764	4.5	18.5	-1.600	-2.525	4	5	0	0	3	1
Yarra@Track 12	41.274	5	27.5	-5.300	-5.750	4	5	1	0	3	2
Yarra@BPT	1092.571	6.5	28	-3.300	-5.275	3	2	1	1	2	3
LtYarra@Lowe	106.132	6	39	-3.610	-5.375	2	2	1	0	2	2
LtYarra@Powltn	26.533	3.5	-	0.363	-	3	3	1	0	2	2
Cement Ck	1.179	3	13	-7.125	-7.000	4	5	0	0	3	2
Watts@Fernshaw	51.887	8.5	22.5	-3.273	-5.913	3	4	0	0	2	2
WooriYlck@Ylngbo	272.406	5.5	50.5	4.525	1.050	4	3	2	0	3	2
Cockatoo Ck	8.844	3	9.5	0.438	-2.738	3	4	0	0	2	2

Note: Shaded sites are reference sites used to formulate the AUSRIVAS models.