Melbourne Water Macroinvertebrate database 1994 – 2002.

A report on its compilation, with recommendations for its use and for future biological monitoring.

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CONTENTS

1. Executive summary and recommendations

This report documents the compilation of a database of all macroinvertebrate data collected by rapid biological assessment methods from 1994 to 2002 by or on behalf of Melbourne Water Corporation. It discusses implications arising from the collation of these data and makes a series of recommendations concerning the database's use and maintenance, future biological monitoring practices and interpretation of data extracted from the database.

This database brings together 1,844 samples from 468 sites, sourced from more than 18 studies in a unified, taxonomically consistent, updateable database with a simple interface for easy extraction of summary data. This is the first time that these diverse datasets (conservatively estimated to have cost more than $1 million to collect) can be widely and easily used in diverse ways for purposes beyond the original reports written following their collection.

The collation of the data has revealed a number of inefficiencies (and resulting inaccuracies) caused by poor coordination of multiple consultancies and lack of curation of existing catchment-scale data. Poor quality control of environmental data is evident. Recommendations are made to prevent these inefficiencies and inaccuracies in the future.

Although the primary objective of this project was to calculate AUSRIVAS scores for all samples, collection of environmental data in projects prior to 1998 was inadequate to permit AUSRIVAS calculations. Therefore AUSRIVAS scores have been calculated for only 222 sites.

However, an assessment of the relative sensitivities of AUSRIVAS and other biological indicators to a disturbance gradient in the east of Melbourne suggests that AUSRIVAS is not a sensitive or reliable indicator of degradation in macroinvertebrate assemblages. SIGNAL and number of EPT families are more sensitive indicators of moderate degradation. An interim recommendation is made for reporting using biological indicators.

1.1. Recommendations

1. If macroinvertebrate data drawn from more than one study are to be used, extreme caution should be taken comparing patterns below the taxonomic level of 'AUSRIVAS groupings'. Studies have variously identified taxa to genus/species level, Family/Subfamily level and to AUSRIVAS groupings. It is safest to lump taxa to AUSRIVAS grouping level as a default.

2. To facilitate ongoing curation of biological monitoring data, MW should adopt the coding system created in this database and require their consultants to use this coding system in their reports.

3. Management of catchment-scale environmental data. The variables discussed in this recommendation need to be determined using GIS. Quality control and quality assurance for all these variables need to be improved. These data should be kept centrally in this database and made available to consultants, rather than leaving it to consultants to re-estimate them for every project

   a. The supplied catchment boundary layer should be used as the basis for calculation of catchment areas of any new sites. Any errors in the layer should be noted for correction in the database. Catchment areas and the catchment boundary layer should be supplied to consultants at the commencement of a study.

b. Consultants should progressively review VEGCAT values, in consultation with MW personnel. Estimates of this variable should NOT be made in the field, but by using land use data. Any required corrections should be noted for inclusion in the database. For areas with changing land use, care should be taken to ensure that date specific VEGCAT values be applied to each site.

c. The appropriate method for estimating distance from source should be determined, and this variable should be determined for all sites.

4. Quality control of substrate estimation and Alkalinity measurements require improvement, if they are to be used. However, the appropriateness of these measures as predictor variables for AUSRIVAS models is questionable and should be reviewed by the model builders (see recommendation 6)

5. A comparative study of biological indicators across a known disturbance gradient similar to the one described herein should be conducted for sites in the north or west of the Melbourne Water area. This will assess if the observed poor performance of AUSRIVAS models applies across the entire MW region.

6. MW should encourage the builders of the Victorian AUSRIVAS models review their choice of environmental predictor variables, and assess the relative performance of models that use only variables that are unambiguously unaffected by human impact.

7. Until the problems with AUSRIVAS models in the MW region are resolved, we recommend that MW rely primarily on SIGNAL scores and secondarily on EPT family richness for biological assessment of stream condition using macroinvertebrates. Where other indicators must be included in SEPP reporting, their lack of sensitivity should be noted.

2. Introduction

Melbourne Water Corporation (MW) has been sampling macroinvertebrates using rapid bioassessment methods (RBA, sensu: Chessman, 1995) since 1994, primarily as part of its ongoing biological monitoring program, but also as part of specific investigations. In June 2002, MW contracted the CRC for Freshwater Ecology to consolidate all its RBA macroinvertebrate data, with the primary aim of determining AUSRIVAS scores (Coysh et al., 2000) for all samples.

The data consisted of 1,844 samples: 1,792 from 18 identified studies and 52 from unidentified sources. The samples covered 468 sites, almost all within the MW area. The data were dispersed across many spreadsheets. The data sources were inconsistent in taxonomic nomenclature, in the quality and type of environmental data collected and in the conventions used for site and sample coding. The major component of this project was reconciling, cross-checking and standardising the multiple conventions of the various data sources.

Because of inadequate environmental data, the primary aim of this project has only been partly accomplished: AUSRIVAS scores from one or more models have been calculated for only 222 of the 468 sites (a total of 888 samples).

However, the project has succeeded in adding enormous value to the macroinvertebrate data by collating them into a unified, taxonomically consistent, updateable database. A conservative estimate of the cost of the collection of these data is $1 million. Only with the creation of this database will this valuable asset be widely and easily useable in diverse ways for purposes beyond the original reports written following the collection of the data.

The process of compiling the database has revealed many inefficiencies and some errors in the collection and use biological monitoring data by MW and its consultants. This report makes a series of recommendations for future biological monitoring and reporting by MW. It also critically assesses the usefulness of biological indicators for ecosystem health as outlined in the Victorian State Environment Protection Policies (for Waters of Victoria, Yarra and Westernport), particularly the implementation and use of AUSRIVAS.

3. The database

3.1. Biological data

The database uses the Victorian EPA 'bugcode' list (supplied by John Dean, Victorian EPA, July 2002) as its taxonomic basis. All taxonomic names (38,022 entries in total) were checked against this list and assigned a bugcode. Some entries (mostly in poorly described groups such as the Ceratopogonidae or Tipulidae) were ambiguous voucher names, which were 'lumped up' to the next taxonomic level. All taxonomic names and bugcodes originally used by the data collectors have been retained in the database, but the corrected bugcodes are the basis for all data calculations.

This project has not assessed the quality of the biological data. Because of the multiple people involved in collecting the data, and because of changes in taxonomy over the last eight years, it is recommended that data identified to species or genus be used with caution, particularly for data spanning more than one study. (One exception to this recommendation is the three 1994-1995 studies [Vic EPA, Streamwatch and CRCFE], which have been taxonomically standardized).

The database is structured so that 'lumping' data up to higher taxonomic levels is simple using the appropriate query. The database distinguishes the following taxonomic levels:

- Species
- Genus
- Family/Subfamily (all taxa to family, except the Chironomidae subfamilies)
- AUSRIVAS groupings (Oligochaeta and mites lumped: all other taxa to family, except the Chironomidae subfamilies)
- Order/Class (Insecta and Crustacea to order, all other taxa to class)
- Phylum/Order (Arthropoda to Order, other taxa to Phylum)

In light of the high standards of biological quality control in the various consultancies, it is assumed that data is of high quality at the family/subfamily level and above.

Recommendation 1: If macroinvertebrate data drawn from more than one study are to be used, extreme caution should be taken comparing patterns below the taxonomic level of 'AUSRIVAS groupings'. Studies have variously identified taxa to genus/species level, Family/Subfamily level and to AUSRIVAS groupings. It is safest to lump taxa to AUSRIVAS grouping level as a default.

3.2. Site and sample coding conventions

From the 18 studies from which the data is drawn, 23 distinct site-coding conventions were identified as relevant to the database. This inconsistency was a serious impediment to consolidation of the data, as not only were many sites attributed with multiple codes, but in some cases, the same codes were used for multiple sites. In some studies, different coding systems were used to describe the same sites depending on whether macroinvertebrate data or water quality data were being discussed.

It appears that this situation has arisen because consultants have been left to create coding systems for each study. If MW is to maximize the long-term usefulness of their monitoring data, then a consistent coding system should be instigated and consultants should be required to use this system.

One possibility is the adoption of the MW asset ID system to describe sites. This option is not recommended for two reasons. Firstly, the asset ID system is reach-based, and in many cases, multiple sites will be sampled within the one reach. Secondly, the asset ID system is not intuitively logical.

It is recommended that MW adopt the site coding system created for this database. It is intuitively logical and site based. It is linked to the asset ID system in the database, and asset IDs can be easily reported using the appropriate query structure.

The site coding system used in the database is a 7-character code consisting of

1. a unique 3-letter stream code (236 streams have been coded, indexed to 66 sub-catchments, in turn indexed to 11 catchments: this can be easily altered if the categories are not considered useful).
2. a 4-digit number corresponding to the catchment size in square km.

In a very few cases, where multiple sites have been sampled along a short reach, an eighth letter can be added to distinguish sub-sites (as has been done for the 3 riffles in Moonee Ponds Creek separated by 100 m: MOO0113U, MOO0113M, MOO0113D).

A secondary advantage of this coding system is that MW will take central control of catchment area calculations, which is discussed further below.

Samples should be identified by 10-character codes consisting of

1. a 2-digit date code (2 date codes per year corresponding to ‘Spring’ = Jul-Dec and ‘Autumn’ = Jan-Jun), starting with 01 in Autumn 1994 (Spring 2002 = 18).
2. the 7-character site code
3. a 1-character habitat identifier (R = riffle, E = edge, C = composite, M = [mid]-channel)

In a very few cases multiple sites have been collected from the same site, same habitat in the same season. These samples are identified by an 11th character.

Recommendation 2: To facilitate ongoing curation of biological monitoring data, MW should adopt the coding system created in this database and require their consultants to use this coding system in their reports.

3.3. Environmental data

The eight AUSRIVAS (family level) models that are applicable to the MW area require a total of 25 environmental variables as listed in the Victorian EPA ‘Field records and habitat assessment sheets’ (Tiller & Metzeling, 1998). These recording systems have only been used consistently in the MW monitoring program since 1998. The coverage of all required variables was therefore incomplete, with enough variables to run at least one model in only ~120 of the 468 sites for which biological data exists. By some supplementation of the existing data (see below), the number of analysable sites was increased to 222.

Where environmental data has been collected, a low-level of quality control is evident in most studies. Key variables are discussed below.

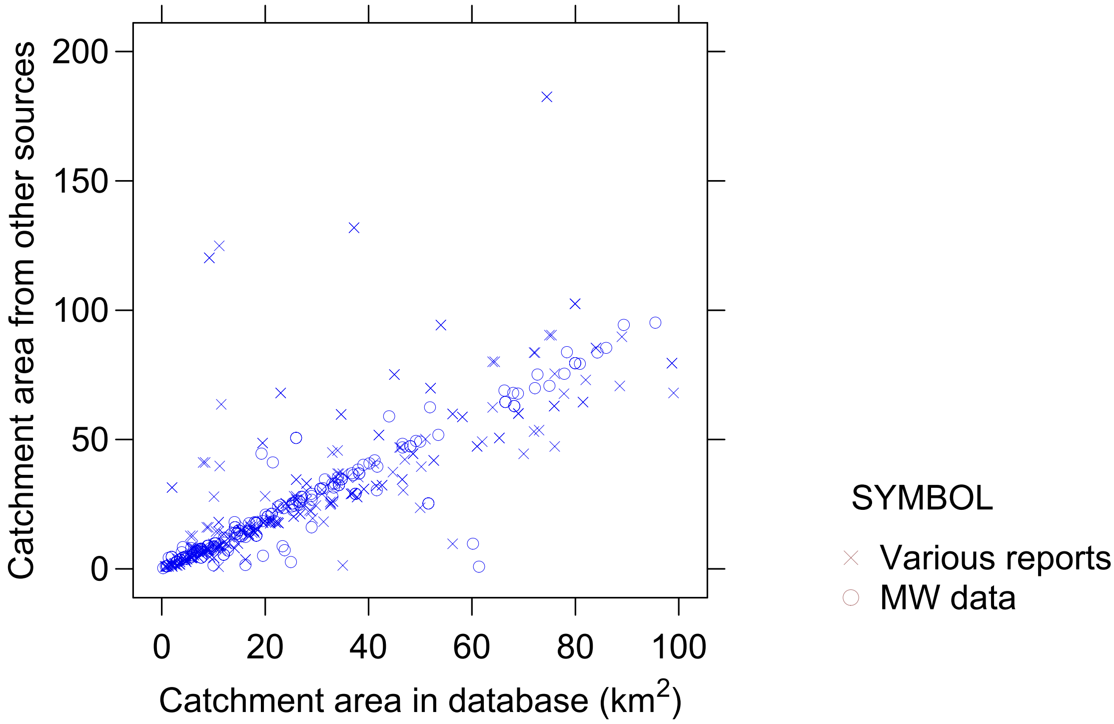

Fig. 1. Variation in supplied estimates of catchment area for catchments less than 100 km^2. MW data was a dataset developed for the determination of catchment imperviousness in 1999.

3.3.1. Catchment area.

Prior to this project, catchment area was quantified for less than half of the 468 sites. Frequent large errors were evident in those that were quantified (Fig. 1). In developing the database, the authors have derived catchment areas for all sites using the 10m contour data from the VicMAP 1:25,000 digital map series. Indexed catchment boundaries for most of the sites have been supplied as a MapInfo layer.

Recommendation 3a: The catchment boundary layer should be used as the basis for calculation of catchment areas of any new sites. Any errors in the layer should be noted for correction in the database. Catchment areas and the catchment boundary layer should be supplied to consultants at the commencement of a study.

3.3.2. Latitude and Longitude

Latitude and Longitude (and Australian map grid references) have been calculated by the authors using MapInfo, following the derivation of all catchment boundaries. The numbers in the database are likely to be slightly different from those in original data sets. In almost all cases, the provided coordinates were close to correct.

3.3.3. VEGCAT

This variable (vegetation category) is peculiar to AUSRIVAS models. It is a categorical variable describing catchment land use: 1. Urban/Residential; 2. Intensive agriculture/some residential; 3. Some forestry/agriculture(eg grazing); 4. Native forest/natural vegetation (L. Metzeling, Victorian EPA personal communication). The catchment-scale nature of the variable is not clear from the AUSRIVAS documentation, which may have been the cause of of this variable being estimated incorrectly in 45% of the 98 sites in which it had been estimated as part of studies. In a number of cases, the same site has been assigned two different VEGCAT values by the same consultants from one season to the next.

The authors have made a rapid attempt at estimating this variable for all sites based on knowledge of the study area. It is likely that, for some areas, our estimates are incorrect (particularly, the differences between categories 2 and 3).

Recommendation 3b: Consultants should progressively review VEGCAT values, in consultation with MW personnel. Estimates of this variable should NOT be made in the field, but by using land use data. Any required corrections should be noted for inclusion in the database. For areas with changing land use, care should be made to ensure that date specific VEGCAT values be applied to each site.

3.3.4. Altitude

This variable has been determined for all sites by the authors using the 10m contour maps as for catchment areas.

3.3.5. Distance from source.

It is not clear from AUSRIVAS documentation by which method this variable should be determined. It has been calculated for 236 sites, but the authors of this report have not checked the quality of the data (other than a general agreement with the downstream trend).

Recommendation 3c: The appropriate method for estimating distance from source should be determined, and it should be determined for all sites.

Recommendation 3: All the above variables need to be determined using GIS. Quality control and quality assurance for these variables need to be improved. These data should be kept centrally in this database and made available to consultants, rather than leaving it to consultants to re-estimate them for every project.

3.3.6. Substrate related variables (percentage of reach that is bedrock, gravel, pebbles, cobbles, reach PHI, riffle PHI, and substrate heterogeneity SUBHETERO)

All of these variables were estimated inconsistently in the majority of cases. Fig 1 shows a plot of estimates of reach PHI in the first season of each of four biological monitoring studies against estimates in the second (and subsequent seasons) in the same study. With the exception of the most recent study, there was a very poor correlation between consecutive estimates of substratum particle size distributions by the same consultants. For most reaches it would be surprising to find large changes in substrate particle size distributions from season to season.

The reliability of most of the estimates of these substrate-related variables is therefore suspect.

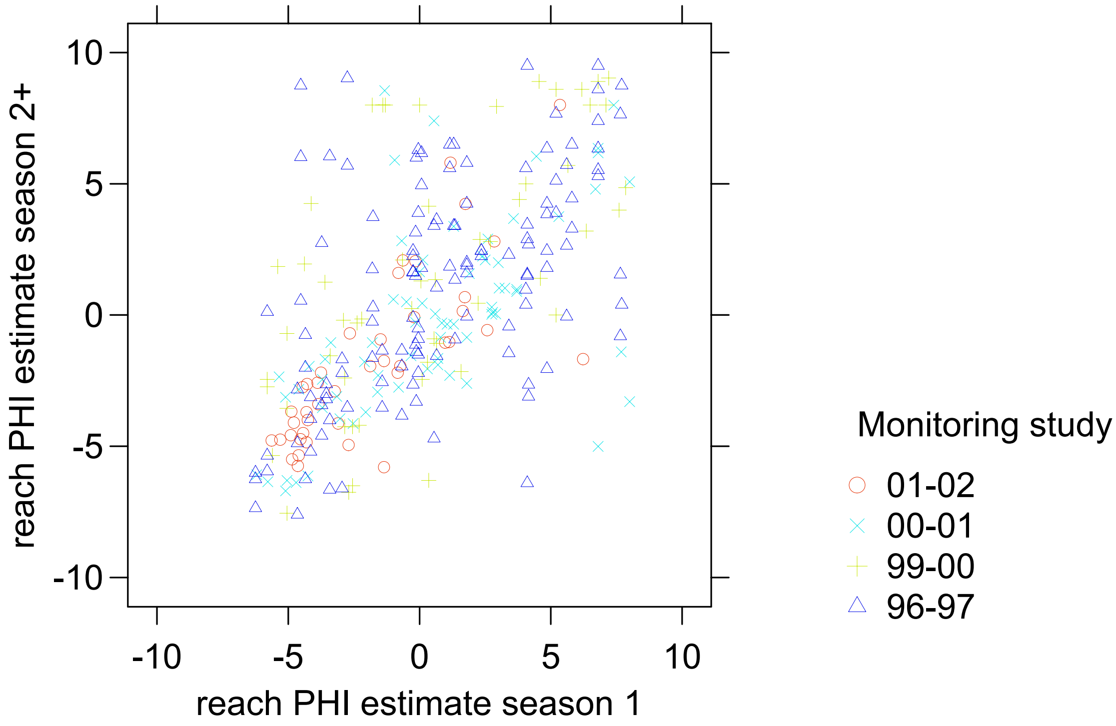

Fig. 2. Reach PHI estimates from the first season plotted against estimates in subsequent seasons in the same study for four monitoring program studies.

3.3.7. Alkalinity

At least one measurement of alkalinity was available for each of 274 sites. The authors have screened the data and marked outlying values as dubious. The existence of dubious outlying values makes the common practice of using a single alkalinity measured at the time of biological sampling questionable. In AUSRIVAS calculations in this project, we used mean values (excluding dubious values). We also have used the regionally conservative nature of this water quality variable to estimate alkalinity values for those of the remaining 194 sites where there were adequate upstream and downstream samples to interpolate an estimate (these interpolated values have been marked as such in the database).

Recommendation 4: Quality control of substrate estimation and Alkalinity measurements require improvement, if they are to be used. However, as discussed below, the appropriateness of these measures as predictor variables for AUSRIVAS models is questionable and should be reviewed by the model builders.

4. An assessment of the reliability of recommended biological indicators for the MW region

4.1. Introduction and methods

Sixteen sites in independent sub-catchments in the eastern suburbs and on the eastern fringe of Melbourne and beyond were selected as part of the CRC FE study of urbanization and ecological function of streams to represent a strong gradient of catchment land use from undisturbed forest to heavily urbanized. Sub-catchments were selected to minimise land use cover other than forest and urban. Catchment characteristics quantified included catchment imperviousness, drainage connection (the proportion of impervious surfaces in the catchment directly connected to the stream by pipes or sealed drains) and septic tank density.

A strong gradient in a suite of environmental indicators was evident across the sixteen sites, with drainage connection and, to a lesser extent, imperviousness explaining a large proportion of the variance in macroinvertebrate community composition, algal community composition, benthic algal biomass, electrical conductivity and concentration of phosphorus.

These sixteen sites have been used here to assess the sensitivity of the biological indicators required in the SEPPs to this gradient.

For this assessment, data were collected according to the AUSRIVAS requirements (rapid bioassessment, field sorted, identified to family, except for Oligochaeta and mites). Compositional similarity was determined using Bray-Curtis similarity on presence-absence data. An index of compositional similarity among the sixteen sites was derived using principal curve analysis (De'ath, 1999; De'ath & Walsh, 2001). Patterns in these direct measures of compositional patterns were compared with numbers of families, numbers of EPT (Ephemeroptera, Plecoptera, and Trichoptera) families, SIGNAL scores, and O/E (Observed: Expected) scores for ten relevant AUSRIVAS models (Six Victorian family models - spring riffles and edges, autumn riffles and edges, combined riffles and combined edges – and four regional models – region 2 combined riffles and edges, and region 4 combined riffles and combined edges. Models of both regions are relevant because the study area straddles the boundary of the two regions.

4.2. Results

For all data treatments (single habitats and single seasons, combined seasons, combined habitats), a strong, consistent gradient that was well explained by drainage connection was evident in the principal curve and SIGNAL scores (Figs. 3, 4). In all cases, the three sites with highest drainage connection (Gardiners, Scotchmans and Brushy) fell at one extreme of the gradient, showing distinct, serious degradation of community composition. Furthermore, five moderately degraded sites were consistently evident. Four of these had high levels of drainage connection, but one, Monbulk, was more degraded than could be explained by drainage connection (Figs. 3, 4). It is likely that this site is degraded by large quantities of grey water being discharged into the stream just upstream. The remaining sites, with low connection, supported less degraded communities as assessed by community similarity and SIGNAL scores (Figs. 3, 4).

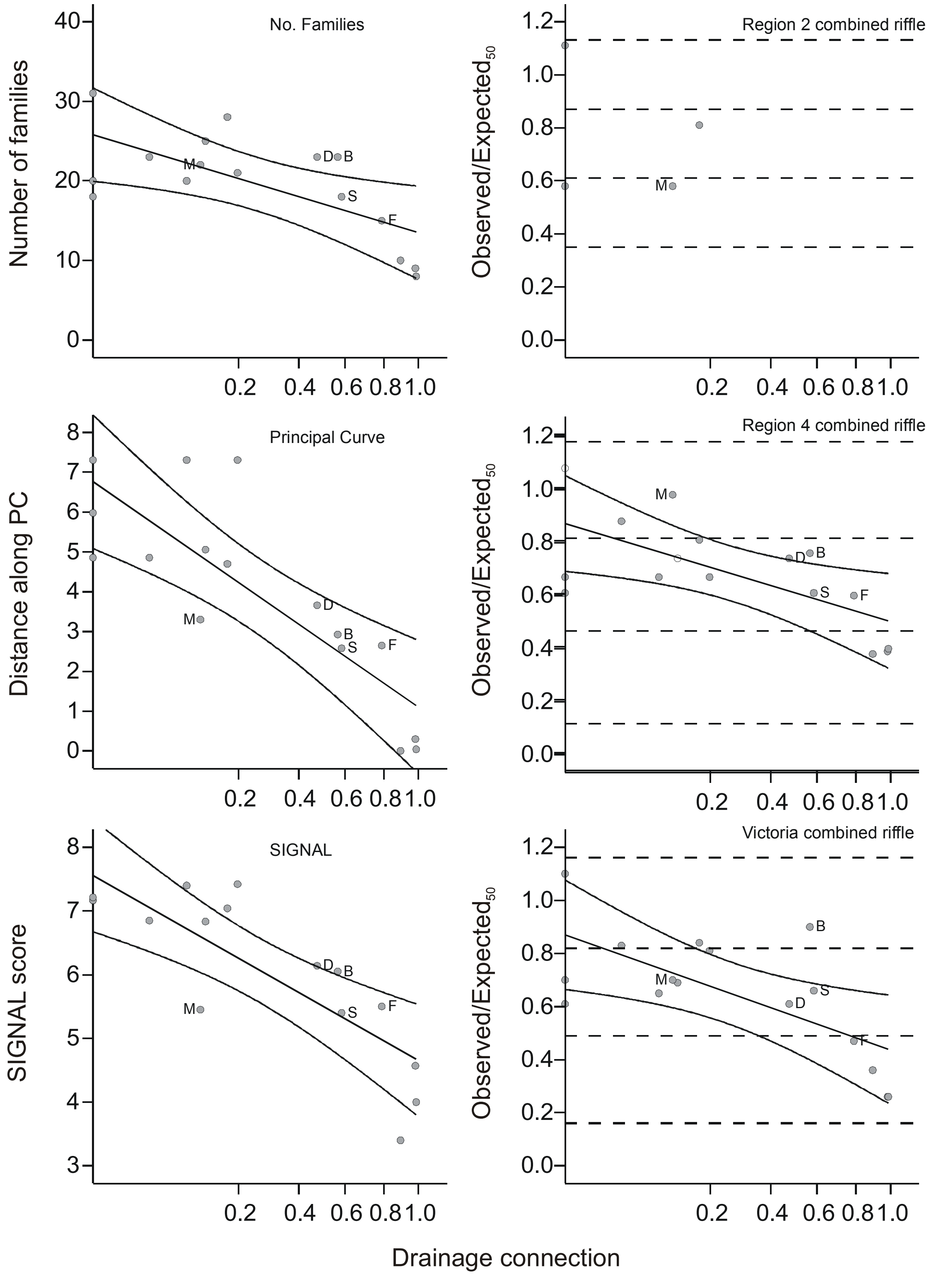

Fig. 3. Summary variables for combined riffle samples in 16 sites to the east of Melbourne. Five moderately degraded sites are indicated **M**onbulk, **D**obsons, **B**ungalook, Little **S**tringybark and **F**erny. AUSRIVAS bands (X, A, B, C, D) are delineated by dashed lines. For Region 2 and Region 4 models, sites > 5km from the regional boundary are identified by open symbols. Samples from most sites were outside the experience of region 2 model. Lines of best fit and 95% confidence limits are indicated.

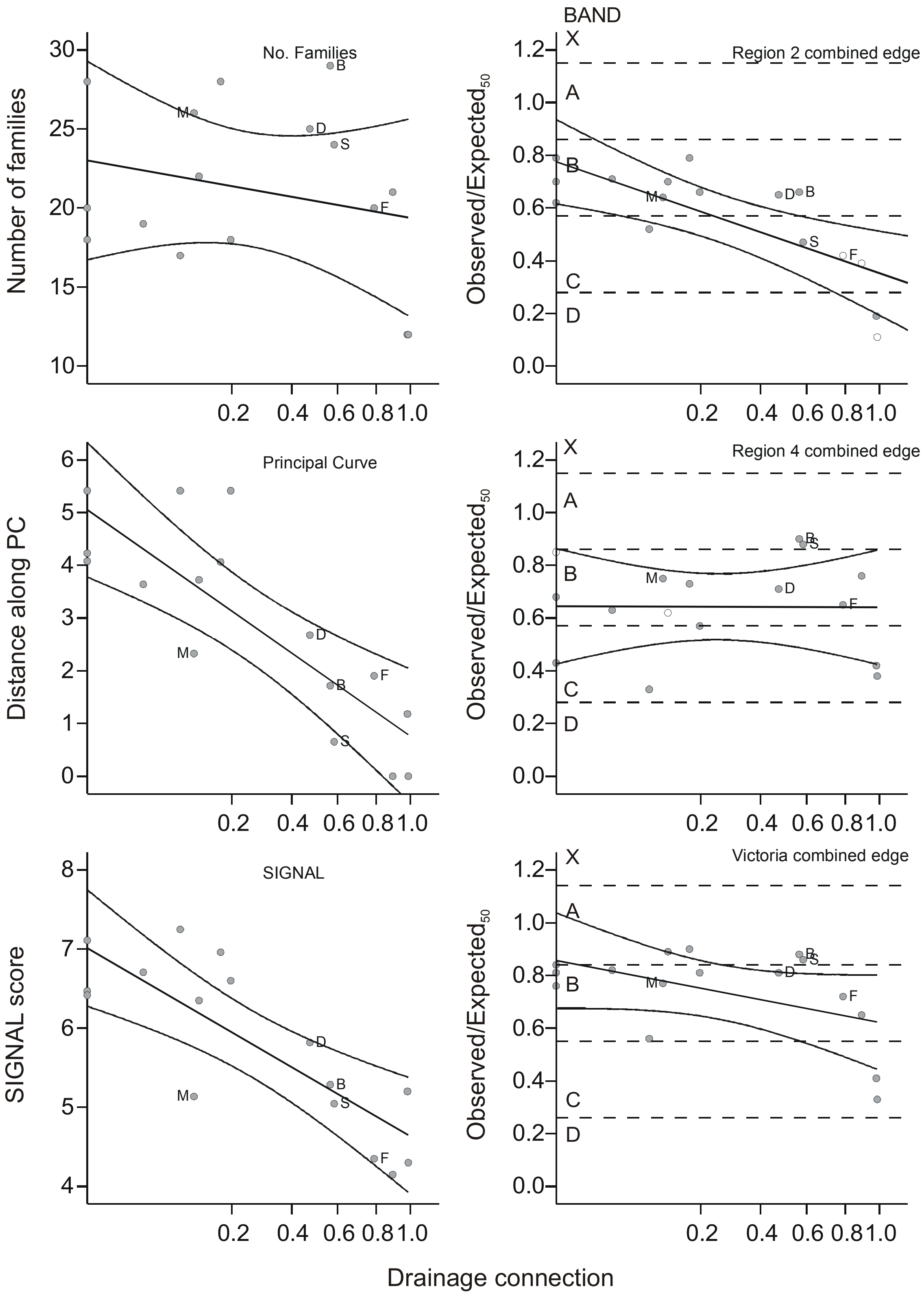

Fig. 4. Summary variables for combined edges in 16 sites to the east of Melbourne. Conventions as for Fig.3.

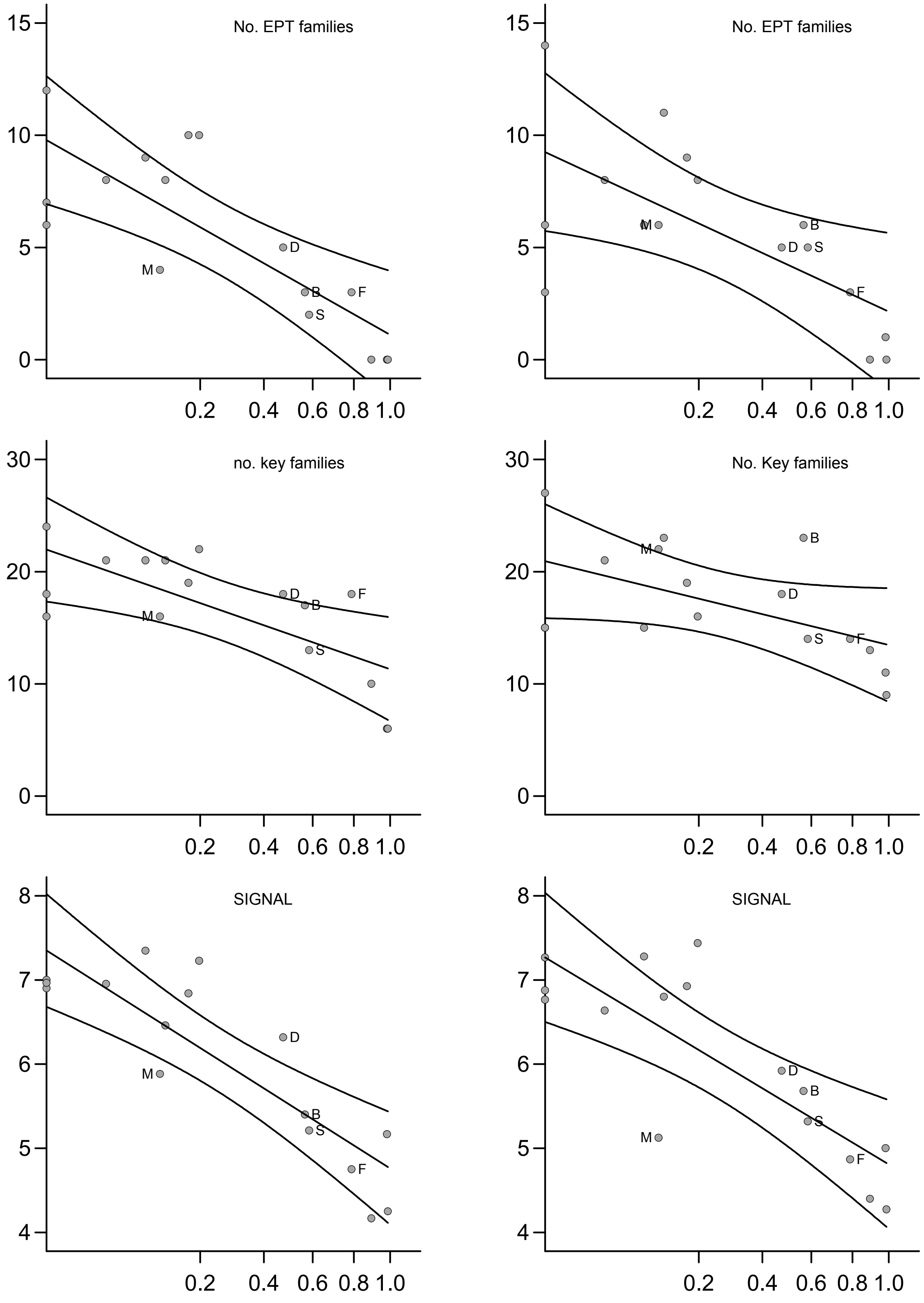

Fig. 5. Summary variables for combined seasons in 16 sites to the east of Melbourne. Conventions as for Fig.3.

Correlations between O/E scores and the drainage connection gradient were weaker than that for principal curves and SIGNAL for all models. No AUSRIVAS model consistently identified the five moderately degraded sites as being intermediate between the three degraded, highly connected sites and the less degraded sites with low connection. In all models at least one of these moderately degraded sites had one of the highest O/E scores of the sixteen. In seven of the models, one or more of these most degraded sites fell within band A (i.e. equal to reference condition). Most models identified the three most highly connected sites as the most degraded, but two models (Victorian autumn edge and Region 4 combined edge) rated Brushy Creek as in better condition than more than half of the sixteen sites. In summary all AUSRIVAS models were insensitive to the pronounced urban gradient across the sixteen sites.

Number of families was also a poor correlate with the urban gradient (Figs.3, 4), as was number of key families (Fig. 5).

Number of EPT families did consistently correctly order the most degraded three and the five moderately degraded sites. However in autumn, two sites with zero connection (Lyerbird and Emerald also had low numbers of EPT families (Fig. 5).

Fig. 6 portrays similarity of patterns for all biological indicators across the sixteen sites. Patterns in Bray-Curtis similarity were very similar for all data treatements. The principal curve and SIGNAL consistently produced patterns very similar to the patterns of Bray-Curtis similarity. Number of EPT families was also similar to community similarity in spring, but was less similar in autumn. Patterns of O/E scores for the ten AUSRIVAS models were very variable and in all cases strongly dissimilar to patterns of community composition and the dominant environmental gradient.

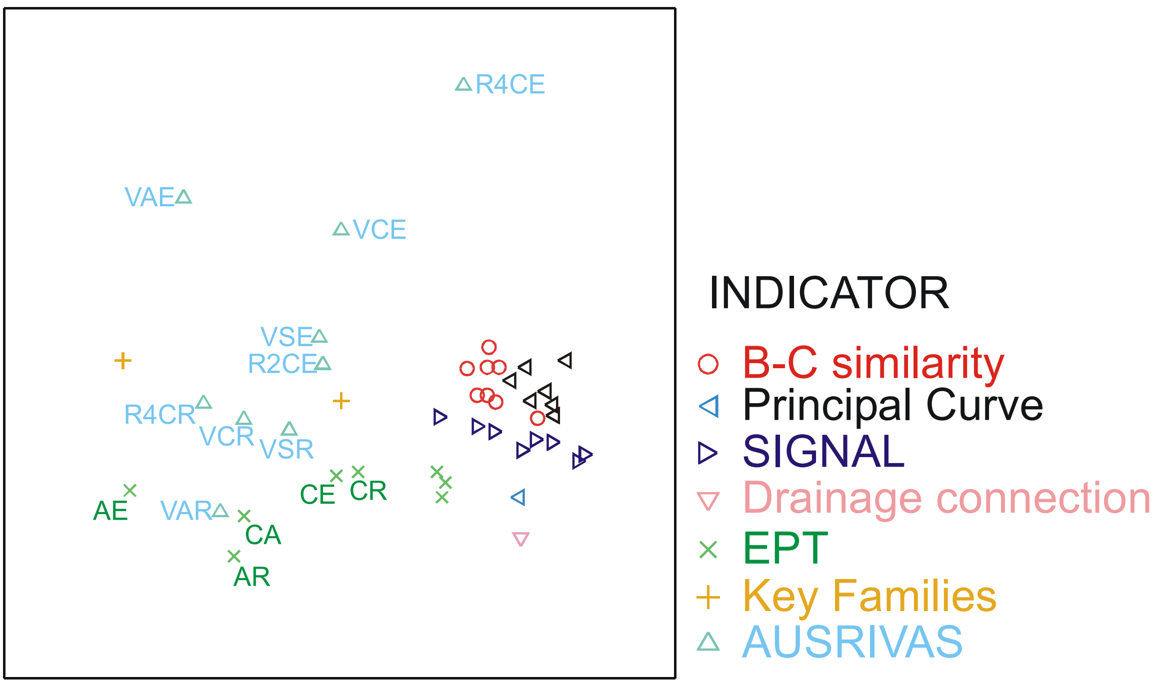

Fig. 6. NMDS ordination of similarity matrices for 16 sites based on Bray-Curtis similarity of macroinvertebrate presence-absence data, and Euclidean distance of each univariate indicator used in the study.

4.3. Possible reasons for the poor performance of AUSRIVAS models in the MW area.

The spread of reference sites used to build AUSRIVAS models for Victoria may have under-represented the region on the eastern fringe of Melbourne. If this is the case and if the stream fauna of the Dandenong Ranges and surrounding areas are distinctly different from areas more comprehensively covered by the Victorian and region 4 and region 2 models, then this may explain the abberant results for the sixteen sites.

However, the findings of this study correspond to those of Perriss (2002), who found many sites in the Mitchell, Tambo and Nicholson catchments to be classed as degraded using SIGNAL, while being classed as band A or B using AUSRIVAS models.

Recommendation 5: It is recommended that a similar comparative study of biological indicators across a known disturbance gradient be conducted for sites in the north or west of the Melbourne Water area. This will assess if the observed poor performance of AUSRIVAS models applies across the entire MW region.

A basic tenet of the modelling approach behind AUSRIVAS and similar models is that environmental predictor variables used to predict which taxa should occur at a site in the absence of environmental stress should be little affected by human activities (Simpson & Norris, 2000; Wright et al., 1984). However, all Victorian models use environmental predictor variables that are demonstrably affected by human impacts. Arguably 15 of the 25 variables used by the ten AUSRIVAS models applicable to the MW region violate this requirement.

Alkalinity, a measure of the concentration of basic ions used in about two-thirds of AUSRIVAS models in Australia (Simpson & Norris, 2000), is strongly affected by CO_2 concentrations. Increase in respiration in streams, an emerging indicator of stream degradation (Bunn et al., 1999), is therefore likely to cause an increase in alkalinity. Among the sixteen streams studied here, with similar catchment size, geology, geomorphology and climate, alkalinity is highly correlated with stormwater drainage connection (Fig. 7). This trend is likely to be caused by a combination of the increased conductivity (and therefore a likely increase in bicarbonate ion concentration) and levels of benthic algal biomass associated with increased stormwater runoff (Catford, 2002).

Land clearance and urban land use result in changes to stream substratum composition (e.g. Thoms & Thiel, 1995). Specifically, the increased runoff from stormwater results in increased channel incision resulting in channel widening, and transport of sediment (e.g. Neller, 1989). A further change associated with substratum composition in urban environments is the common practice of channel stabilization using boulders. All of these effects make the choice of the following variables as predictors for AUSRIVAS models questionable: Bedrock, Gravel, Pebble, Boulder, Cobble, Pebble, ReachPHI, RifflePHI, substrate heterogeneity and stream width.

As a direct result of channel widening, shading (another predictor variable) is also likely to be correlated with catchment urban impacts. Macrophyte taxon richness is also likely to be affected (although models using this variable are currently being reviewed).

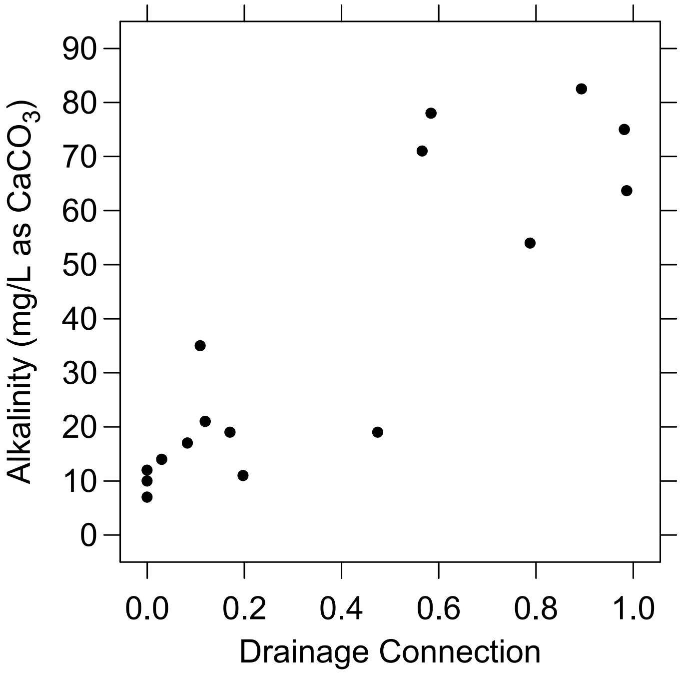

Fig. 7. Mean alkalinity vs Stormwater drainage connection (proportion of impervious areas in catchment directly connected to the stream by stormwater pipes)

Finally, VEGCAT is a direct measure of human impact at the catchment scale. It is a predictor variable in five of the ten models used in this study.

The likely effect of using such human-affected variables to build AUSRIVAS models is that some level of human disturbance is likely to be inherent in the models. It could thus be expected that such models will be insensitive to moderate levels of degradation.

Recommendation 6: MW encourage the builders of the Victorian AUSRIVAS models review their choice of environmental predictor variables, and assess the relative performance of models that use only variables that are unambiguously unaffected by human impact.

4.4. Appropriate Biological indicators for the MW region

Current AUSRIVAS models are insensitive to disturbance at least in small streams in the east of Melbourne. Other variables required by the various SEPPs (Number of families, number of key families) are also insensitive to gradients of disturbance in these streams.

SIGNAL and number of EPT families both produced patterns that were broadly consistent with the putative urban disturbance gradient and with multivariate community composition. Proposed research in the CRCs for Freshwater Ecology and Catchment Hydrology aim to produce predictive models of community composition in response to urban stormwater management that will result in a new index based on compositional similarity.

Recommendation 7: Until the problems with AUSRIVAS models in the MW region are resolved, we recommend that MW rely primarily on SIGNAL scores and secondarily on EPT family richness for biological assessment of stream condition using macroinvertebrates. Where other indicators must be included in SEPP reporting, their lack of sensitivity should be noted.

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