

Temporal variability of macroinvertebrate communities in Australian streams:

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Implications for the prediction and detection of environmental change

by

Chris Humphrey (Principal Investigator)

Environmental Research Institute of the Supervising Scientist, Locked Bag 2, Jabiru, NT 0886.

FINAL REPORT TO

LAND AND WATER RESOURCES RESEARCH AND DEVELOPMENT CORPORATION (Reference No. ARR1)

December 1997

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LWRRDC Final Report

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Project ARR1

Project title: Temporal variability of macroinvertebrate communities in Australian streams (Implications for the prediction and detection of environmental change)

Principal investigators: Dr Chris Humphrey, eriss

Date of submission: December 1997

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Abstract

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The degree and extent of temporal variability of stream macroinvertebrate communities have been investigated across a broad cross-section of climatic/hydrological regimes in Australia. Constancy or persistence of macroinvertebrate communities was found to be significantly and positively correlated with permanence of stream flow, and negatively correlated with interannual variability of annual stream discharge. There was a tendency (only) for macroinvertebrate communities of permanent streams in temperate Australia to be more persistent than those in tropical regions. Temporal variability is believed to have most potential to limit AUSRIVAS sensitivity and to result in greater model output failures for sites in northern Australia (QLD inclusive) and possibly for sites in drought-prone portions of warm-temperate, eastern Australia. Drought in eastern Australia and major disturbance arising from cyclones in northern Australia appear to be the major contributors to high temporal variability of macroinvertebrate communities.

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Whilst a preliminary study was undertaken to determine the consequences to model development (classification) of temporal variability, a more complete sensitivity analysis is required in future MRHI R&D to determine the full implications of collective error and variability (at various spatial scales) for model sensitivity. This analysis would include the determination of the sizes of various sources of error and variation and their effects on the rates of misclassification to quality bands. Data on temporal variability arising from the current study will provide an important information base upon which such an assessment can proceed. Future R&D needs that will assist in this 'sensitivity analysis' have been identified in the report and attachments.

The study formulated a number of approaches to pursue in relation to temporal variability and predictive modelling. This included approaches for assessing implications for predictive model sensitivity arising from temporal variability, as well as approaches that might be used to account for such variability, ie: (i) contextual data for assessing the severity of temporal variability, (ii) modelling temporal variability, (iii) adjusting and updating model output, (iv) models for different climatic conditions, and (v) combined-seasons or -years models.

Whilst at this stage the extent to which high temporal variability may compromise the sensitivity of predictive models is not known, the ability to reliably identify and predict different geographical regions and stream types susceptible to high temporal variability are in themselves informative and valuable for management. The magnitude of persistence indices calculated in this study and modelled according to different regions and stream types, may eventually be related to some measure of AUSRIVAS model 'noise' and variability and, consequently, to poor model predictions. With quantified degrees of 'risk' of model failure, researchers and managers might then be better informed and placed to account for such variability, stipulate error and probability statements around predictions, or recommend alternative monitoring approaches.

Temporal variability of macroinvertebrate communities in Australian streams:

Implications for the prediction and detection of environmental change

Final report to LWRRDC

1 Introduction

In 1993 the Commonwealth of Australia funded the 'National River Health Program' (NRHP) to monitor and assess the health of the nation's rivers and streams (Schofield & Davies 1996). Part of this program is the 'Monitoring River Health Initiative' (MRHI), involving government agencies from all Australian States and Territories in a national program to develop a standardised and coordinated rapid bioassessment approach to biological monitoring of water quality in Australian streams and rivers.

The River InVertebrate Prediction And Classification System (RIVPACS; Wright 1995) was adopted as a national framework for the Australian program. Models were to be based on family-level identifications of macroinvertebrates collected by habitat-specific kick-sweep sampling at an initial 1400 reference sites sampled across Australia in representative seasons (Schofield & Davies 1996). A full description of the program as developed to 1997, AUSRIVAS (AUStralian RIVer Assessment Scheme), is provided by Davies (In draft).

It was recognised early in the development of the MRHI that sample processing error and temporal variability in community composition and structure in a country of climatic extremes such as Australia, would probably pose the most serious risks to development of sensitive, predictive models for biological monitoring. The issue of temporal variability of macroinvertebrate communities and possible implications to successful model development were the subject of this study.

An assumption of predictive modelling is that macroinvertebrate community composition is reasonably constant over time. Surprisingly, temporal variability has gained little consideration during development of RIVPACS. Clarke et al (1996) considered temporal variability as a factor when identifying the sources of uncertainty for RIVPACS, but only as a potential source of error for the 'observed' fauna and not the 'expected' fauna. This is despite the fact that the reference site data base for RIVPACS has accumulated through addition of data for different sites over time (1977-1995) (Wright 1995). The degree of possible variability arising from natural changes in macroinvertebrate community composition over this period and the effect of this, if any, upon model construction has not been reported. Weatherley and Ormerod (1990) quantified the degree of temporal variability evident in Welsh streams over a 5-year period and concluded that this would be too slight to adversely affect development of predictive models. Wright (1995), however, implied that temporal variability of small temporary streams in the UK might be sufficient to be of concern in this respect.

This report and attachments describe results of a broad-scale program that was conducted to quantify the degree of temporal variability evident in long-term data sets from representative streams across Australia. Where lack of 'persistence' is observed, a longer term aim, preliminary steps of which have been taken for one data set, is to explore the implications of the result for model sensitivity by assessing the degree of fidelity of long-term data in groups

- derived from current AUSRIVAS classifications. Some possible ways to account for temporal variability are also raised for discussion. Full implications of temporal variability for modelling will be the subject of more detailed R&D to be commissioned under the second phase of the program.
- The project objectives were to:
 - 1. access long-term data sets from suitable reference streams across Australia; for some of these sites, sampling or sample processing was to be extended so that data sets were sufficiently 'long-term' in nature;
 - 2. measure 'persistence' of macroinvertebrate community structure for these data sets using appropriate statistical analyses of the data;

Where lack of persistence was observed:

- 3. explore the implications of the result by assessing whether the anomalous data classify near or together with those from related disturbed sites;
- 4. seek environmental correlates that may account for any year-to-year variation in community structure and input these variables to the MRHI predictive models; and
- 5. make appropriate recommendations according to different climatic/hydrological regions of Australia.

2 Methods

Objectives 1 - 5 are reported in the following sections under the broader collective aims, and in the logical order:

- access long-term data sets from suitable reference streams and measure 'persistence' of macroinvertebrate community structure;
- where lack of persistence is observed, explore the implications of the result by assessing whether the anomalous data classify near or together with those from related disturbed sites; and
- evaluate possible ways to account for temporal variability and make appropriate recommendations according to different climatic/ hydrological regions of Australia.

A brief description of methods used for the study components follows.

2.1 Measure 'persistence' of macroinvertebrate community structure from long-term data sets

Data from a number of researchers across Australia were compiled to quantify the degree of temporal variability of stream macroinvertebrate communities (Humphrey et al. 1997b). Ten geographical regions, 15 catchments and 38 individual sites were represented. The average duration of the data sets was approximately 6 years, with some data sets extending to 10 years. Sites were located in streams of permanent and seasonal flow and for all but one data set, samples were collected from riffle habitat only.

Temporal variability was expressed in terms of an index of 'Inconstancy', determined for each site and season as the proportion of interannual comparisons of community composition (presence/absence) and structure (rank abundance) for which Bray-Curtis dissimilarity measures (family level identifications) exceeded pre-determined thresholds. As dissimilarity measures are the basis of UPGMA classification of MRHI data for model development, these were potentially best suited to quantifying the degree of temporal variability inherent in a data set.

2.2 Implications of lack of persistence for classification

Where lack of persistence of macroinvertebrate communities was observed in a long-term data set, an objective of the current project was to explore the implications of the results for MRH predictive modelling by assessing the degree of temporal variability in reference sites relative to classifications of related impacted sites. Using long-term data from the upper South Alligator River (SAR) (Humphrey et al 1995a, 1997a), Humphrey et al (1995b) explored the implications of a marked switch in structure of macroinvertebrate communities (rank abundances) that occurred between pre-1993 and post-1992 time periods, by assessing whether the post-1992 data classified near or together with those from both unpolluted/mine-polluted portions of the adjacent Rockhole Mine Creek.

The ultimate test of whether or not temporal variability presents problems for predictive modelling lies in running long-term community compositional data for particular sites, such as those from the SAR, through agency classifications and models. In this context the severity or otherwise of any lack of community persistence can be fully measured. Misclassifications and poor predictions would indicate potential problems for model development. To this end, the same long-term SAR data (but this time using presence-absence data) were incorporated into an NT MRHI agency classification based upon riffle samples gathered throughout the NT.

2.3 Evaluate ways to account for temporal variability and make recommendations

It became evident through the course of this study that seeking environmental correlates that may account for temporal variability would be unlikely to be successful for many of the data sets for which 'high' temporal variability was found. Whilst the reasons for this are reviewed below (section 3.3) and in the attachments, no active research was conducted on this issue.

3 Results

In the following sections, a summary of results, their interpretation, practical significance and a comparison of results against project objectives, are provided.

3.1 Measure 'persistence' of macroinvertebrate community structure from long-term data sets

Degree and extent of temporal variability: rank abundance data

For half of the catchments studied, over 30% of interannual comparisons exceeded a Bray-Curtis dissimilarity value of 0.5 (Humphrey et al 1997b). Only for a relatively small portion of southern Australia, for which interannual variability of discharge is low - Tasmania, southwest WA and possibly parts of Victoria - would there appear to be potential for development of AUSRIVAS models based upon rank abundance data. Given this restriction and the fact that current AUSRIVAS models use compositional data, the rest of the discussion focuses on results using presence-absence data.

Degree and extent of temporal variability: presence-absence data

For 7 of the 10 regions studied for which two seasons of data were available, interannual variation was greatest following seasonal flooding (Humphrey et al 1997b). For 2 northern Australian streams, interannual variation was greatest at the end of the Dry season, attributable to changes in community composition as a result of low flow conditions and drought.

A combined-seasons index was derived by averaging the Inconstancy index across seasons for presence-absence data. Regression analysis was used to seek relationships between dependant Inconstancy index and independent environmental variables. The best predictive relationship was a bivariate equation derived between the Inconstancy index variable and independent variables, Coefficient of Variation of annual flow and flow status (permanent/seasonally-flowing) ($R^2 = 0.77$). Latitude was found to be only weakly (and negatively) correlated with inconstancy (Humphrey et al 1997b).

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Three summary points may be made from the results of Humphrey et al (1997b) and from regression analysis. (The term 'persistence', the converse of 'inconstancy', is used to describe the degree of similarity in community composition over time):

1. (a) A high negative correlation is observed between persistence, and interannual variation of stream discharge.

(b) Persistence of macroinvertebrate communities is significantly higher in streams of permanent flow than in streams of seasonal flow. (For seasonally-flowing streams that dry out considerably, lower persistence is possibly related to the stochastic nature of recolonisation of the fauna following re-wetting.)

(c) There is a tendency (only) for macroinvertebrate communities of permanent streams in temperate Australia to be more persistent than those in tropical regions. (Apart from greater seasonal extremes in discharge, this may also relate to the shorter life cycles of tropical invertebrates; more dynamic, short-term response to disturbance might be expected from these assemblages.)

- 2. For the limited data available, macroinvertebrate communities from riffle habitat appear to be more persistent than those from other habitats, even at the same sites of permanent flow.
- 3. Measures of temporal variability used in the study (family-level, presence-absence data) and averaged across the seasons indicated relatively high persistence of macroinvertebrate communities for all but one or two regions represented. For regions exhibiting high Inconstancy index values, cyclonic disturbance and flooding were attributed as the cause (Humphrey et al. 1997b). Nevertheless, whilst temporal variability of macroinvertebrate communities may be high in only one or two regions represented in this study, these regions represent a large portion of the continent. In particular, Humphrey et al. (1997b) extrapolated the findings to suggest that the sensitivity of AUSRIVAS models developed for much of the drought-prone portion of eastern Australia, particularly NSW and QLD, could be compromised during (and possibly after) drought periods.

3.2 Implications of lack of persistence for classification

From ordinations that were conducted using SAR data, post-1992/pre-1993, and data from both unpolluted/mine-polluted portions of the adjacent Rockhole Mine Creek (RMC), Humphrey et al (1995b) showed that the magnitude of change occurring in the SAR post-1992 was even more severe than that occurring in polluted portions of RMC. Moreover, the direction of change occurring in the SAR data was in the same direction as the pollution gradient in RMC.

The limitations of the approach described above to MRHI modelling are twofold: Firstly, the analysis for SAR-RMC was based upon family-level abundance data. The analysis has not been repeated using presence-absence data but if this was performed it would probably indicate little change in SAR community composition between post-1992 and pre-1993 relative to that between the two RMC sites. Secondly and as described above, the ultimate test of whether or not temporal variability presents problems for predictive modelling lies in running long-term community compositional data for particular sites, such as those from the SAR, through agency classifications and models.

Humphrey and Doig (1997) describe results of a classification incorporating long-term SAR data into an NT MRHI agency classification based upon riffle samples. Results showed misclassification of early (1988) SAR data in a UPGMA classification based upon late Dry

season 1994 and 1995 NT riffle data, whilst for successive years of data (1994 and 1995), about 50% of the 15 comparable sites occurred in different classification groups. However, because of the low interannual pairwise dissimilarity, low inter-site dissimilarity generally, and the fact that the classification was based on few sites (less than 25), no obvious conclusions could be drawn from the study. Despite this, the full implications of any lack of temporal variability present in other long-term data from elsewhere for agency model development, accuracy and precision, will require similar approaches to that used for NT data.

3.3 Evaluate ways to account for temporal variability and make recommendations

As described above, the most appropriate test of whether or not temporal variability presents problems for predictive modelling lies in running long-term community compositional data for particular sites through agency classifications and models. In this context the severity or otherwise of any lack of community persistence - within the bounds of sensitivity of the models - can be fully measured. (Misclassifications and poor predictions would indicate potential problems for model development.) Possible approaches to dealing with temporal variability of macroinvertebrate communities include:

(1) Risk-based assessment using AUSRIVAS models

As either an interim or definitive step, predictive regression relationships between temporal variability and environmental variables as described above, may be used to quantify degrees of 'risk' of model failure for a particular location. This would give managers at least, some indication of how useful and accurate models might be that are developed for a particular location, ie what degree of error could be associated with predictions if temporal variability was the sole factor of concern.

(2) Accounting for temporal variability

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As an improvement upon (1), can temporal variability be accounted for?

(i) Modelling temporal variability

Humphrey et al (1997b) concluded that seeking environmental correlates that may account for temporal variability would be unlikely to be successful for a number of situations: (i) seasonally-flowing streams where shifts in community composition over time may be associated with stochastic recolonisation processes (see also Wright 1995); (ii) longer-term (several years) recovery and recolonisation of streams following massive disturbance (eg Robe R, north-west WA); and (iii) switches between different community 'steady states' where triggers for the switch may be clearly identified, but the trajectory of community composition thereafter is either lagged, or unknown and unpredictable (eg SAR and Yuccabine Ck, north-east QLD; see also Boulton & Lake 1992). Associated with these difficulties is the possibility of inter-catchment differences in community responses, as described for the South Alligator R and Magela Ck (NT) in Humphrey & Doig (1997).

Modelling of drought-related changes to macroinvertebrate communities would be particularly useful for AUSRIVAS model development in eastern Australia. However, there is presently little understanding of the responses of macroinvertebrate communities to drought, including how responsive the fauna is to environmental change. Moreover, Humphrey et al. (1997) reported very different responses to drought across Australia at regional and inter- and intra-catchment scales. Examination of existing agency data sets, some of which span periods of major drought (eg QLD, 1994-1995) would assist in redressing these information deficiencies.

(ii) Adjusting and updating model output

This would entail the re-sampling of suitable reference sites simultaneously in time with monitoring sites in order to adjust model output by some factor. A problem with this approach is that it assumes the 'scaling' or 'correction' factor is similar across classification groups and between reference and disturbed sites. This assumption is unlikely to hold because, as described in (i) above, macroinvertebrate community response to a similar disturbance is likely to differ at different spatial scales. In addition, the degree of change to natural disturbance is likely to be greater for reference sites than for anthropogenicallydisturbed sites. Hence there would be a need to include sufficient reference sites that were representative of each of the classification groups, as well as a need to incorporate resampling of selected disturbed sites, in order to derive appropriate scaling factors.

(iii) Models for different climatic conditions (especially drought vs non-drought)

Models empirically derived for different climatic conditions, such as drought vs non-drought, would have the advantage that fewer assumptions are made about the responses of macroinvertebrate communities in different habitats, between different parts of a catchment, amongst catchments, or across a disturbance gradient. The disadvantage in this approach is one of expense, whilst the (untested) assumption is made that responses to one drought will be the same as the next, even though droughts differ in their intensity. At best, interpolation and extrapolation between different models may enable some allowance to be made for different climatic conditions. Nevertheless, some of the current agency data sets span a period of 'drought' and 'non-drought'; processing of all these data and derivation of different models for different climatic conditions may be exceedingly valuable.

(iv) Combined-seasons/years models

There is little doubt that temporal variability would be reduced substantially with an approach in which data for different seasons of the year or consecutive years for the same season were combined. One disadvantage with this approach is the need to accumulate two seasons/years of data before an assessment of water quality based upon macroinvertebrate communities can be made. Although this may provide some indication of longer-term severity of a water quality problem, it is contrary to the ethos of rapid biological assessment and rapid turnaround of results. Another disadvantage of this approach may lie in construction of a model so robust and overly-inured to natural environmental change that only impacts of a particularly severe nature are detected whilst impacts isolated to only one of the seasons may pass undetected.

Related to approaches (iii) and (iv), some agencies have constructed models by adding new reference sites gathered for a given season and from consecutive years of sampling, to an existing model (eg UK RIVPACS, MRHI ACT agency). Without simultaneous sampling of some common reference sites to account for possible temporal variation, this approach runs the risk of deriving models that are temporally confounded.

Some combination of approaches (ii) and (iii) may provide adequate solutions to developing AUSRIVAS models that account for temporal variability. For some geographical regions, temporal variability may be too large for useful predictive models to be developed. For these situations, it it may be necessary to resort to more traditional hypothesis-testing approaches involving BACl designs and derivatives (Underwood 1991, Faith et al 1995, Keough & Mapstone 1995).

4 Adoption of results

Communication for this project has focused on reporting of progress at NRHP technical advisory and steering committee meetings, annual MRHI workshops (Canberra), feedback on milestone reports sent to a number of researchers from across Australia and two conference presentations (Aust Soc Limnology, Jenolan Caves 1995; RIVPACS International Workshop, Oxford 1997).

The results of the project have been discussed with the national NRHP coordinator, Dr Peter

Davies, who has indicated his support in forwarding a number of recommendations arising from this report and attachments to the NRHP committee for further R&D funding. Further communication with the national coordinator is required to decide on how results might be adopted. Some of the findings have been reported in the draft National Water Quality Management Strategy (NWQMS) Water Quality Guidelines (ie guidance to users on geographical regions for which model failures might be expected to be relatively high as a consequence of temporal variability). These caveats should also appear on the AUSRIVAS web page.

5 Publication titles

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Apart from milestone and final reports to LWRRDC listed in section 7 below, one external publication has been prepared from the work conducted in this project:

Humphrey CL, Storey AW & Thurtell L In draft. AUSRIVAS - operator sample processing errors and temporal variability: implications for model sensitivity. Proceedings of International RIVPACS Workshop, 16-18 September 1995, Jesus College, Oxford, Organised and funded by Institute of Freshwater Ecology and Environment Agency (UK) and the Land and Water Resources Research and Development Corporation (Australia).

6 Additional information

Recommendations as to future needs for R&D are summarised in Humphrey et al (1997). Additional information can be obtained in the milestone and final reports to LWRRDC listed in section 7 below, or by contacting the author directly.

Acknowledgments

This project was jointly funded by the Commonwealth Environment, and Primary Industry and Energy Departments through the Land and Water Resources Research and Development Corporation. Numerous staff and volunteers of *eriss* assisted throughout the project; these individuals are listed as co-authors of cited reports or duly acknowledged within these reports. I thank Robyn Graham, Daryl Lehmann and their staff of *eriss* for managing the finances of the project.

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Additional uncited milestone report

Humphrey C, Doig L, Macfarlane W, Galbreath R & Masiero M 1997. Degree of temporal variability of macroinvertebrate communities in Australian streams. In: *Temporal* variability of macroinvertebrate communities in Australian streams, by CL Humphrey. Milestone Report 2 to Land and Water Resources Research and Development Corporation (Reference No. ARR1), August 1997.

ATTACHMENT 1

واليرواج لمقامر لحرافته فالمتاذ والمتادية والجلي المتراسين

Degree of temporal variability of macroinvertebrate communities in Australian streams

FINAL REPORT

by

Chris Humphrey¹, Andrew Storey² & Lorne Doig¹ ¹ERISS, Locked Bag 2, Jabiru, NT 0886; ²Department of Zoology, The University of Western Australia, Nedlands, WA 6907, Australia.

December 1997

Summary and recommendations

- 1. The degree and geographical extent of temporal variability of macroinvertebrate communities in Australian streams have been quantified and modelled for family-level data according to simple measures of flow regime and flow variability characteristics. Constancy or persistence of macroinvertebrate communities was found to be significantly and positively correlated with permanence of stream flow, and negatively correlated with interannual variability of annual stream discharge. There was a tendency (only) for macroinvertebrate communities of permanent streams in temperate Australia to be more persistent than those in tropical regions.
- 2. Temporal variability has most potential to limit AUSRIVAS sensitivity and to result in greater model output failures for sites in northern Australia (QLD inclusive) and possibly for sites in drought-prone portions of warm-temperate, eastern Australia. Drought in eastern Australia and major disturbance arising from cyclones in northern Australia appear to be the major contributors to high temporal variability of macroinvertebrate communities. The effects of cyclonic disturbance, as observed in data sets from northeast QLD and particularly for north-west WA where incidence of cyclones is the highest in Australia, may persist for several years.
- 3. For future sampling by MRHI agencies, a selection of reference sites *and* disturbed sites should be re-sampled with the aim of using data from these to adjust and update models as a consequence of temporal variability. Guiding principles governing choice of reference sites for selection are presented.
- 4. Further R&D studies are required to:

i) Assess the implications for model development of temporal variability by running longterm data (or agency data from consecutive years) through existing agency models. This would include the development of statements of risk of predictive failures that may apply to different regions across Australia as a consequence of temporal variability.

ii) Quantify the degree and extent of temporal variability of macroinvertebrate communities for habitat other than riffle. Repeat issue i) for each of these habitats;

iii) Assess the degree of uniformity of macroinvertebrate community response to disturbance (especially drought) and recovery from disturbance, at various catchment scales, from between- (adjacent) catchments to amongst all catchments for which data are incorporated into a single regional model.

iv) Assess the degree to which macroinvertebrate community change (especially taxa loss) for sites across a gradient of anthropogenic disturbance varies under drought vs non-drought conditions.

v) Extend and initiate long-term data bases generally so that persistence for a greater number of locations can be determined and better predicted.

vi) Assess whether temporal variability between consecutive years is sufficient to compromise the precision of models constructed from the regular addition of reference sites through time.

vii) Assess the degree to which combined-seasons/years models result in loss of sensitivity to detection of impact.

viii) Incorporate the above in an overall analysis of sensitivity of AUSRIVAS models. This would include estimating errors in 'observed' and 'expected' taxa as a consequence of natural temporal variability.

ix) Make appropriate recommendations according to different climatic/hydrological regions of Australia.

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Degree of temporal variability of macroinvertebrate communities in Australian streams

1 Background

Long-term data sets have many virtues. One valuable attribute is in the ability to test assumptions behind broad-scale models for monitoring. For predictive models such as those employed for AUSRIVAS, there is a key assumption concerning the constancy of community composition over time. If this constancy or persistence is not observed and if changes in communities from year to year cannot be accounted for using environmental data, then the models may fail in their classifications and predictions of invertebrate community composition.

It is well known that the degree of environmental variation in streams can affect the persistence of invertebrate communities, i.e. the tendency for community composition or structure to remain unchanged (see review of Hildrew & Giller 1992). It is surprising, therefore, that temporal variability has received very little attention during development of RIVPACS in the UK. Nevertheless, studies conducted by a number of British workers indicate that the degree of temporal variability evident in long-term macroinvertebrate data from UK streams would probably be too slight to adversely affect development of predictive models, based on the concordance of site classification (Townsend et al. 1987, Weatherley & Ormerod 1990). Wright (1995), however, cautioned that temporal variability of macroinvertebrate communities of small temporary streams in the UK might be sufficient to be of concern in this respect.

By world standards, Australian streams have low discharges and considerable variability in flow (see review of Lake 1995). Given the vicissitudes of stream flow patterns in Australia, therefore, temporal variability of stream macroinvertebrate communities is an issue that needs to be closely investigated in relation to development of impact assessment models based on predictive modelling.

In 1993, the *eriss* was commissioned by the Land and Water Resources Research and Development Corporation (LWRRDC), on behalf of the DEST-funded, national Monitoring River Health Initiative (MRHI), to conduct further sampling and sample processing (if necessary), and data compilation of macroinvertebrate communities in Australian streams. This R&D project would determine the degree of temporal variability evident in these long-term data sets and enable a preliminary assessment of the implications of the results for predictive modelling being developed as part of the MRHI. Specific objectives of the project included:

- 1. Access long-term data sets from suitable reference streams across Australia. For some of these sites, sampling or sample processing will need to be extended so that data sets are sufficiently 'long-term' in nature.
- 2. With these data sets, measure 'persistence' of macroinvertebrate community structure using appropriate statistical analyses of the data.

Where lack of persistence is observed:

- 3. Explore the implications of the result by assessing whether the anomalous data classify near or together with those from related disturbed sites.
- 4. Seek environmental correlates that may account for any year-to-year variation in community structure and input these variables to the MRHI predictive models.
- 5. Make appropriate recommendations according to different climatic/hydrological regions of Australia.

A number of custodians of long-term data sets across Australia provided, or were subcontracted by *eriss* to extend sampling and to provide, long-term data for analysis. Data were to be derived from relatively undisturbed (reference) sites that had been sampled continuously over time or in a disjunct and interrupted fashion. Custodians for respective geographical regions were:

- Dr Peter Davies, University of WA (dry tropical data, WA);
- Dr Chris Humphrey, Environmental Research Institute of the Supervising Scientist (wet-dry tropical data, NT);
- Assoc. Prof. Richard Pearson, Centre for Tropical Freshwater Research, JCU (wet tropical data, QLD);
- Prof. Angela Arthington, Centre for Catchment and In-stream Research, Griffith Uni (sub-tropical data, QLD);
- Dr Satish Choy, Water Resources Centre, QLD Dept Natural Resources (sub-tropical data, QLD);
- Assoc. Prof. Richard Norris, CRC Freshwater Ecology, Canberra Uni (sub-alpine data, NSW);
- Mr Leon Metzeling, VIC EPA & Dr Richard Marchant (temperate data, VIC);
- Dr Peter Davies, Freshwater Systems/University of TAS (temperate data, TAS);
- Dr Andrew Boulton, University of New England (semi-arid data, SA); and
- Dr Andrew Storey, University of WA (temperate data, south-west WA).

No additional sampling under this project was conducted in the Pilbara region of WA (dry tropics), south-west WA, Thredbo River in (sub-alpine) NSW and Wet tropics, and custodians of data sets from these regions provided data for no charge. The results presented in this report meet objectives 1, 2 and 5 from above, and provide information upon which to assess the feasibility of objective 4 for future R&D. Results are also used elsewhere in a preliminary assessment of the implications of temporal variability for MRHI predictive modelling (ie objective 3 from above; Humphrey & Doig 1997). Analyses for quantifying temporal variability comprise, for each season separately, pairwise, year-to-year comparisons of macroinvertebrate structure and composition by way of multivariate (dis)similarity measures.

Two terms are used in this report to define the degree of temporal variability of macroinvertebrate communities over time. Thus, the terms 'persistence' and 'inconstancy' are used in relation to describing the degree to which macroinvertebrate community composition or structure remains unchanged over time. Greater persistence (or constancy) and inconstancy are observed for those communities where higher and lower pairwise, interannual similarity in composition or structure are found, respectively.

2. Study sites and data analysis procedures

2.1 Location of study sites and data-set custodian

Data from 10 geographical regions representing 15 catchments and 38 individual sites were compiled for analysis of temporal variability (Table 1). (Rockhole Mine Ck, NT, is a small tributary of the South Alligator River.) The extent of permanence of stream flow and of surface water availability at the sites are indicated in Table 1.

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Table 1. Source of data for	use in analysis of persistence	of stream macroinvertebrate	communities in
relation to flow regime.			

Region	Catchment	Flow regime	No. of sites
Dry tropical (Pilbara, WA)	Robe R	Seasonal (permanent pools)	1
Wet-dry tropical (Alligator	South Alligator R	Permanent	3
Rivers Region, NT)	Rockhole Mine Ck	Seasonal (little or no surface water by end of dry season)	1
	Magela Ck	As per Rockhole Mine Ck	2
Wet tropical (NE QLD)	Yuccabine Ck	Permanent	1
Subtropical (SE QLD)	Barker-Barambah Cks	Permanent	2
	Stony Ck	Permanent	2
Sub-alpine (Snowy Mountains, SE NSW)	Thredbo R	Permanent	1
Temperate mild & semi-arid	Latrobe R	Permanent	9
(coastal [LR] and inland [WR] VIC)	Wimmera R	Seasonal	2
Temperate cool (TAS)	Musselboro-Coquet Cks	Permanent	2
Temperate semi-arid (Flinders	Brachina Ck	Permanent	1
Ranges, SA)	Oratunga Ck	Permanent	1
Temperate mild (south-west WA)	Canning R	Seasonal (little or no surface water by end of summer 'dry season') & one permanent site	6
	North Dandalup R	Permanent	4

Details of the sites sampled are as follows:

Dry tropics (Pilbara, WA)

Robe River. Data were derived from one site, Gnieraoora Pool, located on the Robe River at 116 10' 12" E, 21 43' 58" S. Flow through the permanent riverine pools of Pilbara streams occurs for about one to three months in the summer wet season of each year (P Davies pers. comm.).

Wet-dry tropics (Alligator Rivers Region, NT)

South Alligator River. Data analysis was for three sites located on the upper, perenniallyflowing section of the South Alligator River. Sites were 1, 5 and 8 of Humphrey et al (1997); this report provides detailed locality data. Whilst flow is permanent, it is highly seasonal, recessional flows occurring from May-October following the intense summer wet season.

Rockhole Mine Ck. This is a small third-order tributary of the upper South Alligator River. The lower reaches of Rockhole Mine Ck (RMC) are polluted by acid mine drainage emanating from an abandoned mine adit. A series of experimental manipulations have been conducted in the stream to (i) assess the efficacy of particular design and analysis approaches to biological monitoring programs using macroinvertebrate communities (Faith et al 1992, 1995) and (ii) examine the recovery of the macroinvertebrate fauna following removal of the contaminant source (Sinith 1994). Data from an unpolluted site well upstream of the mine adit were analysed in this study. RMC is seasonally-flowing and for several months in the dry season of each year, there are no surface waters at the site for which data were derived for this study. The study site is described in detail in Dostine et al (1992), Smith (1994) and Faith et al (1992, 1995).

Magela Creek. This stream lies in the catchment of the East Alligator River. Data analysis was for two sites located on the seasonally-flowing portion of Magela Creek; one site was situated 1 km upstream of the Ranger Uranium Mine release pipe and the other 5-6 km downstream of the release pipe.

Wet tropical (North-east QLD)

Yuccabine Creek. This upland stream lies in the catchment of the Herbert River. Data for analysis were derived from a study site located at 18°12' S, 145°46' E. Further descriptions of the site can be found in Pearson et al (1986). Whilst flow is permanent, it is highly seasonal, flow between May-October being much reduced from that in the intense summer wet season.

Subtropical (South-east QLD)

Barker-Barambah Cks. Data from two sites on Barambah Ck, a tributary of the Burnett River in south-east QLD, were used for analysis. Sites are described in Arthington et al (1992) who designate the sites C8/M8 (Litzows) and C1/M1 (Ban Ban) (see section 4.3.1 and Map 6, p.448 of cited report). Grid references for the sites are $26^{\circ}18'$ S, $152^{\circ}03'$ E (Litzows) and $25^{\circ}43'$ S, $151^{\circ}48'$ E (Ban Ban).

Stony Creek. Two upland sites in this region were located on Stony Creek, a tributary of the Stanley and subsequently Brisbane Rivers in south-east Queensland. These streams are located in the Conondale Ranges. Site SC 3 was on the main Stony Creek while SC2 was on a small un-named tributary. Grid references for the sites are 26°52' 30" S, 152°43' 45" E (SC2) and 26°52' 42" S, 152°42' 45" E (SC3). This stream is nominally classed as one of permanent flow though drought conditions prevailing in the period 1995-96 meant that samples collected in Spring of 1996 were taken when there was negligible or no flow at either of the sites.

Sub-alpine (Snowy Mountains, SE NSW)

Thredbo R. Data from a site on the Thredbo River, located approximately 1 km upstream of the Thredbo township, were used for analysis. Flow in the Thredbo River is permanent, and peaks in spring in association with snow melt.

Temperate mild/temperate semi-arid (Victoria)

Latrobe River. This is a coastal drainage of southern Victoria. Data from 9 sites in the catchment were analysed for this study, 8 from the upper Latrobe and tributaries and one from the lower Latrobe. Upper Latrobe (ULT) sites are described in Metzeling et al (1984); these sites together with codes from these authors are:

Ada River at Ada River Road (ULT 4) Loch River, Loch River Road, 14 km from Noogee (ULT 6) Latrobe River at Hawthorn Bridge (ULT 15) Western Tanjil River at Saxtons (ULT 28) Middle Creek at Middle Creek Road (ULT 41) Western Tyers River at Christmas Creek Track (ULT 52) Middle Tyers River at Tyers Junction(ULT 53), and Traralgon Creek, 4.3 km from Grand Ridge Road (ULT 60).

The one lower Latrobe River site was Willow Grove (LLT1) (or site A, Willow Grove, described in Chessman and Robinson (1987)).

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Wimmera River. Located in semi-arid north-western Victoria, this stream rises in the Grampian Ranges eventually draining into Lakes Hindmarsh and Albacutya of the Mallee Region. Data from two sites on the Wimmera River were analysed in this study, one site (1) located 5 km upstream of Horsham and the other (site 4) 3 km downstream of Dimboola. Site descriptions are contained in Metzeling et al (1993, pp. 13-14).

Temperate cool (Tasmania)

Musselboro and Coquet Cks. These streams, located in north-eastern Tasmania, are part of the North Esk River catchment. Data from one site on Musselboro Ck (a tributary of the North Esk River) and another on Coquet Ck, a tributary of St Patricks River (which flows into the North Esk River), were analysed. Grid references for the sites from the 1:100 000 Tasmap "St Patricks" are: Coquet Ck 529300 E & 5420600 N, and Musselboro Ck 536200 E & 5411700 N.

Temperate semi-arid (Flinders Ranges, SA)

Brachina and Oratunga Cks. Data from a site on each of these permanent streams in the Flinders Ranges were analysed. Brachina and Oratunga Cks drain independently towards Lake Torrens, Brachina draining to the west whilst Oratunga located further north in the ranges joins the Parachilna system to drain to the west. The Brachina site is located at the junction of Brachina and Elatina Creeks, 500 m upstream of Brachina Gorge Road crossing. Grid reference for the site on the Oraparinna map (1: 50 000, 6635-3) is 31°20' S, 138° 36' E. The Oratunga site occurs 500 m upstream of the Glass Gorge road crossing of Parachilna Creek (before this road joins the Blinman-Parachilna Rd). Grid reference for the site on the Blinman map (1:50 000, 6653-IV) is 31°08' S, 138° 31' E.

Temperate mild (south-west WA)

Canning River. Data from five seasonally-flowing sites (CD1-CD5) and one site of permanent flow (CD6) in the upper Canning River catchment were analysed. Descriptions of the sites may be found in Storey et al (1990). The sites (and codes) are:

Kangaroo Gully (CD1) Death Adder Creek (CD2) Poison Gully (CD3) Canning River East (CD4) Canning River South (CD5), and 31 Mile Brook (CD6)

North Dandalup River. Data from four sites of permanent flow in the North Dandalup River catchment were analysed in this study. Descriptions of the sites may be found in Storey et al (1991). The sites (and codes) are:

Foster Brook (ND1) Finlay Brook (ND2) North Dandalup River (ND3), and Wilson Brook (ND4).

2.2 Description, extent and quality of long-term data for interannual comparisons

A summarised description of the sampling and sample processing methods adopted in each of the long-term studies is provided in Table 2. Unless indicated otherwise in the table, samples were preserved in the field for later subsampling and sorting in the laboratory.

The habitat sampled in each of the regional studies is provided in the respective tables summarising results of analyses for each data set (- see Appendix B, Tables B1-B12). If possible, two seasons were selected for analysis of temporal variability, Autumn and Spring - or corresponding early and late Dry seasons respectively for tropical northern Australia. These seasons were the same as those sampled by MRHI agencies. Other seasons were selected if these aforementioned seasons were unavailable or if a much longer time series was available for another season.

Table 2	. Sampling and	sample processir	ig methods adopte	ed in each of th	ne long-term s	studies according
to year of	of sampling.					

Region	Catchment	Years/ sampling and sample processing procedures per site, per habitat and per sampling occasion
Dry tropical (Pilbara, WA)	Robe R	1991-96: Dip net sampling (composite combined-habitat sample), quantitative laboratory sample processing; 250 μm mesh
Wet-dry tropical (Alligator	South Alligator R	1987-96: 4 x 0.063 m ² Surber samples; 500 μm mesh.
Rivers Region, NI)	Rockhole Mine Ck	1991-96: 10 x artificial substrates; 500 μm mesh.
	Magela Ck	1988, 90-93: 5 x 0.063 m ² Surber samples; 500 μm mesh 1994: 5 x 0.04 m ² Boulton suction samples; 500 μm mesh 1995-96: 3 x 0.5 m ² dip net, with 'quantitative' live-sorting; 500 μm mesh
Wet tropical (NE QLD)	Yuccabine Ck	1981-95: 20 x 0.063 m^2 kick net samples; 400 μm mesh
Subtropical (SE QLD)	Barker-Barambah Cks	1988-89: 2 x 0.04 m² Surber samples; 500 μm mesh 1995, 97: 4 x 0.04 m² Surber samples; 500 μm mesh
	Stony Ck	1989-90, 95-96: 5 x 0.04 m^2 Surber samples; 500 μm mesh
Sub-alpine (Snowy Mountains, SE NSW)	Thredbo R	1982-83: 4 x 0.05 m ² Surber samples; 300 μm mesh 1989-94: 5 x 0.09 m ² Surber samples; 500 μm mesh 1995-96: Dip net (single replicate) MRHI sampling, quantitative laboratory sample processing; 250 μm mesh
Temperate mild/temperate semi-arid (coastal [LR] and inland [WR] VIC)	Latrobe R	Upper, 1979-80: 10 x 0.05 m ² Surber samples; 150 μ m mesh Lower, 1979-81: 30 x 0.02 m ² airlift samples; 150 μ m mesh Lower, 1982-86: Dip net RBA sampling, composite combined- habitat sample derived from 3 reps x 3 habitats x 30 min live- sorting per rep; 250 μ m mesh. Upper & lower, 1994-95: Dip net MRHI sampling, composite combined-habitat sample derived from 2 habitats x 30 min live- sorting per habitat; 250 μ m mesh.
	Wimmera R	1985-95: 8 x 0.08 m^2 modified Pearson air-lift sampler; 300 μm mesh
Temperate cool (TAS)	Musselboro & Coquet Cks	1992-96: 10 x 0.09 m^2 Surber samples; 500 μm mesh
Temperate semi-arid (Flinders Ranges, SA)	Brachina & Oratunga Cks	1992-93: 8-12 x 0.02 m ² benthic core samples; 250 μ m mesh. 1994-95: Dip net (single replicate) MRHI sampling, quantitative laboratory sample processing; 250 μ m mesh.
Temperate mild (south- west WA)	Canning & North Dandalup Rivers	1985-89: 6 x 0.063 m ² Surber samples; 250 μm mesh.

Data provided by custodians for each site and sampling occasion were generally in the form either of total counts of invertebrates across replicates, mean counts per replicate, or counts per individual replicate. Unless indicated below, data were forwarded in standard MRHI taxa categories, ie presented mostly at family-level, whilst no numerically uncommon taxa were removed from data sets prior to their arrival at *eriss* for analysis. In all cases, chironomid data were presented at family-level and not subfamily-level (the latter as per MRHI approach). Details of the interannual comparisons that were made are described below together with comments on deviations within any data set from standardised sampling and sample processing procedures that might have the potential to limit the conclusions drawn.

Dry tropics (Pilbara, WA), Robe River. Standardised sampling and sample processing have been conducted each year (single occasion in late Dry season, Sept-Oct) by the same operator, over a consecutive six-year period, 1991-96. A composite sample was derived by sampling each pool habitat (edge, macrophyte, shale bed) in proportion to its overall coverage and combining the individual samples.

Wet-dry tropics (Alligator Rivers Region, NT), South Alligator River. Standardised sampling and sample processing have been conducted for two seasons, early Dry season (Apr/May) and late Dry season (Oct) over the period 1987-96. Data analysed in this study may be found in Humphrey et al (1995b, 1997). The matrix of data used for the 3 sites in the current analysis included:

Early Dry season, 6 years: Apr 1988, May 1989-91, May 1995-96.

Late Dry season, 9-10 years: Oct 1987-95, and for site 8 only, Oct 1996.

Wet-dry tropics (Alligator Rivers Region, NT), Rockhole Mine Ck. Standardised sampling and sample processing have been conducted for the early dry season (Apr-Jun) of 1991-93 and 1996. Samples were obtained from artificial substrates, 10 per sampling occasion, positioned amongst natural pebble substrates in cascading portions of the stream. (See Dostine et al (1992) for sampling methods.) Data used in analysis were confined to those gathered for a single sampling occasion in late May of each year. Data for the period 1991-92 were derived from Dostine et al (1992), for 1993 from Smith (1994) and for 1996 from sampling conducted by *eriss* (unpublished). Data from Smith (1994) were derived from samples collected from 12 artificial substrates; to ensure comparability with data from other years (derived from 10 substrates), a 83% (10/12) random "subsample" of the Smith (1994) data was taken using the computer macro of Walsh (1997).

Wet-dry tropics (Alligator Rivers Region, NT), Magela Creek. Late Wet/Early Dry season sampling (recessional flow, Mar/May) of two sites has been conducted in each of 8 years (Table 2). Sampling was conducted in late March 1988, April 1990-94 and 1996, and early May 1995. Variations in sampling intensity and sample processing procedures over this period are described in Table 2. One of the sites lies downstream of the Ranger uranium mine and receives some very dilute mine waste waters each wet season (mostly the relatively benign salt, MgSO₄). As of 1994, the downstream site was re-located approximately a further one kilometre upstream of its previous location. For the period 1988-1994, samples from only 3 of the 5 replicates collected at each site and on each sampling occasion were processed and data subsequently analysed for this study.

Wet tropical (North-east QLD), Yuccabine Creek. Standardised sampling and sample processing have been conducted on most sampling occasions (ie whenever possible) at this site. For the present study, analyses were conducted for two seasons of data, early Dry season (May) and late Dry season (Oct/Nov) over the period 1981-95. The matrix of data used for the sites in the current analysis included:

Early Dry season, 5 years: May 1982-84, May 1994-95. Late Dry season, 4 years: Oct 1981-83, Nov 1993. Subtropical (South-east QLD), Barker:& Barambah Cks. Alterations to standardised sampling and sample processing at these two sites have included a doubling of the replication at each site in recent sampling over earlier sampling (Table 2). So that analyses amongst years were based upon standardised sampling effort, only the first two replicates from each site and on each sampling occasion from 1995 and 1997 were included in analysis. Data provided in the complete Barker-Barambah data set were for families in 6 orders only, Gastropoda, Decapoda, Ephemeroptera, Odonata, Coleoptera and Trichoptera. For the present study, analyses were conducted for two seasons of data, late Autumn/early Winter and Spring, over the

1988-97. The matrix of data used for both Ban Ban and Litzows sites in the current analysis included:

Late Autumn/early Winter, 3 years: Jun 1988, May 1989, May 1995.

Spring, 4 years: Sept 1988-89, Sept 1995, Nov 1997.

Subtropical (South-east QLD), Stony Creek. Standardised sampling and sample processing have been conducted for two seasons, Autumn/early Winter and Spring, over the period 1989-96. A. Arthington noted in forwarding these data (pers. comm.) that Surber samples 3, 4 and 5 from site Stony 2, 7/9/89 were missing common taxa that occurred in all other samples and that the replicates may therefore be incomplete. (In the event, no pairwise interannual dissimilarity that involved data from this site and sampling occasion was high as a consequence of missed common taxa (Table B5) and hence these data were retained in subsequent analyses.) The matrix of data used for the two Stony Creek sites in the current analysis included:

Autumn/early Winter, 3 years: Jun 1989, Mar 1990, Jun 1996.

Spring, 3 years: Sept 1989, Oct 1995-96.

Sub-alpine (Snowy Mountains, SE NSW), Thredbo R. A large data set has accrued for a number of sites in the Thredbo River from the early 1980s to the present. For reference sites in the river (upstream of the main Thredbo township), the longest time series available has been for Spring and Summer samples, hence comparisons for these seasons were made in the present study. Data for Summer (Feb) 1982 were unavailable for the site located 1 km upstream of the township and instead data from a reference site downstream (- upstream of the township but downstream of the golf course -) were used. A cursory examination of other data gathered in the period 1982-83 common to these two sites and for any particular sampling occasion indicated very little difference in macroinvertebrate community composition and structure. Variations in sampling intensity and sample processing procedures over the period 1982-96 are described in Table 2. The data used in this study were summed abundances of taxa across all the replicates that were taken on a particular sampling occasion. The matrix of data used for the Thredbo River site included:

Spring, 9 years: Nov 1982, Nov 1989-90, Oct 1991, Nov 1992-96.

Summer, 7 years: Feb 1982, Jan 1983, Feb 1990, 1992, Jan 1993-94, Feb 1995.

Data for the period 1982-83 were derived from McKaige (1986), for the period 1989-90 from Thurtell (1992) whilst other data were collected and held by the CRC for Freshwater Ecology (Canberra Uni).

Temperate mild (Victoria), upper Latrobe River. Over the period 1979/80, 6 surveys were taken of benthic macroinvertebrates from upper Latrobe River sites (May, Aug, Nov 1979 and Feb, May and Nov 1980). The 10 samples were taken on each visit over a range of velocities in the main channel. Data for each of the sites forwarded to *eriss* by the Museum of Victoria were taxa abundances per 0.1 m^2 averaged across the 6 surveys and 2 habitats.

(Data are tabulated in Appendix 5 of Metzeling et al (1984); column values divided by 30 yield average abundances per 0.1 m² across the 6 surveys and 2 habitats.) Data provided by VIC EPA that were to be used for comparison with the 1979/80 results consisted of livesorted taxa abundances for each of the sites, separated according to habitat (edge and rifflekick) and season (Spring 1994 and Autumn 1995). In order for the recent 1994/95 data to be made comparable to the earlier 1979/80 data for data analysis, the recent data were reduced to a single data set by averaging across seasons and habitat. Thus, the 1979/80 and 1994/95 comparison used combined seasons and habitat data for each of the 8 sites.

Temperate mild (Victoria), lower Latrobe River, Willow Grove. Over the period 1979-81, 12 surveys were taken of benthic macroinvertebrates from 10 lower Latrobe River sites including Willow Grove (May 1979 - March 1981). The 30 samples collected from each site per sampling occasion comprised 15 edge and 15 main-channel replicates (Marchant et al 1984a). Willow Grove data forwarded to *eriss* by the Museum of Victoria were taxa abundances per 0.2 m² averaged across the 12 surveys and two habitats. (Data are presented as site 1 in Table 1 of Marchant et al (1984b); column values divided by 36 yield average abundances per 0.2 m² across the 12 surveys.)

Additional Willow Grove data were obtained from VIC EPA. Autumn-early Winter data for a 4-year period 1982-86 are presented in Robinson (1988), ie Jun 1982, Mar 1983, Apr 1985 and May 1986. These are live-sorted data which, for each sampling occasion, represent a composite of 3 sampled habitats (logs, stream bed and edge), with 3 replicate samples taken of each habitat (30 mins sorting for each of the 3 replicates). A description of these data is also provided by Chessman and Robinson (1987). Live-sort data for this site were also obtained for the period 1994/95. These data were forwarded separately according to habitat (edge and riffle-kick) and season (Spring 1994 and Autumn 1995). For compatibility with data gathered from 1979-86, the 1994/95 data were both (i) reduced to a composite habitat for each season by averaging across the 2 habitats (for comparison with 1982-86 data) and (ii) reduced to a single data set by averaging across made for the period 1979-95 are shown in Tables B5 and C9.1.

Temperate semi-arid (Victoria), Wimmera River. Standardised sampling and sample processing have been conducted at Wimmera sites over the period 1985-1995. Data for two seasons, Autumn/Winter and late Spring/early Summer were analysed in the present study. The matrix of data used for the 2 sites in the current analysis included:

Autumn/Winter, 4 years: Jun 1985, May 1986, Aug 1987, May 1988.

Late Spring/early Summer, 6-7 years: Nov 1985-88, Nov 1991 (site 4 only), Dec 1993, Nov 1995.

Temperate cool (Tasmania), Musselboro and Coquet Cks. Standardised sampling and sample processing have been conducted at Musselboro-Coquet sites over the period 1992-1996. Samples were processed by pooling the 10 replicates for each site and sampling occasion then subsampling the composite sample to derive a sample size of approximately 200 animals. Data for two seasons, Autumn and Spring, were analysed in the present study. The matrix of data used for the 2 sites in the current analysis included:

Autumn, 3-4 years: Apr 1992 (Coquet site only), Apr 1993-94, Apr 1996.

Spring, 3-5 years: Oct 1992-93 (Coquet site only), Nov 1994, Oct 1995, Nov 1996.

Temperate semi-arid (Flinders Ranges, SA), Brachina and Oratunga Cks. The data set forwarded to *eriss* comprised family abundance data ranked on a scale 0-1 (absent to most abundant taxa), pooled for each sampling occasion and habitat. The matrix of data used for the streams - where codes OR and BR apply to sole sampling of Oratunga and Brachina sites respectively - included:

Winter, 2-3 years for each of riffle, macrophyte and pool habitat: Jun 1993-95, except OR macrophyte where Jun 1993 data were unavailable.

Spring, 4 years, riffle: Sep 1992 (OR), Oct 1992 (BR), Aug 1993 (OR), Oct 1993 (BR), Nov 1994, Oct 1995.

Spring, 2-4 years, macrophyte: Sep 1992 (OR), Oct 1992 (BR), Oct 1993 (BR), Nov 1994, Oct 1995 (BR).

Spring, 3-4 years, pools: Sep 1992 (OR), Aug 1993 (OR), Oct 1993 (BR), Nov 1994, Oct 1995.

Temperate mild (south-west WA), Canning & North Dandalup Rivers. Standardised sampling and sample processing have been conducted for two seasons, Winter and Spring. All sites were sampled in the Winter and Spring of 1985, 1986 and 1987. In addition, the two sites of seasonal flow, CD2 and CD3, were also sampled in the Winter of 1988 and 1989.

A summary of the quality of the data sets from each region in terms of their standardised nature for interannual comparison is provided in Table 3.

standardised nature for interannual comparison.							
Region	Quality of data set; other comments						
Dry tropics (WA)	High quality						

Table 3. Quality of the long-term stream macroinvertebrate data sets from each region in terms of their

Region	Quality of data set, other confinents
Dry tropics (WA)	High quality
Wet-dry tropical (SAR, NT)	High quality
Wet-dry tropical (RMC, NT)	High quality
Wet-dry tropical (Magela, NT)	Medium quality. (Some differences in site location, sampling intensity and sample processing procedures, whilst one site downstream of Ranger mine)
Wet tropical (NE QLD)	High quality
Subtropical (SE QLD)	High quality
Sub-alpine (NSW)	Medium-high quality. (Different sampling intensity between early 1980's and recent data. Spring 1995 & 1996 sampling by kick net, other years by Surber).
Temperate mild (VIC-Latrobe)	RBA live-sorted data compared with early quantitative data; combined seasons and habitat data.
Temperate semi-arid (VIC- Wimmera	High quality
Temperate cool (TAS)	High quality
Temperate semi-arid (SA)	Medium-high quality. (Lab subsampled and sorted data but cores vs kick sampling between early and late years)
Temperate mild (S-W WA)	High quality

2.3 Data analysis

Two features of macroinvertebrate community data were compared in interannual comparisons conducted for each site, namely community composition (taxa present or absent) and community structure (taxa and their relative or rank abundances). The Bray-Curtis dissimilarity measure was used to describe the degree of similarity in samples of both compositional and structural nature. As this measure is the basis of UPGMA classification of MRHI data for model development, dissimilarity values derived in interannual comparisons are potentially best suited to assessing the degree of temporal variability inherent in a data set and determining the implications for model development.

2.3.1 Method and criteria for selecting taxa to include in analysis

Previous studies determining the degree of persistence of biotic communities have included rank correlation methods (eg Spearman) to compare community structure data amongst years (eg Grossman et al 1982, Townsend et al 1987, Weatherley & Ormerod 1990). These measures, however, were deemed less suitable for the analyses applied here, comparing data sets across regions. Rank correlation methods are sensitive to sample size in determining statistical significance. Thus, for comparing data across regions where there are natural differences in taxa richness, lack of significance in between-year correlations in taxa poor sites (for example) might falsely be attributed to lack of persistence rather than to the low taxa richness of the site. (The correlation values themselves, however, might be appropriate for these comparisons.)

In order to compare validly the persistence of macroinvertebrate communities across different regions, each region varying in the extent of taxonomic richness and absolute abundances, standardised methods of data analysis were required. Two approaches could be applied for comparison: (i) setting a fixed taxon number (eg the 20 most abundant taxa per site over time), or a proportion of the taxon number (eg the top 50% of taxa as adjudged by their overall abundance per site over time). On the surface, setting a fixed taxon number would appear to be advantageous in standardising data sets and in enabling rank correlation methods to be applied to the data (these methods being sensitive to sample size). Again, however, a major disadvantage of this approach lies in different taxa richness amongst regions. Thus, the top 20 taxa in one region could comprise half the taxon number whilst in another could represent virtually all of the taxa. Considering the lognormal distributions of macroinvertebrate taxa in a stream community, only 'common' taxa would be represented in the data set of high taxa richness whilst 'common' and 'rare' taxa would appear in the data set from taxa poor sites. Because of the sporadic occurrence of rare taxa across time, analyses would reveal, and lead to the false conclusion, that the low taxa richness site was less persistent than the site of high taxa richness. Thus, all analyses for this study were conducted on proportional taxa number.

For each site and season, interannual data were prepared and analysed in a manner that enabled selection of taxa according to their overall numerical (rank) dominance. The following steps were applied, where data are aligned in a taxa-column and year-row fashion:

- 1. Firstly, taxa abundance data for each year of sampling were divided by the maximum abundance value found for a taxon in that year. This resulted in a taxa list ranked 0-1 from least abundant taxon (in this case absent) to most abundant taxon.
- 2. Rank values for each taxon were then averaged across the number of years represented in the data set.
- 3. The data set was then arranged and aligned from most abundant taxon to least abundant taxon on the basis of the ranks derived from the overall rank average determined from 2.
- 4. Pairwise interannual dissimilarities were calculated using a proportion of top-ranking taxa, the latter as determined from step 3. Where interannual comparisons were based upon rank abundance, rank values from step 1 were used in the analysis whilst for analysis of taxa presence-absence, these values were converted to binary form.
- 5. Bray-Curtis measures were calculated using the PATN software package (Belbin 1993).

Two proportions of taxon number were considered for analysis in terms of overall, top-most abundant taxa per site over time, 50% and 90% of taxa. Dissimilarity measures based on relative or rank abundance data are less sensitive to proportional taxon number as defined

here. Thus in analyses conducted on data sets derived from regions of both naturally high and low taxa number, the measures for a given data set were virtually the same whether the basis of comparison was top 50 or 90%. For presence-absence data, however, dissimilarities were sensitive to the proportion of the taxa used in analysis with values increasing, as would be expected, with greater proportion of the taxa included. For a given site, plots of mean pairwise interannual dissimilarity (calculated as per description above) against different proportions of taxa included in analysis, resulted in a non-linear relationship. In a single plot of each of the relationships derived for sites from a number of different regions, a 'top 50% of taxa' criterion best appeared to separate the different sites (plots not shown here) and hence best appeared to distinguish the degree of persistence amongst sites. However, the 90% threshold was also deemed valuable for inclusion in this study in that derived data were more similar to, (and therefore most relevant to,) MRHI data sets used for modelling. For MRHI modelling, taxa occurring at only 10% or less of sites for a given regional data set are eliminated.

In this study, a top 50% of taxa criterion was applied to rank abundance data whilst both top 50% and 90% criteria were applied to presence-absence data.

2.3.2 Possible thresholds of 'exceedance' to apply to dissimilarity values

A number of thresholds of dissimilarity "exceedance" were considered useful for this study. For rank abundance data, dissimilarities that exceeded 0.5 were considered to no longer preserve any measure of community similarity between any pairwise interannual comparison. For presence-absence data, Storey and Humphrey (1997) have shown that for an MRHI data set based on ACT edge samples, the dissimilarity threshold separating mean pairwise 'within group' samples from mean pairwise 'between group' samples from the UPGMA classification, was about 0.4. This indicates that a subsequent sample supposedly similar to another sample say pairs of samples taken in time or taken for OA/OC purposes - could be expected to misclassify if pairwise dissimilarity exceeded this value. In terms of broader application of this threshold value to other MRHI data sets (eg for defining QA/QC acceptance criteria), Storey and Humphrey regarded the value as generally conservative (rationale not provided here). This threshold also represented the *total* error or variation in inter-sample comparisons that would result in misclassification and thus for this (ACT) data set, the dissimilarity associated with operator error at any stage of sample processing and identification, or with temporal variability (interannual comparison) would need to be below a value of 0.4 if misclassification is to be avoided. Thus, two thresholds are provided here, a value of 0.4 associated with total variation tolerable if misclassification is to be avoided, and a value of 0.35 being (arbitrarily) selected as a maximum target for any one source of variation or error associated with MRHI data sets.

It is acknowledged that for probably most other MRHI (non-ACT) data sets, greater thresholds of dissimilarity would distinguish classification groupings (Storey & Humphrey 1997). Thus, threshold exceedance as defined here might suggest potential problems only for models based upon data from a similar small geographical area and scale as the ACT.

For presence-absence data, the percentage of pairwise dissimilarities from the total of such interannual dissimilarities (that could possibly be calculated for a given site and season) exceeding 0.35 and 0.4 was recorded for both top 50% and top 90% of taxa. In addition, a mean dissimilarity was calculated from each dissimilarity matrix (site and season) for the top 50% (rank abundance data) or 90% (presence-absence data) of taxa.

2.3.3 Ensuring the comparison of similar types of data

Only for dissimilarity data from one site, Willow Grove on the lower Latrobe River, were interannual comparisons restricted because of differences in the manner in which macroinvertebrate data were summarised for different sampling occasions. Thus, composite 1979/81 data (seasons and habitats combined) were compared only with similar composite data from 1994/95. Otherwise, pairwise interannual comparisons of combined-habitat data were made for Autumn/early Winter of 5 years, 1982-83, 1985-86 and 1995.

2.3.4 Validity of comparing data gathered by different sampling methods

Latrobe River data were characterised by the greatest discrepancies in sampling and sample processing methods over time (Table 2). Apart from some minor changes in sampling area at a site over time (eg Magela Ck, Thredbo R), the one major difference in methodology over time that had the potential to compromise the interannual comparisons in this study was a move from quantitative areal sampling (ie cores, Surber) to single kick/sweep net sampling (as occurred with Thredbo R and Flinders Ranges streams, Table 2).

Data gathered from simultaneous sampling of riverine sites from 4 different regions of Australia using quantitative Surber sampling and single-replicate kick-net sampling were compared to evaluate the validity of combining data gathered using the two different methods. This study is described in detail in Appendix A of this report.

2.3.5 Correlates of temporal variability

A regression approach was used to quantify and describe relationships between summary measures of temporal variability ('inconstancy'), and the regime of stream hydrology, discharge variability and latitude of study sites. Data for each of these variables are shown in Table 5. The MINITAB software package was used for this analysis (MINITAB 1995). Non-riffle habitat data from Flinders Ranges streams were excluded from all analyses, whilst Latrobe R data were also not used in analyses associated with rank abundance because of the unreliability of the live-sort method (used to process some of the samples in the data set) for recovering rank abundance data (Humphrey & Thurtell, 1997).

3. Results

3.1 Validity of comparing data gathered by different sampling methods

In Appendix A, results of the comparison of community compositional data derived using quantitative Surber sampling and single-replicate kick sampling in different streams are described. Relatively small dissimilarity values were derived in the comparison of data from the two methods at sites of low seasonal discharge and (relative) habitat homogeneity (Appendix A). On the basis of these results, it was decided that interannual comparison of data derived from the two methods within Flinders Ranges stream data sets would be acceptable, as these environmental traits would generally characterise these streams. However, relatively higher dissimilarity values were derived for data from the two sampling methods conducted in the Thredbo R (Appendix A) and on this basis, interannual comparisons for this stream were confined to data gathered using a common sampling method (see Table C7.1). The approach adopted for the Flinders Ranges data set may need to be reviewed as the results of any studies that were conducted in this region to compare methods came to hand.

3.2 Degree of temporal variability of macroinvertebrate communities in Australian streams

Summary results for pairwise interannual comparisons (viz dissimilarity measures), are shown for individual sites of each region according to season and habitat in Tables B1-B12 of Appendix B. Much of the raw data are presented in Appendix C. For each season, the number of years available for comparison and total number of pairwise comparisons made, are indicated (Appendices B & C). Of the total number of pairwise comparisons made, the percentage of these comparisons in which dissimilarity values exceeded thresholds - 0.35 & 0.4 for presence-absence data, 0.5 for rank abundance data - are shown in Tables B1-B12. These thresholds were calculated separately for the top 50% and 90% of taxa ranked according to overall abundance at the site. Mean dissimilarity averaged over the total number of pairwise comparisons is also shown in these tables (B1-B12), for presence-absence and rank abundance data.

Where data for more than one site were analysed for a given region, average values across the sites of the pairwise interannual summaries described above, are also provided in Tables B1-B12. These average values were calculated separately for each season and are designated 'combined' in the tables. For the two Flinders Ranges streams, these values were also averaged across the three different habitats represented in the data (Table B11). The average or summary data derived for each region, according to season, are shown in Table 4.

The extent and the nature of temporal variation in macroinvertebrate communities of Australian streams are summarised in the sections below. Whilst some generalisations can be drawn from the data, the different duration of study length represented amongst the regions (3-16 years, details provided above) is a factor that places some limitations on drawing too strong conclusions. Studies encompassing a longer time series are likely to be far more informative in describing the response of macroinvertebrate communities in streams to longer-term climatic variability in Australia.

Finally, no attempt has been made in this report to describe actual changes in taxonomic composition associated with temporal variability of macroinvertebrate communities at any of the study sites. (For this purpose, data pertaining to the top 5 numerically-abundant taxa at each site and on each sampling occasion, are provided in Appendix C.) Further, whilst the degree of persistence of macroinvertebrate communities is interpreted mainly in terms of climatic and flow-related factors, it is possible that features of the life histories of constituent taxa might also be relevant in this regard. Variations in the timing of seasonal sampling, for example, might be critical in explaining presence or absence of univoltine taxa or taxa whose emergence is otherwise highly synchronous. This would apply mainly to temperate and seasonally-flowing streams, there being sufficient evidence that the majority of insect taxa from northern Australia are multivoltine with overlapping and continuous life-cycles (eg Bunn & Hughes 1997).

3.2.1 Interannual variation on a seasonal basis Rank abundance data

Tables B1-12 and Table 4 summarise interannual variation in community rank abundance data from different regions, according to season. In general, interannual variability of stream macroinvertebrate communities was greater following seasonal rains and flooding (northern Australian sites and Thredbo River, or during the annual 'wet season' (Winter, SW WA). Disturbance to streams arising from annual flooding would, not surprisingly, result in greater variation in the rank abundance of benthic fauna at or shortly after these seasons than when flows were in a recessional phase during a 'dry season'.

The cause of the higher interannual variability observed in Autumn compared with Spring or Winter for Tasmanian, Victorian and South Australian streams, is not known. Normally at this time of year flow in these streams is constant though if sampling followed, or was coincident with, low flows - which in these streams are more unpredictable than Spring high flows (PS Lake pers comm) - higher temporal variability might be expected. Together with flow data, life history features of common taxa (ie timing of recruitment and emergence) would need to be examined to explain these results further. For the lower Latrobe River site (Willow Grove), all interannual comparisons with data for Autumn 1995 resulted in high dissimilarity values (Tables B8 and 4) though whether this is a consequence of mild drought in 1995 or an artefact of samples processed using a live-sort method (not reliable for recovering rank abundance data, Humphrey & Thurtell (1997)) is not known.

Presence-absence data

The seasonal patterns observed for rank abundance data were not necessarily mirrored for presence-absence (p-a) data. Thus, of the 9 regions for which data were available for two seasons, 4 data sets displayed a seasonal pattern that was the reverse of those described for community rank abundance data above. Given that the dissimilarity based upon abundance data is weighted by numerically 'common' taxa, values could more readily reflect the seasonal (and predictable) changes in the rank abundance of these taxa. The dissimilarity based upon p-a data, however, would be expected to reflect variation in the complete assemblage of taxa, including less common taxa. Large changes to dissimilarities based upon p-a data would be expected to reflect large-scale changes to macroinvertebrate communities, involving taxa elimination and addition. Thus, high pairwise interannual dissimilarities based upon p-a data in this study to some extent reflected greater disturbance than that associated with seasonal and predictable changes to stream flow. Factors that influenced pairwise interannual dissimilarities between seasons for the different regions may be listed:

1) Higher temporal variability following seasonal flooding

The same pattern of shift in seasonal mean or threshold interannual dissimilarity was observed for p-a and rank abundance data for Yuccabine Ck (north-east QLD), Thredbo R (NSW), Flinders Ranges streams (SA), streams in south-west WA, and for the upper 2 sites of the South Alligator River (NT). The same mechanisms thought to be responsible for seasonal changes in interannual dissimilarity for rank abundance data (ie greater variation following seasonal flooding) might also be responsible for the seasonal changes observed for dissimilarities based upon p-a data. This might also extend to Tasmanian and Victorian (Wimmera) stream data where pairwise dissimilarity values are higher in Spring ('post wet season') than those observed in Autumn (Table 4).

2) High flow events

These refer to more extreme events than the seasonal flooding regime discussed in 1) above, thus:

- The high Spring interannual dissimilarities observed in the Thredbo River were associated almost entirely with pairwise comparisons that involved 1992 (Table C7.1), exceptional and extended flooding in this year resulting in very significant losses of taxa (partially resulting as well from the inability to sample effectively, K Thomas, pers. comm).
- Pairwise dissimilarities for Yuccabine Ck are dichotomous in that an 'event' occurring between the samples taken in the 1980s and those taken in the 1990s has changed community structure considerably. Most 1980s and 1990s data are similar within these

time periods, but between the time periods interannual comparisons may be high. Because sampling was not continuous between these two sampling periods (Table 4), it is difficult to isolate the cause of this disjunction. Apparently the canopy of this rainforest stream has opened up in recent years (R Pearson, pers comm) though whether changing light conditions or possible cyclonic disturbance and scouring of the stream that caused this change in the first place are the cause, is unknown. The high dissimilarities observed in the early Dry season in this stream may be more a reflection of the fact that more 'postevent' (1990s) data are available for this season than for the late Dry season (Table 4).

• Although data are available for only one season for the Robe River (north west WA), the high dissimilarities observed after 1992 are the result of cyclonic flooding that occurred early in 1993 and which eliminated about half the taxa present before this date (P Davies, pers comm). This disturbance and slow and continuing recovery of the fauna after this event are the cause of the high interannual dissimilarities observed for this site.

3) Low flow events

- By the late Dry season, the most downstream site sampled in the upper South Alligator River (NT) was only several kilometres upstream of the point at which the river ceased to flow. Hence, flow at this site was more variable at this time than at the two sites located further upstream and in years of particularly low discharge (1991-93), many flowdependant taxa were absent from the site. Reflecting these observations, interannual dissimilarities at this site during the late Dry season were the highest of any of the sites (Table B2).
- Very significant losses in taxa were observed in the Spring of 1995 at sites in Barker and Barambah Cks, south-east QLD, associated with drought and low flow conditions (Table C6.3). Macroinvertebrate communities were seemingly unaffected at this time at the two upland sites in Stony Ck in this same region (Tables B6 & C6.7), despite cessation of flow at the sites at the time of the Spring 1996 sampling (A Arthington pers comm).
- Although possible drought-related change to community rank abundances may have occurred at Willow Grove in the lower Latrobe River in Autumn 1995 (see above), this effect was not reflected to any significant degree in analyses of p-a data where interannual dissimilarities were found to be generally low (Table B8). This concords with the finding of Chessman and Robinson (1987) who also reported little change to macroinvertebrate community composition as a result of prolonged drought and record low flows (far more extreme than in 1995) in parts of the lower Latrobe River.

3.2.2 Temporal variation in relation to habitat

For Flinders Ranges streams, data were available for three habitats, riffles, pools and macrophyte. Summary results for pairwise interannual comparisons are shown separately for different habitat in Table B11. Pairwise dissimilarities based upon both community rank abundance and p-a data are generally much lower for any site and season in riffle habitat compared with those values found in the other two habitats. Presumably greater variation in macroinvertebrate communities of pools and macrophyte reflects the greater microhabitat variation present in these habitats compared with that in riffle habitat.

3.2.3 Temporal variation for seasons combined

To compare the long-term data further across regions, additional summaries and information were drawn together, restricting the comparisons this time to results based upon presenceabsence data. Thus in Table 5, various 'inconstancy indices' are shown. These were calculated by averaging the seasonal summaries shown in Table 4 to derive annual indices. Index 1. "%dissim>0.35", is the average of the seasonal values of 'percent of interannual comparisons in which dissimilarity values exceeded 0.35 (presence-absence data) for analyses using the top 90% of taxa'. Index 2, "mean threshold", is the average of the seasonal values of 'percent of interannual comparisons in which dissimilarity values exceeded both 0.35 and 0.4 (presence-absence data) using both the top 50% and 90% of taxa'. The third index 3, "mean dissimilarity", is the average of the seasonal values of 'mean dissimilarity of all interannual comparisons using the top 90% of taxa'. Also shown in Table 5 are the coefficients of variation associated with the mean of annual flow for streams in the region from which data were derived; these (CV) values were obtained from McMahon (1979) or from long-term data held by state/territory government water authorities.

Lower inconstancy index values shown in Table 5 reflect higher persistence of macroinvertebrate communities. The overall ranking of most persistent to least persistent communities in Table 5 (ie top to bottom row) is based upon threshold dissimilarity data as opposed to mean dissimilarity data, the former better reflecting the notion of misclassification and predictive failure arising in MRHI models. For Flinders Ranges streams (SA), data for riffle and non-riffle habitat have been treated separately. Finally, the summary data shown in Table 5, averaged across seasons, are useful in enabling a preliminary assessment to be made of the extent of temporal variability present in combined-seasons data and implications of this for successful model development. It is worth noting, however, that calculation and scrutiny of pairwise interannual dissimilarities derived from combined-seasons data (rather than average values of dissimilarity calculated for seasons separately) would best serve the purposes of such an assessment; such dissimilarities are likely to be lower than those based upon a mean of seasonal values.

Rank abundance data for seasons combined

From regression analysis, no significant (P<0.1) relationships could be found between summary measures of inconstancy based upon rank abundance, and the regime of stream hydrology, discharge variability and latitude of study sites. Nevertheless, the following observations were made:

For all streams in northern Australia (including south-east QLD), temporal variability was high for analysis based upon community rank abundance data. Not evident from the summary results of Table 4 (but presented for individual sites in the tables of Appendix C), is the observation that dissimilarities based upon rank abundance data for these streams more often increased either progressively or abruptly with increasing interval in time of the pairwise interannual comparison. (Thus, community structure in the streams has shifted with time.) These changes have occurred: (i) between any two interannual comparisons for sites from south-east QLD; (ii) abruptly from 1992 or 1993 in the case of most sites on the upper South Alligator R (NT) and from the 1990s for the Yuccabine Ck site (QLD), a consequence of decline in base flow in the former stream and cyclonic disturbance between the 1980s and 1990s for the latter; (iii) abruptly and progressively in the case of the Robe R site (north-west WA), where the fauna has been recovering progressively from cyclonic disturbance that occurred in 1993; and (iv) progressively in the case of sites on Magela Ck (NT).

For southern temperate Australia, temporal variability for data based upon community rank abundance is generally low for permanent streams (Table 4). (The high dissimilarities observed for the upper Latrobe R data are likely to be an artefact of the comparison of livesort data with data derived from laboratory subsampling and sorting. As indicated above, the live-sorting technique is not particularly useful for recovering rank abundance data.) The high pairwise interannual dissimilarities observed for Thredbo R data, as discussed above, are associated with high temporal variability found in one season only (ie Spring snow-melt flooding in the river).

Temporal variability for data based upon community rank abundance is generally higher for seasonally-flowing streams than for streams of permanent flow found in the same region (see data for NT, VIC and SW WA in Table 4).

Presence-absence data for seasons combined

Summary measures of inconstancy based upon family presence-absence data for different catchments are provided in Table 5. Comments on inconstancy and possible reasons for relative lack of persistence are also provided in this table. A variety of combinations of parameters was used in regression analysis of dependant inconstancy variables and independent environmental variables. The best predictive equations were those that used the dependent inconstancy index variable, '% dissim > 0.35 for top 90% of taxa', and independent variables, CV of annual flow and flow status. Derived regression equations from inclusion of single to multiple independent variables were:

(1)	$\log_{10}ICI = 0.670 + 0.776CV$	$R^2 = 0.57, P = 0.002,$
(2)	$\log_{10}ICI = 0.620 + 0.704CV + 0.265FS$	$R^2 = 0.73, P < 0.001.$

where

ICI = inconstancy index, dissimilarity threshold > 0.35,

CV = CV of annual flow (mean of any range values), and

FS = Flow status, using a dummy variable, 0 = permanent flow, 1 = seasonal flow.

The two independent variables were significant for respective equations at:

(1) P = 0.002 (CV),
(2) P = 0.001 (CV) and P < 0.05 (FS).

Latitude was found to be only weakly (and negatively) correlated with inconstancy (P = 0.24 for this variable in the best of the derived regression equations).

Three summary points may be made from the results presented in Table 5 and from regression analysis:

1. (a) A high positive correlation is observed between persistence, and predictability and low interannual variation of stream discharge.

(b) Persistence of macroinvertebrate communities is significantly higher in streams of permanent flow than in streams of seasonal flow. (For seasonally-flowing streams that dry out considerably, lower persistence is possibly related to the stochastic nature of recolonisation of the fauna following re-wetting.)

(c) There is a tendency (only) for macroinvertebrate communities of permanent streams in temperate Australia to be more persistent than those in tropical regions. (Apart from seasonal extremes in discharge, this may also relate to the shorter life cycles of tropical invertebrates; more dynamic, short-term response to disturbance might be expected from these assemblages.)

- 2. For the limited data available, macroinvertebrate communities from riffle habitat appear to be more persistent than those from other habitats, even at the same sites of permanent flow.
- 3. For the data analysed in this study, measures of temporal variability averaged across the seasons indicate relatively high persistence for all but one or two regions represented.

These points are expanded upon below.

Short-term vs long-term temporal variation

As discussed in the section 'Rank abundance data' above, the summarised results of analyses presented in this study belie features of the data concerning the duration and temporal pattern of observed changes in structure of macroinvertebrate communities. As discussed above, community structure in the streams of northern Australia has generally shifted with time; evidence for this may be found in the raw interannual dissimilarity values reported in the tables of Appendix C. Thus, for upper South Alligator R sites (NT) and the Yuccabine Ck site (QLD), different dichotomous community 'states' are evident over time. For Magela Ck sites (NT) and the Robe R site (north-west WA), progressive changes are evident in the data which for the latter site is related to faunal recovery after massive disturbance. Only for South Alligator R communities was this dichotomy less evident in p-a data, with smaller decreases in persistence observed over time at the sites compared with those in other streams.

High pairwise interannual dissimilarities found for the Thredbo R were seasonal with large disturbances (Spring floods) appearing not to result in major long-term shifts in community composition and structure. Other data sets appeared to be inherently variable throughout the time series of data available as a consequence of the high climatic variability of the region and/or response to seasonal or aseasonal drought (ie Wimmera R, VIC and Barker-Barambah Cks, QLD).

×. <u> </u>		Region																					
	NW WA	NT (SAR)		NT (RMC)	NT (Mag)	NE QLD		SE QLD		NSW		VIC (Latrobe)		VIC (Wimmera		Т	TAS		A	SW WA (seasonal)		SW WA (permanent)	
Site details	-	- 3	- 3	- 1	- 2	-	-	-	-	-	-	upper 8	lower 1	-	- 2	-	- 2	- 2	- 2	- 5	- 5	- 5	- 5
Permanent (P) or seasonally- flowing (S)	S	P	P	S	S	P	P	P	P	P	P	P	·	P	P	P	P	P	P	s	s	P	P
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	LD	ED	LD	ED	ED	ED	LD	A	S	S	Su	с	C/A	A	S	A	S	w	S	W	S		S
Habitat (Riffle, Macrophyte, Pool, Combined)	Р	R	R	R	R/M	R	R	R	R	R	R	с	с	Р	Ρ	R	R	С	С	R	R	R	R
No. of years (N comparisons)	6 (15)	6 (45)	10 (117)	4 (6)	8 (56)	5 (10)	4 (6)	5 (12)	5 (18)	9 (22)	7 (21)	2 (1)	7 (11)	4 (12)	7 (36)	4 (9)	5 (13)	3 (16)	4 (31)	5 (29)	3 (15)	3 (15)	3 (15)
Range of years	91-96	88-91, 95-96	87-96	91-93, 96	88, 90-96	82-84, 94-95	81-83, 93	88-90, 95-96	88-89, 95-97	82, 89-96	82-83, 90, 92-95	79/80- 94/95	79/80 & 82- 86, 95	85-88	85-68, 91,93, 95	92-94, 96	92-96	93-95	9 2-95	85-89	85-87	85-87	85-87
Between-year comparisons Rank abundance % dissim > 0.5 (top 50%)	27	42	39	0	36	50	17	67	38	56	19	100	36	50	33	11	0	6	6	17	13	7	0
Mean dissim (top 50%)	0.443	0.475	0.440	0.399	0.427	0.468	0.359	0.563	0.463	0.528	0.371	0.830	0.670	0.501	0.438	0.434	0.375	0.355	0.298	0.360	0.350	0.299	0.221
Presence-absence % dissim > 0.35 (top 50%)	27	0	1	o	5	0	0	0	17	5	0	0	0	o	0	o	0	6	6	10	0	0	0
% dissim > 0.35 (top 90%)	93	13	14	17	21	30	0	0	38	36	19	0	9	0	39	0	15	38	45	21	27	13	o
% dissim > 0.4 (top 50%)	27	0	0	0	2	0	0	0	17	5	0	0	0	0	0	0	0	6	6	3	0	0	0
% dissim > 0.4 (top 90%)	93	2	4	0	11	20	0	0	33	23	10	0	0	0	28	0	0	25	29	17	13	0	0
Mean dissim (top 90%)	0.431	0.225	0.242	0.237	0.279	0.294	0.217	0.246	0.339	0.303	0.232	0.245	0.286	0.184	0.329	0.192	0.216	0.378	0.340	0.277	0.250	0.233	0.214

Table 4. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures) for stream sites located in various parts of Australia

Table 5. Temporal variability of stream macroinvertebrate communities across different regions of Australia, based upon family-level, presence-absence data. (See text for explanation of inconstancy indices.)

Region	Flow status	No. of years	Inconstancy index (%dissim>0.35)	Inconstancy index (mean threshold)	Inconstancy index (mean dissimilarity)	CV of annuał flow	Latitude (°; decimal minutes)	Comments on persistence and mechanism for relative lack of persistence
Temperate (VIC-Latrobe)	Permanent	2 (upper) 7 (lower)	4.5	1.1	0.266	0.32	38.0	High persistence (to some degree an artefact of combined seasons and habitat data).
Temperate (SW WA)	Permanent	3	6.5	1.6	0.244	0.49-0.73	32.3	High persistence (predictable pattern of flow)
Temperate (TAS)	Permanent	4 or 5	7.5	1.9	0.204	0.47	41.3	High persistence (predictable pattern of flow)
Wet-dry tropical (SAR, NT)	Permanent	6 or 10	13.5	4.0	0.234	0.58	13.35	High persistence (predictable pattern of flow)
Wet tropical (NE QLD)	Permanent	4 or 5	15.0	6.3	0.256	0.5	18. 1	High late dry season persistence; cause of low early dry season persistence unknown (cyclonic disturbance/opening of canopy in early 1990s?)
Wet-dry tropical (RMC, NT)	Seasonal	4	17.0	4.3	0.237	0.58	13.35	Lower taxa richness in 1992 associated with low wet season rains and discharge
Subtropical (SE QLD)	Permanent	5	19.0	13.0	0.293	1.04-1.07	26.3	High autumn persistence; low persistence in spring associated with drought (1995)
Temperate-dry (VIC-Wimmera)	Seasonal	4 or 7	19.5	8.3	0.257	0.58-0.98	36.3	Seasonal flow (pools in dry season)
Wet-dry tropical (Magela, NT)	Seasonal	8	21.0	9.8	0.279	0.56	12.4	Seasonal flow (little or no surface water by end of dry season)
Temperate (SW WA)	Seasonal	3 or 5	24.0	11.4	0.264	0.49-0.73	32.3	Seasonal flow (little or no surface water by end of summer 'dry season')
Temp. semi-arid (Flinders, SA)	Permanent (riffle)	3 or 4	25.0	8.3	0.290	1.25	31.1	Reasonably high persistence (sites of permanent flow)
Sub-alpine (NSW)	Permanent	8 or 6	27.5	12.3	0.268	0.5-0.75	36.3	High summer persistence; low persistence in spring associated with snow-melt floods (eg 1992).
Temp. semi-arid (Flinders, SA)	Permanent (macro, pool)	3 or 4	51.7	30.9	0.387	1.25	31.1	Low persistence of pool and macrophtye fauna compared with that in riffles. 'Flashiness', and occasional severe floods characteristic of these streams may affect fauna of the habitats differently.
Dry tropics (Pilbara, WA)	Seasonal	6	93.0	60.0	0.431	1.4	21.3	
Summary

Despite the different duration of study length and other limitations represented in the data sets analysed from across Australia, synthesis of data from across the continent in a metaanalysis has enabled statistical associations to be made between temporal variability of macroinvertebrate communities and degree of environmental variation. The patterns of temporal variability of macroinvertebrate communities observed in Australian streams are common to those reported in a number of isolated studies conducted elsewhere (see review of Hildrew & Giller 1992). For example, extreme drought and above-average wet season rainfall (McElravy et al 1989) or catatrophic flooding (Giller et al 1991) have been shown to result in considerable reductions in taxa richness in streams of the Northern Hemisphere. Stream order and location along the length of a stream (upstream, downstream) (Townsend et al. 1987, Weatherley & Ormerod 1990), flow status (permanent vs seasonal flow) (Wright 1995) and habitat type (Weatherley & Ormerod 1990) may also affect persistence of invertebrate communities.

Some generalisations drawing on the results of the present study can possibly be made:

- Persistence of macroinvertebrate communities is significantly and positively correlated with permanence of stream flow, and negatively correlated with interannual variability of annual stream discharge. These relationships are consistent with the findings of other researchers for other parts of the world as reviewed above. There is a tendency (only) for macroinvertebrate communities of permanent streams in temperate Australia to be more persistent than those in tropical regions.
- For the streams of tropical northern Australia, community composition and structure has generally changed, either quite abruptly with time with emergence of different dichotomous community 'states', progressively and continuously, or abruptly followed by progressive change. These changes appear to have arisen as the result of short-term seasonal (annual drying) or event-based (eg cyclonic) disturbance or from subtle, longer-term change (eg gradual decrease in riverine base flow). Slow recovery rates (several years) were observed in Robe River (WA) following cyclonic flooding (Appendix C1). Such slow recovery rates of macroinvertebrate communities following catastrophic floods are not unusual (Giller et al 1991).
- Occurrences of high temporal variability in macroinvertebrate communities in temperate Australia appear to be restricted to a single season and for the single data set for which a relatively long time series is available (Thredbo R) there was evidence of a rapid return to a pre-disturbance community structure following a discrete disturbance event. The rapid recovery of macroinvertebrate communities to flooding reported in this stream and in seasonally-flowing streams elsewhere in Australia (Boulton & Lake 1992) contrasts with the relatively slow recovery (several years) observed in Robe River following flooding (see above).

Other observations are based on too limited data for generalisations to be made at this stage, thus:

• For south-east QLD, the response of the fauna to drought (1995-96) in streams of two adjacent catchments differed. The fauna of Stony Ck, an upland forested stream, changed very little in response to drought despite cessation of flow in 1996, whilst the fauna in more open sites of Barker-Barambah Cks, located in a neighbouring catchment and at lower altitude, did change substantially in this same period even though some flow was recorded on all sampling occasions (Table B6). It is possible that water quality

deteriorated more markedly at the open Barker-Barambah sites than at the closed upland sites, accounting for significant losses of taxa from the former sites.

There is some parallel to this pattern (SE QLD) observed in the upper South Alligator River (SAR) catchment of the NT, where the fauna of Rockhole Mine Ck (RMC), the small (rain)forested tributary of the SAR appears to have remained relatively unchanged in community structure over the same period that significant changes were occurring in the SAR (Table 4). This is despite the fact that RMC is seasonally-flowing and surface waters at the site for which data were derived disappear over the dry season. The high fidelity that is reported of the fauna to these forested, steep-sloping upland sites of seasonal flow (eg Bunn and Hughes (1997) for these and other Conondale Range sites) and adaptations presumably inure the resident assemblages to seasonal or less frequent periods of drought.

Townsend et al (1987) also observed in the UK greatest persistence in shaded headwater streams of narrow range in temperature and discharge and of low pH. Hildrew & Giller (1992) attributed this finding to the greater flow refugia provided in such streams. Weatherley and Ormerod (1990) observed that persistence of riffle faunas increased with *decreasing* altitude, a possible consequence of increasing habitat stability (vegetation in marginal habitats) over this gradient.

• For streams in one region (Flinders Ranges), persistence of macroinvertebrate communities was high in riffle habitat and low in pool and macrophyte habitat. Weatherley and Ormerod (1990) also reported lower persistence in edge compared with riffle habitat in 18 upland streams of Wales.

4. Implications of results for MRHI predictive model development: a preliminary assessment

4.1 Appraisal of the degree and geographical extent of temporal variability across Australia

In this study, quantification and assessment of the degree of temporal variability of macroinvertebrate communities in Australian streams have required long-term data from relatively undisturbed sites. In effect, for temperate and north-eastern Australia at least, this need has restricted many of the useful data sets to those from upland stream sites typically of permanent flow. This represents some bias in ascribing the degree and geographical extent of temporal variability of stream macroinvertebrate communities amongst different regions in Australia. Another bias in the data sets used here for the analysis of temporal variability is the near-exclusive representation of macroinvertebrate data from riffle habitat only.

The lack of long-term data on macroinvertebrate communities for habitat other than riffle is a serious limitation for MRHI information needs. This is because riffle habitat is only one of several habitats being sampled by agencies in the program and is either unavailable for sampling or relatively unimportant in many seasonally-flowing, as well as lowland portions, of streams throughout Australia. The bias towards upland sites of permanent flow is not such a limitation given that extrapolation beyond these situations is possible, with correlations found between persistence, and flow regime/variability and (to a lesser extent) latitude amongst the data sets analysed in this study (see below).

Given the seasonal extremes of discharge in streams of tropical northern Australia, it is perhaps not surprising that persistence of macroinvertebrate communities in these streams is, overall, lower than in temperate Australia. The various patterns of temporal change in macroinvertebrate communities of these streams have been described above. Because the flow regime for Magela Creek, NT, is more typical of the hydrology of streams of the Wet-Dry tropics at least, the pattern of temporal variability for stream macroinvertebrate communities in this part of Australia is perhaps best exemplified in this data set. The pattern in this stream is one of a community structure and composition shifting through time.

Information that may be used to assess the effects of drought on stream macroinvertebrate communities of eastern Australia can be sought from long-term data sets that include interannual comparisons for years in the periods 1982-83 and 1994-96. The 1994-96 drought was not as severe in VIC and TAS as the 1982-83 drought. Long-term data for the period 1982-83 is available only for the lower Latrobe River. As stated above, both the 1982-83 and 1995-96 droughts appeared to have little effect upon the composition of macroinvertebrate communities of the lower Latrobe River (VIC), though these results were derived from combined-habitat data that would be relatively inured from such environmental change. In a study of temporary streams of Victoria around the time of the 1982-83 drought, Boulton and Lake (1992) found reductions in taxa richness only *after* the drought had broken.

The only response to the 1994-96 drought observed in this study was for the Barker and Barambah Ck sites in south-eastern QLD in 1996, a region for which drought conditions in the period 1994-96 were particularly severe. The sites sampled in this catchment are thought to be reasonably representative of mid-altitude reference sites sampled in QLD for the MRHI in the period 1994-96 (S Choy, pers comm). The taxa richness in these sites was markedly reduced by the Spring of 1996 (Table C6.3), a finding apparently mirrored at many other sites in QLD between 1994 and 1996 (S Choy, pers comm). (Faunal recovery to levels of taxa richness measured prior to the 1994-96 drought appeared to be completed by Spring of 1997 - see Appendix C6.)

Extrapolating results from SE QLD to areas of similar climate, flow regime of streams, variability of flow and geofluvial characteristics of sites, would indicate that temporal variability is high for a very large portion of temperate/sub-tropical Australia.

Only in mild- and cool-temperate Australia was there little evidence of temporal variability present amongst any of the long-term data sets analysed in this study.

The regression equations relating persistence of macroinvertebrate communities in different regions to flow characteristics of streams in the regions, may prove to be a useful tool for delimiting the extent of temporal variability in Australia. Additional applications of these simple predictive models are discussed in the section below.

The preceding discussion has been based upon analysis of persistence of macroinvertebrate communities from riffle habitat of streams. If results showing increased temporal variability in non-riffle habitat, as observed in Flinders Ranges streams and in other parts of the world (Weatherley & Ormerod 1990), are applicable to other parts of Australia, any account of the implications for MRHI predictive modelling based solely upon riffle habitat would need to be re-assessed. Thus the degree to which temporal variability of macroinvertebrate communities differs in different habitat, and the causes for this, need to be determined. In their study, Weatherley & Ormerod (1990) noted that relative monitoring effort expended on different habitat could depend upon the cause of this observation.

4.2 Possible implications of results for MRHI predictive model development

Rank abundance data

The highest interannual variability found in the analyses of this study - in relative and absolute terms - was that associated with family-level rank abundance data. The results

reported here would suggest that only for permanently-flowing streams in southern Australia where interannual variability of discharge is low and rainfall predictable - in particular, TAS, south-west WA (Table 4) and possibly parts of VIC - is there potential for development of AUSRIVAS models based upon rank abundance data. It is generally assumed that models based on rank abundance would be more sensitive to human disturbance than current models based on p-a data. Thus water quality assessment programs applied to only a small part of Australia would benefit from development of models based on rank abundance data. (As discussed above, live-sort sample processing by agencies in these states would compromise this potential.)

Presence-absence data

Having quantified the degree and extent of temporal variability of stream macroinvertebrate communities across Australia, the original objectives of this R&D project sought, where lack of persistence was observed, to:

- Explore the implications of the result by assessing whether the anomalous data classified near or together with those from related disturbed sites.
- Seek environmental correlates that may account for any year-to-year variation in community structure and input these variables to the MRHI predictive models.

These and other possible approaches are discussed below:

1. Contextual data for assessing the severity of temporal variability

Humphrey et al (1995a) explored the implications of a switch in structure of macroinvertebrate communities (rank abundances) of the upper South Alligator River (SAR) between pre-1993 and post-1992 time periods, by assessing whether the post-1992 data classified near or together with those from related disturbed sites. From ordinations conducted using data from both unpolluted/mine-polluted portions of the adjacent Rockhole Mine Creek (RMC) and SAR data, post-1992/pre-1993, it was shown that the magnitude of change occurring in the SAR post-1992 was even more severe than that occurring in polluted portions of RMC. Moreover, the nature of the change in community response in the SAR mimicked the pollution gradient evident in the mine-impacted stream.

The limitation of the approach described above to MRHI modelling is related to scale: Firstly, the analysis for SAR-RMC was based upon family-level abundance data. The analysis has not been repeated using presence-absence data but if this was performed it would probably indicate little change in SAR community composition between post-1992 and pre-1993 relative to that between the two RMC sites. Secondly, the ultimate test of whether or not temporal variability presents problems for predictive modelling lies in running long-term community compositional data for particular sites through agency classifications and models. In this context the severity or otherwise of any lack of community persistence - *within the bounds of sensitivity of the models* - can be fully measured. Misclassifications and poor predictions would indicate potential problems for model development. An exercise of this nature has been conducted, incorporating long-term SAR data into the NT MRHI agency classification based upon riffle samples. Whilst the results showed misclassification of early (1988) SAR data in a UPGMA classification based upon late Dry season 1994 and 1995 NT riffle data, the classification was based on less than 25 sites, amongst which there was relatively low inter-site dissimilarity (Humphrey & Doig 1997).

Further studies are required in which long-term data of the type compiled for this study are incorporated into existing agency classifications and models. A variation on this approach - and the supreme test of the implications of temporal variability for modelling - lies in running

data from the same agency reference sites gathered in time, through models constructed from earlier data. A particularly useful data set for this purpose is that of the QLD MRHI agency who gathered additional reference site data after the 1994-96 drought. (Models in this state have been based upon data gathered during drought years, 1994-95.) For any of the MRHI agencies, the running of year 2 reference site data through a model constructed from year 1 data for the same season will provide useful information as to the presence, extent and influence of short-term temporal variability.

2. Modelling temporal variability

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Seeking environmental correlates that may account for temporal variability is unlikely to be successful for the following situations, each pertinent to streams of northern Australia: (i) seasonally-flowing streams where shifts in community composition over time may be associated with stochastic recolonisation processes; (ii) longer-term (several years) recovery and recolonisation of streams following massive disturbance; and (iii) switches between different community 'steady states' where triggers for the switch may be clearly identified, but the trajectory of community composition thereafter is either lagged, or unknown and unpredictable. Associated with these difficulties is the possibility of inter-catchment differences in community responses. Humphrey and Doig (1997), for example, describe the structure of macroinvertebrate communities in the permanent reaches of the South Alligator River and Magela Creek (adjacent catchments) between 1988 and 1995; the SAR observed considerable community changes over the time interval whereas virtually no change was observed in Magela Creek.

Modelling of drought-related changes to macroinvertebrate communities would be particularly useful for MRHI model development in eastern Australia. As is the case for northern regions, however, there is presently little understanding of the responses of macroinvertebrate communities to drought, including how responsive the fauna is to environmental change, as well as the degree to which differences in response may vary at regional and inter- and intra-catchment scales (cf results above for lower Latrobe R, VIC, Barker-Barambah Cks and Stony Ck sites, QLD). Stream order and altitudinal differences in persistence have also been observed in other countries (reviewed above) whilst Boulton and Lake (1992) observed lags in community response to drought in seasonally-flowing streams of Victoria. Collectively, these observations suggest that modelling of drought-related changes might not be possible. Examination of existing agency data sets would assist in redressing current information deficiencies (see above comments pertaining to QLD MRHI samples).

3. Adjusting and updating model output

It has been suggested that where community composition, and particularly taxa richness, has changed due to broad-scale climate change (especially drought), suitable reference sites be resampled simultaneously with monitoring sites in order to adjust model output. Thus, reference sites in times of drought would have a lower taxa richness than that 'expected'; a scaling factor equivalent to the difference in O/E between non-drought and drought conditions would then be applied to monitoring site output to 'correct' or 'adjust' for the response due to climatic variation. Analogous to the problem identified in item 2 above, however, there would be a need to include sufficient reference sites that were representative of each of the classification groups - as well as important catchment differences represented within a group - making up the agency model. As discussed above, macroinvertebrate community response to drought may differ within a catchment (upland vs lowland) whilst for a model based upon a large geographical area (QLD, NSW), the response may differ depending upon latitude. A further problem with such adjustments is that it is unlikely that the scaling factor would be the same across the entire gradient of disturbance. Thus, the relative loss of taxa from reference sites as a consequence of drought may be greater than that from sites disturbed as a consequence of drought *and* impaired water quality. The assumption of simple additive change (taxa loss) across the gradient of undisturbed to very disturbed sites during times of drought requires testing, with appropriate scaling factors derived if the assumption is found wanting. Of course the conservative and obvious fall-back to account for such non-additive change in this case is to re-sample in time a selection of both reference *and* disturbed sites, thereby deriving the appropriate scaling factor empirically.

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4. Models for different climatic conditions

Models empirically derived for different climatic conditions, such as drought vs non-drought, would have the advantage that fewer assumptions are made about the responses of macroinvertebrate communities in different habitat, between different parts of a catchment, amongst catchments, or across a disturbance gradient. The disadvantage in this approach is one of expense, whilst the (untested) assumption is made that responses to one drought will be the same as the next, even though droughts differ in their intensity. At best, interpolation and extrapolation between different models may enable some allowance to be made for different climatic conditions. Nevertheless, some of the current agency data sets span a period of 'drought' and 'non-drought'; processing of all these data and derivation of different models for different climatic conditions may be exceedingly valuable.

Some combination of approaches 3. and 4. may provide adequate solutions to developing AUSRIVAS models that account for temporal variability.

5. Combined-seasons or combined-years models

No analysis of combined-seasons data (eg Autumn and Spring) for a particular habitat was carried out in this study. There is little doubt that temporal variability would be reduced substantially with this approach. (This may be the cause, for example, of Latrobe R communities being the most persistent of all those compared in this study.) Weatherley and Ormerod (1990) suggested further that for regions of relatively high climatic variability where persistence of macroinvertebrate communities may be low, development of models based on more than one year of data would result in more robust models.

One disadvantage with this approach is the need to accumulate two seasons/years of data before an assessment of water quality based upon macroinvertebrate communities can be made. Although this may provide some indication of longer-term severity of a water quality problem, it is certainly contrary to the ethos of rapid biological assessment and rapid turnaround of results. Another disadvantage of this approach may lie in construction of a model so robust and overly-inured to natural environmental change that only impacts of a particularly severe nature are detected whilst impacts isolated to only one of the seasons may pass undetected.

Related to approaches 4. and 5., some agencies have constructed models by adding new reference sites gathered for a given season and from consecutive years of sampling, to an existing model (eg UK RIVPACS, MRHI ACT agency). Without simultaneous sampling of some common reference sites to account for possible temporal variation, this approach runs the risk of introducing temporal confounding to models.

Risk-based assessment using AUSRIVAS models

Whether or not it is possible to account for temporal variability for AUSRIVAS modelling, the information provided in this report will be valuable to managers and researchers alike. In particular, the magnitude of the persistence indices calculated (Table 5) and modelled in this study according to different regions and stream types, may eventually be related to some measure of AUSRIVAS model 'noise' and variability and, consequently, to incidence of inaccurate model predictions. Hence, for a particular location in Australia, there would be some measure of the accuracy and reliability of AUSRIVAS output for water quality assessment if temporal variability alone was the main source of 'noise' occurring in models. With quantified degrees of 'risk' of model failure, researchers and managers might then be better informed and placed to account for such variability, stipulate probability and error statements around predictions or recommend alternative monitoring approaches.

Thus, concomitant with improving the accuracy of predictive models, there is also a need to extend and improve the persistence models developed in this study to a greater number of locations and habitats relevant to MRHI.

Concluding remarks

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Temporal variability has the potential to reduce the efficacy of predictive models at any spatial scale, but in the case of assessments conducted at small scales (sites, catchment) using models derived for entire states and territories, predictions will be sensitive to the relatively localised effects of various natural disturbances - for example, drought effects arising in part of the state only, or cyclonic disturbance that affects only two or three catchments. Precision and accuracy with which water quality assessments can be made at these small scales will be reduced. Thus for geographical regions of Australia where temporal variability may reasonably high, our results are consistent with the promotion of AUSRIVAS as a coarse, broad-scale screening tool for biological monitoring. In these regions and where site-specific assessments are required, it may be necessary to resort to more traditional hypothesis-testing approaches involving BACI designs and derivatives around local reference sites (Underwood 1991, Faith et al 1995, Keough & Mapstone 1995).

The relatively high degree of temporal variability observed at family level for a number of geographical regions of Australia would suggest that models developed for lower levels of taxonomic resolution would probably perform quite poorly. Major temporal changes would be expected at generic and species level giving rise to low constancy within and amongst years.

Acknowledgments

The provision of long-term data sets for analysis and ensuing discussions on interpretation of results is gratefully acknowledged from the following custodians: Peter Davies (WA), Richard Pearson, Angela Arthington, Satish Choy, Richard Norris, Leon Metzeling, Richard Marchant, Peter Davies (TAS), Andrew Boulton and Andrew Storey. Ken Thomas, Jon Marshall, Laurie Cook and Chris Madden also assisted in compiling and forwarding the long-term data from NSW, south-east QLD, TAS and SA, respectively. Ruth O'Connor of *eriss* provided data for Magela Creek (NT). A special thanks to Satish Choy who sampled and forwarded data at short notice; he also provided useful information on MRHI sites sampled in QLD and effects of drought on the stream fauna of that state. We are grateful to Bill Macfarlane, Robin Galbreath, David Norton and Marcia Masiero of *eriss* for assistance with data analysis and compilation. Finally, we thank Sam Lake, Richard Marchant and Andrew Boulton for comments on an earlier draft that have improved this report considerably.

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APPENDIX A

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A comparison of macroinvertebrate community data gathered by different sampling and sample processing methods

Introduction and methods

Data gathered from simultaneous sampling at sites from a number of Australian streams, using quantitative Surber sampling and single-replicate MRHI/FBA 10 m kick samples, were compared. This was conducted in order to assess whether data gathered using different sampling methods from the same sites over time were sufficiently similar that they could be combined for analysis of temporal variability. Details of the sites sampled (riffle habitat only), and sampling and sample processing methods used, are described in Table B1. Both Surber and kick net samples were preserved in the field for later laboratory subsampling and sorting. All replicate samples (single replicate for kick sample) were subsampled and sorted to ~ 100 (WA) -200 animals. Thus, for a given site and sampling occasion, a much greater number of animals was sorted from Surber samples compared with kick samples.

Geographical region, river and source of data	Sites	Sampling and sample processing method
Wet-Dry tropics, South Alligator River R (NT)	Same 3 sites as described in section 2.1 of the main report.	Standard MRHI kick-sweep net (250 μ m mesh) & 4 x 0.063 m ² Surber samples (250 and/or 500 μ m meab)
Data source: C Humphrey,		Surber sample processing: mean abundances
6//35		across 4 reps, each rep a subsample of ~200 animals
Sub-alpine, Thredbo R (NSW)	Two sites: site 1 as described in section 2.1 of the main	Standard MRHI kick-sweep net (250 μm mesh) & 5 x 0.09 m^2 Surber samples (500 μm mesh)
Data source: R Norris, CRC Freshwater Ecology, UC	report and site 2 located 1 km downstream, immediately below township of Thredbo	Surber sample processing: mean abundances across 5 reps, each rep a subsample of ~200 animals
Cool temperate streams in Mt Lyell region of western	Comstock Creek (site 4) and Governor R, as described in	Standard MRHI kick-sweep net (250 μm mesh) & 10 x 0.09 m² Surber samples (250 μm mesh)
Tasmania	Davies et al (1996)	Surber sample processing: mean abundances
Data source: P Davies, Freshwater Systems/UTAS		across 10 reps, each rep a subsample of 100-200 animals
Warm temperate, south- west WA, North Dandalup	Sites 1, 2 & 4 are upland sites in heterogeneous substrates,	Standard FBA kick-sweep net (250 μm mesh) & 8 x 0.063 m² Surber samples (250 μm mesh)
River	and sites 7, 9 & 11 are	Surber sample processing: mean abundances
Data source: A Storey, UWA	homogeneous sand substrate. Site locations presented in Storey et al (1991)	across 6 reps, each rep a subsample of ~100 animals.

Table A1. Sites sampled, and sampling and sample processing methods used for comparison of Surber vs kick-sweep net sampling

The South Alligator River (NT) comparative study comprised quantitative Surber sampling by *eriss* and standard 10 m kick sampling by the NT MRHI agency (NT Lands, Planning and Environment Dept, LP&E). At any of the sites, DLP&E sampled generally within 100 m of *eriss*, the same section of riffle never being disturbed more than once. DLP&E samples were retained by 250 µm mesh net and sieves whilst *eriss* samples were retained by 500 µm mesh net and sieves. For selected sites and sampling occasions, however, a $250 \mu m$ mesh net sleeve was placed over the 500 μm mesh net of the Surber sample to compare community structure of the samples retained by the two different meshes (ie 250 & 500 μm fractions combined vs 500 μm fraction. *eriss* personnel processed and identified both Surber and kick net samples.

Data gathered by each method were compared for each site and sampling occasion by way of Bray-Curtis dissimilarity measures, using presence-absence and rank abundance data. For data from each pair of samples, comparisons were made for the top ranking 50% of taxa (presence-absence (p-a) and rank abundance data) and top ranking 90% of taxa (p-a data) using data averaged between the two samples. The method for determining the different taxa rankings for each pair of samples is described in section 2.3.1 above of the main report.

Results and discussion

The comparative results for different sampling methods obtained from simultaneous sampling of the riverine sites from the four regions, are shown in Tables A2-A5. The results are discussed firstly in relation to those obtained for the South Alligator River (SAR) and secondly, across all streams. More detailed interpretation is provided for the SAR results because of the personal involvement of the senior author in all phases of the study; moreover, this study was important to the analyses conducted in a related project (Humphrey & Doig 1997).

Table A2. Dissimilarity values and taxa richness for comparison of macroinvertebrate community data derived using Surber and kick sampling methods at sites on the upper South Alligator River, NT. The '250 μ m' designation refers to comparisons made between the agencies where Surber samples were retained by 250 μ m mesh as opposed to 500 μ m mesh for other samples. P-A and R-A refer to presence-absence and rank-abundance data respectively, while top 50 and 90% refer to top ranking 50 and 90% of taxa respectively, averaged between the two samples.

Year and site	No of Taxa	Bi	ray-Curtis Dissimilar	ity
	(Surber/kick)	P-A (top 50%)	P-A (top 90%)	R-A (top 50%)
Oct 1994	<u></u>			
site 1	22/14	0.1	0.176	0.869
site 2	22/17	0.043	0.135	0.283
site 3	25/17	0.083	0.179	0.332
May 1995				
site 1	22/17	0.0	0.105	0.277
site 1 (250 μm)	22/17	0.0	0.105	0.273
site 2	19/20	0.0	0.128	0.555
site 2 (250 µm)	23/20	0.0	0.073	0.518
site 3	19/20	0.0	0.081	0.384
site 3 (250 μm)	21/20	0.0	0.053	0.296
Oct 1995				
site 1	19/16	0.0	0.152	0.231
site 2	19/17	0.0 0.118		0.268
site 3	20/19	0.0	0.027	0.165

South Alligator River

The results for sampling of SAR riffle habitat, presented in Table A2, indicate generally small differences in family-level, macroinvertebrate community data derived using different sampling methods, particularly with analyses based upon presence-absence data. This is despite differences in methods, including replicate Surber sampling vs single replicate kick sampling, variation in mesh sizes employed and data summarised for a subsample of 200 animals only in the case of the DLP&E agency compared with summary data derived from an

average across 4 replicates, each replicate comprising 200 animals in the case of *eriss* samples.

Discrepancies in dissimilarities calculated using rank abundance data occurred for site. 1 in October 1994 and sites 2 and 3 in May 1995 (Table A2). In each of the DLP&E samples for these sites and occasions, a disproportionately large number of Acarina and Simuliidae were retained compared with numbers in the *eriss* samples (data not shown here). Differences in community structure between the two samples may have arisen because of different microhabitats sampled by the two agencies or because most individuals of these taxa present at the sites on these occasions may have been of a size intermediate between 250 and 500 µm.

This explanation concerning mesh sizes can account for differences in Acarina abundance. Thus, although abundance data are not provided, the small 'improvement' in the results of Table A2 after DLP&E data are compared with data derived from samples retained by 250 μ m mesh, is mainly a result of the addition of large numbers of individuals of this taxon and, to a lesser extent, elmid beetles, to the *eriss* samples. Only in one sample (site 3, May 1995) were relatively large numbers of simuliids found of a size intermediate between 250 and 500 μ m. The *eriss* samples were always collected from 'small pebble' habitat (Humphrey et al 1997) whereas DLP&E samples were collected from all size classes of bed material present in riffles. Thus, the likely occurrence of relatively higher numbers of simuliids present on cobbles and boulders sampled by DLP&E in faster-flowing waters of the riffles would explain the discrepancy in numbers for this taxon.

Given that generally only small decreases in dissimilarities between *eriss* and DLP&E community data occurred after data for similar mesh size $(250 \,\mu\text{m})$ were compared, the results presented in Table 4 would suggest that the main contribution to the discrepancies arising between the two agencies was in different micro-habitats sampled and in the differences in numbers of animals sorted and identified from the samples derived from the different methods (see below).

Year and site	Number of taxa	B	ray-Curtis Dissimilar	ity
	(Surber/kick)	P-A (top 50%)	P-A (top 90%)	R-A (top 50%)
May 1994				
site 1	17/14	0.048	0.310	0.337
site 2	16/14	0.0	0.214	0.345
Aug 1994				
site 1	8/15	0.143	0.333	0.430
site 2	23/12	0.044	0.273	0.207
Nov 1994				
site 1	22/17	0.040	0.278	0.274
site 2	23/12	0.143	0.333	0.141
Feb 1995				
site 1	24/20	0.0	0.122	0.243
site 2	27/14	0.120	0.263	0.497
May 1995				
site 1	25/17	0.083	0.180	0.411
site 2	15/16	0.100	0.310	0.484

Table A3. Dissimilarity values and taxa richness for comparison of macroinvertebrate community data derived by Surber and kick sampling methods at two sites on the Thredbo River, NSW. P-A and R-A refer to presence-absence and rank-abundance data respectively, while top 50 and 90% refer to top ranking 50 and 90% of taxa respectively, averaged between the two samples.

Table A4. Dissimilarity values and taxa richness for comparison of macroinvertebrate community data derived by Surber and kick sampling methods at two sites in western Tasmania. P-A and R-A refer to presence-absence and rank-abundance data respectively, while top 50 and 90% refer to top ranking 50 and 90% of taxa respectively, averaged between the two samples.

Year and site	Number of taxa	Bray-Curtis Dissimilarity				
	(Surber/kick)	P-A (top 50%)	R-A (top 50%)			
Spring 1995	, <u></u>					
Comstock Ck	6/6	0.0	0.273	0.089		
Governor River	17/19	0.091	0.235	0.716		

Table A5. Dissimilarity values and taxa richness for comparison of macroinvertebrate community data derived by Surber and kick sampling methods at sites on the North Dandalup River, WA. P-A and R-A refer to presence-absence and rank-abundance data respectively, while top 50 and 90% refer to top ranking 50 and 90% of taxa respectively, averaged between the two samples.

Year and site	Number of taxa	Bray-Curtis Dissimilarity				
	(Surber/kick)	P-A (top 50%)	P-A (top 90%)	R-A (top 50%)		
June 1987						
site 1	19/15	0.0	0.188	0.197		
site 2	26/22	0.0	0.067	0.172		
site 4	24/20	0.083	0.095	0.314		
site 7	19/14	0.200	0.355	0.086		
site 9	18/11	0.177	0.333	0.223		
site 11	17/11	0.0	0.231	0.230		
Sept 1987						
site 1	16/19	0.0	0.152	0.147		
site 2	16/17	0.0	0.226	0.245		
site 4	20/13	0.048	0.226	0.216		
site 7	21/14	0.048	0.212	0.076		
site 9	10/6	0.0	0.200	0.294		
site 11	12/8	0.0	0.158	0.295		
Dec 1987						
site 1	24/12	0.182	0.394	0.086		
site 2	18/18	0.048	0.177	0.174		
site 4	22/15	0.143	0.200	0.254		
site 7	25/8	0.238 0.484		0.287		
site 9	11/13	0.067	0.273	0.245		
site 11	12/9	0.0	0.100	0.062		

Across all streams

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When results are viewed collectively across all streams (Tables A2-A5), two features are noteworthy. Firstly, Surber data are characterised by greater taxa richness than data for kick samples. The most obvious explanation for this lies in the greater number of animals sorted and identified from Surber samples, and therefore, the greater chance of recovering additional taxa using this approach. A further explanation may lie in the greater localised intensity with which the stream bed is disturbed in Surber sampling compared with kick net sampling. As a result, animals from additional microhabitats might be recovered in Surber samples.

The second feature of the collective results, is the differences found amongst streams in degree of similarity in community composition (family-level, p-a data) between the two sampling methods. Variable dissimilarity values observed are presumably a result of differences in taxa recovery and (micro)habitats sampled (as discussed above). Mean compositional dissimilarity values (top 90% of taxa) observed for the 4 regions were: 0.122,

SAR, NT; 0.261, Thredbo R; NSW; 0.254, Mt Lyell streams, TAS; and 0.226, North Dandalup River, WA. The lower values observed for the SAR and North Dandalup River might be associated with greater homogeneity of habitat and/or lower seasonal discharges observed in these streams at the time of sampling, compared with conditions observed in the Thredbo R and west Tasmanian streams.

On the basis of the relatively small dissimilarity values (family-level p-a) derived from quantitative areal sampling and single dip/sweep net sampling at sites of low seasonal discharge and (relative) habitat homogeneity, it was decided that comparison of data derived from the two methods (i) within Flinders Ranges stream data sets would be acceptable, and (ii) for the Thredbo R would not be appropriate. Even so, it is stressed that combining data in this fashion is risky; our results suggest that any evaluation of the compatibility or otherwise of data derived using the two approaches would need to be carried out on a site by site basis. Thus the approach adopted for the Flinders Ranges data set may need to be reviewed as the results of any studies that were conducted in this region to address this issue came to hand.

For the Thredbo River data set, interannual comparisons were confined to data gathered using a common sampling method, see Table C7.1.

References

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- Humphrey C & Doig L 1997. Benthic macroinvertebrate communities in riffle substrates of streams in the Northern Territory, 1994-1995: temporal variability and implications for MRHI model development. In: Temporal variability of macroinvertebrate communities in Australian streams: Implications for the prediction and detection of environmental change, by CL Humphrey. Final Report to Land and Water Resources Research and Development Corporation (Reference No. ARR1), December 1997.

APPENDIX B

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Tables B1-B12 summarising results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures) for stream sites located in various parts of Australia

Table B1. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a site on Robe River, north-west WA.

•	Pilbara (NW WA)
Site details	
Site (#)	1
Permanent (P) or seasonally- flowing (S)	S
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	LD
Habitat (Riffle, Macrophyte, Pool, Combined)	Р
No. of years (N comparisons)	6 (15)
Between-year comparisons	
Rank abundancə	
% dissim > 0.5 (top 50%)	27
Mean dissim (top 50%)	0.443
Presence-absence	
% dissim > 0.35 (top 50%)	27
% dissim > 0.35 (top 90%)	93
% dissim > 0.4 (top 50%)	27
% dissim > 0.4 (top 90%)	93
Mean dissim (top 90%)	0.431

Table B2. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on the upper South Alligator River, NT.

	South Alligator R (NT)							
Site details Site (# and COMbined)	1	5	8	COM	1	5	8	СОМ
Permanent (P) or seasonally- flowing (S)	Р	Ρ	Р	Р	Р	Ρ	Ρ	P
Season (W in, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	ED	ED	ED	ED	LD	LD	LD	LD
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	R	R	R	R	R	Ŕ
No. of years (N comparisons)	6 (15)	6 (15)	6 (15)	6 (45)	9 (36)	9 (36)	10 (45)	10 (117)
Between-year comparisons Rank abundance								
% dissim > 0.5 (top 50%)	33	47	47	42	50	17	49	39
Mean dissim (top 50%)	0.416	0.481	0.527	0.475	0.469	0.355	0.497	0.440
Presence-absence % dissim > 0.35 (top 50%)	0	0	0	0	0	0	2	1
% dissim > 0.35 (top 90%)	13	27	0	13	3	0	38	14
% dissim > 0.4 (top 50%)	o	0	0	0	0	0	0	0
% dissim > 0.4 (top 90%)	7	0	0	2	0	0	13	4
Mean dissim (top 90%)	0.222	0.249	0.203	0.225	0.215	0.206	0.304	0.242

Table B3. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for an undisturbed site on Rockhole Mine Ck (RMC), NT.

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	RMC (NT)
Site details Site (#)	1
Permanent (P) or seasonally- flowing (S)	S
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	ED
Habitat (Riffle, Macrophyte, Pool, Combined)	R
No. of years (N comparisons)	4 (6)
Between-year comparisons	
% dissim > 0.5 (top 50%)	0
Mean dissim (top 50%)	0.399
Presence-absence % dissim > 0.35 (top 50%)	0
% dissim > 0.35 (top 90%)	17
% dissim > 0.4 (top 50%)	0
% dissim > 0.4 (top 90%)	0
Mean dissim (top 90%)	0.237

Table B4. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on Magela Creek, NT.

	Ma	gela Ck (N	IT)
Site details Site (#)	1	3	СОМ
Permanent (P) or seasonally- flowing (S)	S	S	S
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	ED	ED	ED
Habitat (Riffle, Macrophyte, Pool, Combined)	R-M	R-M	R-M
No. of years (N comparisons)	8 (28)	8 (28)	8 (56)
Between-year comparisons			
% dissim > 0.5 (top 50%)	36	36	36
Mean dissim (top 50%)	0.436	0.418	0.427
Presence-absence % dissim > 0.35 (top 50%)	0	11	5
% dissim > 0.35 (top 90%)	18	25	21
% dissim > 0.4 (top 50%)	0	4	2
% dissim > 0.4 (top 90%)	7	14	11
Mean dissim (top 90%)	0.257	0.300	0.279

Table B5. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a site on Yuccabine Creek, north-east QLD.

	Yuccabine Ck (NE QLD)		
Site details	1	•	
Sile (#)		,	
Permanent (P) or seasonally- flowing (S)	Р	Р	
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	ED	LD	
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	
No. of years (N comparisons)	5 (10)	4 (6)	
Between-year comparisons			
Rank abundance	50	17	
% dissim > 0.5 (top 50%)	50	17	
Mean dissim (top 50%)	0.468	0.359	
Presence-absence			
% dissim > 0.35 (top 50%)	0	0	
% dissim > 0.35 (top 90%)	30	0	
% dissim > 0.4 (top 50%)	0	0	
% dissim > 0.4 (top 90%)	20	0	
Mean dissim (top 90%)	0.294	0.217	

	South-east QLD									
Site de ta ils										
Site (# and COMbined)	BB	Litz	Ston2	Ston3	COM	BB	Litz	Ston2	Ston3	СОМ
Permanent (P) or seasonally- flowing (S)	Р	Ρ	Ρ	Ρ	P	Ρ	Ρ	Ρ	Ρ	P
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	A	A	A	A	A	S	S	S	S	S
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	R	R	R	R	R	R	R	R
No. of years (N comparisons)	3 (3)	3 (3)	3 (3)	3 (3)	5 (12)	4 (6)	4 (6)	3 (3)	3 (3)	5 (18)
Between-year comparisons										
% dissim > 0.5 (top 50%)	67	67	67	67	67	67	50	33	0	38
Mean dissim (top 50%)	0.488	0.715	0.515	0.534	0.563	0.545	0.546	0.495	0.265	0.463
Presence-absence										
% dissim > 0.35 (top 50%)	0	0	0	0	0	50	17	0	0	17
% dissim > 0.35 (top 90%)	0	0	0	0	0	50	100	0	0	38
% dissim > 0.4 (top 50%)	0	0	0	0	0	50	17	0	0	17
% dissim > 0.4 (top 90%)	0	0	0	0	0	50	83	0	0	33
Mean dissim (top 90%)	0.179	0.287	0.238	0.281	0.246	0.365	0.456	0.278	0.257	0.339

Table B6. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on Barker-Barambah (BB, Litz) and Stony Cks, south-east QLD.

Table B7. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a site on the Thredbo River, south-eastern NSW.

	Thredbo R (NSW)		
Site details			
Site (#)	1	1	
Permanent (P) or seasonally- flowing (S)	Ρ	Ρ	
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	S	Su	
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	
No. of years (N comparisons)	9 (22)	7 (21)	
Between-year comparisons			
Rank abundance			
% dissim > 0.5 (top 50%)	56	19	
Mean dissim (top 50%)	0.528	0.371	
Presence-absence			
% dissim > 0.35 (top 50%)	5	0	
% dissim > 0.35 (top 90%)	36	19	
% dissim > 0.4 (top 50%)	5	0	
% dissim > 0.4 (top 90%)	23	10	
Mean dissim (top 90%)	0.303	0.232	

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						Latrob	e R (VIC))				
Site details Site (# and COMbined)	Ult4	Ult6	Ult15	Ult28	Ult41	Uit52	Ult53	Ult60	COM	Llt1	Llt1	COM
Permanent (P) or seasonally- flowing (S)	Р	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	с	С	С	С	С	С	С	С	С	С	A	C/A
Habitat (Riffle, Macrophyte, Pool, Combined)	с	С	С	С	С	С	С	С	С	С	С	С
No. of years (N comparisons)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	5 (10)	7 (11)
Between-year comparisons												
Rank abundance % dissim > 0.5 (top 50%)	100	100	100	100	100	100	100	100	100	100	40	36
Mean dissim (top 50%)	0.871	0.871	0.854	0.742	0.879	0.779	0.849	0.798	0.830	0.930	0.410	0.670
Presence-absence % dissim > 0.35 (top 50%)	0	0	0	0	0	0	0	0	0	0	0	0
% dissim > 0.35 (top 90%)	0	0	0	0	0	0	0	0	0	0	10	9
% dissim > 0.4 (top 50%)	0	0	0	0	0	0	0	0	0	0	0	0
% dissim > 0.4 (top 90%)	0	0	0	0	0	0	0	0	0	0	0	0
Mean dissim (top 90%)	0.344	0.200	0.278	0.263	0.282	0.171	0.188	0.235	0.245	0.345	0.226	0.286

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Table B8. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on the upper (Ult) and lower (Llt) Latrobe River, in southern Victoria.

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Table B9. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on the Wimmera River, north-western VIC.

Site details			Wimmera	R (VIC)			
Site details Site (# and COMbined)	1	4	COM	1	4	СОМ	
Permanent (P) or seasonally- flowing (S)	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	A	A	A	S	S	S	
Habitat (Riffle, Macrophyte, Pool, Combined)	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	
No. of years (N comparisons)	4 (6)	4 (6)	4 (12)	6 (15)	7 (21)	7 (36)	
Between-year comparisons Rank abundance							
% dissim > 0.5 (top 50%)	67	33 50		47	24	33	
Mean dissim (top 50%)	0.516	0.486	0.501	0.470	0.406	0.438	
Presence-absence % dissim > 0.35 (top 50%)	0	0	0	0	0	0	
% dissim > 0.35 (top 90%)	0	0	0	33	43	39	
% dissim > 0.4 (top 50%)	0	0	0	0	0	0	
% dissim > 0.4 (top 90%)	0	0	0	27	29	28	
Mean dissim (top 90%)	0.184	0.183	0.184	0.321	0.337	0.329	

	Musselboro-Coquet Cks (Tas)								
Site details Site (# and COMbined)	Muss	Coq	сом	Muss	Coq	сом			
Permanent (P) or seasonally- flowing (S)	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ			
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	A	A	A	S	S	S			
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	R	R	R	R			
No. of years (N comparisons)	3 (3)	4 (6) 4 (9)		3 (3)	5 (10)	5 (13)			
Between-year comparisons Rank abundance		47							
% dissim > 0.5 (top 50%)	0	17	11	0	0	0			
Mean dissim (top 50%)	0.448	0.452	0.434	0.395	0.355	0.375			
Presence-absence									
% dissim > 0.35 (top 50%)	0	0	0	0	0	0			
% dissim > 0.35 (top 90%)	0	0	0	0	20	15			
% dissim > 0.4 (top 50%)	0	0	0	0	0	0			
% dissim > 0.4 (top 90%)	0	0	0	0	0	0			
Mean dissim (top 90%)	0.136	0.248	0.192	0.1 9 4	0.237	0.216			

Table B10. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a sites on Musselboro-Coquet Cks, TAS.

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Table B11. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a sites on Oratunga (OR) and Brachina (BR) Cks, Flinders Ranges, SA.

	Flinders Ranges (SA)														
Site details Site (# and COMbined)	OR	OR	OR	BR	BR	BR	сом	OR	OR	OR	BR	BR	BR	WR	сом
Permanent (P) or seasonally- flowing (S)	Р	Р	Ρ	Ρ	Ρ	Р	Ρ	Р	Р	Ρ	Ρ	Ρ	Ρ	S	Ρ
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	w	W	W	W	W	W	w	S	S	S	S	S	S	S	S
Habitat (Riffle, Macrophyte, Pool, Combined)	R	М	Ρ	R	М	Ρ	С	R	Μ	Ρ	R	М	Ρ	Р	С
No. of years (N comparisons)	3 (3)	2 (1)	3 (3)	3 (3)	3 (3)	3 (3)	3 (16)	4 (6)	2 (1)	4 (6)	4 (6)	4 (6)	3 (3)	3 (3)	4 (31)
Between-year comparisons															
Rank abundance % dissim > 0.5 (top 50%)	0	100	0	0	0	0	6	0	0	16	0	0	0	33	6
Mean dissim (top 50%)	0.247	0.763	0.364	0.210	0.268	0.280	0.355	0.181	0.333	0.382	0.218	0.300	0.210	0.459	0.298
Presence-absence % dissim > 0.35 (top 50%)	0	100	0	0	0	0	6	0	0	33	0	0	0	0	6
% dissim > 0.35 (top 90%)	67	100	33	0	33	33	38	0	0	83	33	50	33	100	45
% dissim > 0.4 (top 50%)	0	100	0	0	0	0	6	0	0	33	0	0	0	0	6
% dissim > 0.4 (top 90%)	33	100	33	0	33	0	25	0	0	50	0	33	33	100	29
Mean dissim (top 90%)	0.362	0.688	0.357	0.232	0.327	0.300	0.378	0.282	0.260	0.428	0.285	0.337	0.290	0.498	0.340

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Table B12. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a sites on Canning (CD) & North Dandalup (ND) Rivers, south-west WA.

	South-west WA																							
Site details Site (# and COMbined)	CD1	CD2	CD3	CD4	CD5	сом	CD6	ND1	ND2	ND3	ND4	COM	CD1	CD2	CD3	CD4	CD5	сом	CD6	ND1	ND2	ND3	ND4	сом
Permanent (P) or seasonally- flowing (S)	s	S	S	S	S	S	Ρ	Ρ	Ρ	Ρ	Ρ	Ρ	S	S	S	S	S	S	Ρ	Ρ	Ρ	Ρ	Р	Ρ
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	S	S	S	S	S	S	S	S	S	S	S	S	w	w	w	w	w	w	w	w	w	w	w	w
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
No. of years (N comparisons)	3 (3)	3 (3)	3 (3)	3 (3)	3 (3)	3 (15)	3 (3)	3 (3)	3 (3)	3 (3)	3 (3)	3 (15)	3 (3)	5 (10)	5 (10)	3 (3)	3 (3)	5 (29)	3 (3)	3 (3)	3 (3)	3 (3)	3 (3)	3 (15)
Between-year comparisons Rank abundance																					• • •	٠	.**	
% dissim > 0.5 (top 50%)	0	33	0	0	33	13	0	0	0	0	0	0	0	0	40	33	0	17	0	0	33	0	0	7
Mean dissim (top 50%)	0.337	0.402	0.262	0.365	0.386	0.350	0.296	0.156	0.243	0.237	0.173	0.221	0.306	0.308	0.464	0.465	0.239	0.360	0.252	0.265	0.386	0.260	0.330	0.299
Presence-absence % dissim > 0.35 (top 50%)	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	0	0	10	0	0	0	0	0	0
% dissim > 0.35 (top 90%)	0	0	o	100	33	27	0	0	0	0	0	0	33	10	30	33	0	21	0	33	0	0	33	13
% dissim > 0.4 (top 50%)	0	0	0	0	G	0	0	0	0	0	0	0	0	10	0	0	0	3	0	0	0	0	0	0
% dissim > 0.4 (top 90%)	0	0	0	33	33	13	0	0	0	0	0	0	33	10	20	33	0	17	0	0	0	0	0	0
Mean dissim (top 90%)	0.142	0.208	0.213	0.374	0.314	0.350	0.200	0.203	0.199	0.239	0.231	0.214	0.333	0.260	0.322	0.263	0.187	0.277	0.264	0.306	0.082	0.219	0.293	0.233

ATTACHMENT 2

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Macroinvertebrate communities from riffle habitat of streams in the Northern Territory, 1994-95: temporal variability and possible implications for MRHI model development

FINAL REPORT

by

Chris Humphrey & Lorne Doig ERISS, Locked Bag 2, Jabiru, NT 0886;

December 1997

Macroinvertebrate communities in riffle habitat of streams in the Northern Territory, 1994-95: temporal variability and possible implications for MRHI model development

1 Background and objectives

An important virtue of long-term data sets lies in the ability to test assumptions behind broadscale models for monitoring. For predictive models such as those employed for AUSRIVAS, there is a key assumption concerning the constancy of community composition over time. If this constancy or persistence is not observed and if changes in communities from year to year cannot be accounted for using environmental data, then the models may fail in their classifications and predictions of invertebrate community composition. This is an issue therefore, that needs to be closely investigated in relation to development of impact assessment models based on predictive modelling in Australia.

In 1993, the *eriss* was commissioned by the Land and Water Resources Research and Development Corporation (LWRRDC), on behalf of the DEST-funded, national Monitoring River Health Initiative (MRHI), to conduct further sampling and sample processing (if necessary), and data compilation of macroinvertebrate communities in Australian streams. This R&D project would determine the degree of temporal variability evident in these long-term data sets and enable a preliminary assessment of the implications of the results for predictive modelling being developed as part of the MRHI. Where lack of persistence was found in long-term data from across Australia, the R&D project sought to:

- Explore the implications of the result by assessing whether the anomalous data classified near or together with those from related disturbed sites;
- Seek environmental correlates that could account for any year-to-year variation in community structure and input these variables to the MRHI predictive models; and
- Make appropriate recommendations according to different climatic/ hydrological regions of Australia.

Humphrey et al (1995) reported lack of persistence in macroinvertebrate communities of the upper South Alligator River (SAR). In particular, a switch in structure of macroinvertebrate communities (relative abundances) was observed between pre-1993 and post-1992 time periods. These authors explored the implications of this result by assessing whether the post-1992 data classified near or together with those from related disturbed sites. From ordinations conducted using data from both unpolluted/ mine-polluted portions of the adjacent Rockhole Mine Creek (RMC) and SAR data, post-1992/ pre-1993, it was shown that the magnitude of change occurring in the SAR post-1992 was even more severe than that occurring in polluted portions of RMC. Moreover, the nature of the change in community response in the SAR mimicked the pollution gradient evident in the mine-impacted stream (Humphrey et al 1995).

The limitations of the approach described above to MRHI modelling are twofold: Firstly, the analysis for SAR-RMC was based upon family-level abundance data. The analysis has not been repeated using presence-absence data but if this was performed it would probably indicate little change in SAR community composition between post-1992 and pre-1993 relative to that between the two RMC sites. Secondly, the ultimate test of whether or not temporal variability presents problems for predictive modelling lies in running long-term community compositional data for particular sites, such as those from the SAR, through agency classifications and models. In this context the severity or otherwise of any lack of community persistence - within the bounds of sensitivity of the models - can be fully

measured. Misclassifications and poor predictions would indicate potential problems for model development.

In April 1996, the NRHP committee approved a request from *eriss* for funds to carry out for the NT MRHI agency (Dept Lands, Planning & Environment or DLP&E), the sorting and identifying of the NT agency samples gathered from riffle habitat throughout the NT. This would enable the incorporation of long-term SAR data into the NT MRHI agency classification based upon riffle samples and an assessment to be made of the severity of lack of persistence in the SAR data.

Thus, specific objectives of this study included:

- 1. The sorting and identification of MRHI samples gathered by the NT agency from riffle habitat across NT sites from 3 sampling rounds, late dry season 1994, early dry season 1995 and late dry season 1995;
- 2. Incorporation of long-term riffle data from the Alligator Rivers Region, including SAR and upper Magela Ck, into the NT MRHI agency UPGMA classification based upon late Dry season samples from 1994 and 1995, and (if available) predictive model; and
- 3. Assessment of the possible implications to MRHI modelling of misclassifications and/or predictive model failures arising from 'high' temporal variability in the SAR long-term data as well as interannual differences (1994 and 1995) inherent in the NT MRHI agency data.

2 Methods

2.1 List of samples processed

NT MRHI agency samples from riffle habitat of 26 sites were sorted and identified in this study. Streams at each of the site locations flow all year round. Table A1 of the Appendix lists the sites, site codes and site locations for which macroinvertebrate samples were collected for processing. Sites in 7 major catchments were sampled, namely Victoria, Daly, Adelaide, Mary, South Alligator, Goyder and Roper Rivers, as well as small catchments located in the Darwin region and on Melville Island. Samples that were processed in this study were collected in 3 seasons, late dry season 1994, early dry season 1995 and late dry season 1995. Not all 26 sites were sampled in each season owing to access difficulties, onset of seasonal rains in different seasons etc. A listing of the sites sampled in each of these seasons is provided in Tables A2-A4 respectively. Complete site descriptions and environmental data accompanying the biological samples are held by NT DLP&E.

Each of the DLP&E samples was collected using the protocols described by Davies (1994). Thus, a standard MRHI 10 m kick sample using a dip net of 250 μ m mesh was taken at riffle habitat from each of the sites on each of the sampling occasions.

2.2 Sorting and identification of samples at eriss

Each of the 56 samples was subsampled at *eriss* using a modified Marchant multi-cell subsampler (Storey & Humphrey 1997). A sufficient subsample was taken such that at least 200 animals were obtained from the sorting of each sample. Invertebrate specimens were hand-picked from detritus contained in a sorting tray, using a Wild MZ8 microscope.

Identifications of the invertebrates were conducted mostly to family level by the junior author. A proportion of the identifications was checked by Mr Robin Galbreath (macroinvertebrate biologist with *eriss*).

2.3 Additional macroinvertebrate data used in UPGMA classification

Additional macroinvertebrate data from riffle habitat of streams of the Alligator Rivers Region (ARR) were incorporated in the UPGMA classification conducted in this study. These riffle data had been gathered and compiled by *eriss* from mid-late Dry season sampling in 1988 and 1995 at a site on each of upper Magela Ck (Bowerbird) and upper South Alligator River. The samples were collected using 500 µm mesh nets and sieves. The SAR and 1988 Bowerbird data were derived from quantitative Surber sampling (see Humphrey et al (1997b) for methods), whilst the Bowerbird 1995 sample was derived from a 10 m kick sample using a dip net. The 1995 SAR samples were taken at the same site and concurrently with those of the NT DLP&E. Persistence of macroinvertebrate communities of the upper SAR was believed to be much lower than that of upper Magela Creek. If this was the case, it would be anticipated that the Magela samples from 1988 and 1995 would classify much closer together than the SAR samples from 1988 and 1995 in the UPGMA of all NT data.

Humphrey et al (1997a) showed that there was generally little difference in family-level data derived from quantitative areal sampling and concurrent single dip/sweep net sampling, particularly for presence-absence data. Moreover, differences in community composition between samples gathered using 250 and 500 μ m mesh nets and sieves were very minor. These results indicate that it is valid to use in the same analysis, data derived from the two different sampling methods. As a check on this finding, DLP&E and *eriss* data for one SAR site sampled in the late Dry season of 1995 were both incorporated in the UPGMA classification; occurrence of both samples in the same classification group would indicate high similarity of community composition and structure. The samples that were used in the UPGMA classification that were additional to those of LP&E, together with codes and rationale for inclusion, are described in Table 1.

Sample (and agency)	Code	Rationale for inclusion
Bowerbird, upper Magela, 1988 (<i>eriss</i>)	BBRD88	Macroinvertebrate communities seemed persistent over time
Bowerbird, upper Magela, 1995 (eriss)	BBRD95	Macroinvertebrate communities seemed persistent over time
SAR site 3, 1988 (<i>eriss</i>)	SA03R88	Lack of persistence of macroinvertebrate composition and structure evident in long-term data.
SAR site 3, 1995 (<i>eriss</i>)	ERIS3R95	Lack of persistence of macroinvertebrate composition and structure evident in long-term data; compare with sample SA03R95 collected simultaneouly and from same site by DLP&E using different sampling method and mesh size
SAR site 3, 1995 (DLP&E)	SA03R95	NT DLP&E sample

Table 1. Additional riffle samples from the ARR used in the UPGMA classification together with codes and rationale for inclusion.

2.3 Data analysis

2.3.1 UPGMA classification

Classifications were conducted on presence-absence (p-a) and rank abundance data for all DLP&E sites sampled in the late Dry seasons of 1994 and 1995, as well as the additional (4) samples from the ARR listed in Table 1. Rank abundance data for each sample were obtained by dividing the abundance value for each taxon by the maximum abundance value found for a taxon in that sample. (This resulted in a taxa list ranked 0-1 from least abundant taxon (in this case absent) to most abundant taxon.) Prior to multivariate analysis, taxa present at 10% or less of samples were removed from the data set, as per standard approach to preparation of

MRHI data for construction of predictive models . Numerical classifications for both p-a and rank abundance data were derived using flexible UPGMA in the FUSE option in PATN (Belbin 1993), with the beta parameter set at the default (-0.1), as well as -0.3 for p-a data. The association matrix used to derive the classification was calculated using the Bray-Curtis dissimilarity measure.

2.3.2 Further analysis of the data

The UPGMA classifications derived for p-a and rank abundance data from NT riffles were forwarded to Mr Justen Simpson of the CRC for Freshwater Ecology (Canberra Uni) for his assessment of the potential in these results for further predictive model development.

3 Results and discussion

3.1 Degree of temporal variability amongst NT riffle communities

Classifications from UPGMA based upon default settings of beta (-0.1) are shown for rank abundance and p-a data in Figures 1 and 2 respectively. The rank abundance classification has three clearly defined groups at about the 0.8 dissimilarity level (Fig 1) whilst the p-a classification lacked any clearly-defined divisions in the classification (Fig 2). With a more dilating beta value of -0.3, there was an improvement in the definition of the p-a classification to four groups at about the 0.6 dissimilarity level (Fig 3).

The extent of misclassifications in the data was assessed by determining the percentage of sites for which data were available for successive years (1994 and 1995) that did not pair in the same classification group for both years. Fifteen DLP&E sites were available for such assessment. This was conducted for the rank abundance classification as well as the dilated p-a classification (Figs 1 & 3). (It is acknowledged, nevertheless, that groupings based on a beta value of -0.3 may merely be an artefact of the dilating procedure (Belbin 1993).) The extent of misclassification in the long-term ARR data (SAR and Magela Ck) was also determined from these classifications.

From the rank abundance classification, successive years of data for 20% of the 15 comparable sites occurred in different classification groups whilst for the p-a classification, this figure was slightly less than 50% of the comparable sites.

For the ARR data, the different sampling methods used concurrently and at the same SAR site gave similar results in terms of community composition and structure (SA03R95 vs ERIS3R95 samples, Table 2). (This result and those of Humphrey et al (1997a) verify that quantitative data derived from Surber samples and 10 m kick samples - as per data analysed in this study - may be validly combined in the same analysis.) Analyses of temporal variability showed that macroinvertebrate communities of upper Magela Creek were highly persistent between 1988 and 1995, with low interannual dissimilarity and occurrence in the same classification groups of both years of data for both p-a and rank abundance (Table 2). This contrasted with macroinvertebrate communities of the SAR site for which temporal variability - based upon rank abundance data at least - was high for the same interannual comparison (Table 2).

Table 2. Interannual and methodological comparison of ARR macroinvertebrate data according to different multivariate criteria. Site codes are provided in Table 1.

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Comparison	Analysis	Pres-abs	Rank abund		
BBRD88 vs BBRD95: Temporal variability	Dissimilarity	0.05	0.361		
	(Mis)Classify	С	C ÷		
SA03R88 vs ERIS3R95: Temporal variability	Dissimilarity	0.256	0.676		
	(Mis)Classify	Μ	Μ		
SA03R95 vs ERI\$3R95: Methodology	Dissimilarity	0.077	0.17 7		
	(Mis)Classify	С	С		



Figure 1. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon rank abundance data. Site codes provided in Tables 1 and A1.



Figure 2. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon presence-absence data. Beta set at -0.1. Site codes provided in Tables 1 and A1.

3.2 Further assessment of results and implications for predictive modelling

3.2.1 Rank abundance data

Only for a relatively small portion of southern temperate Australia is the rank abundance of macroinvertebrate communities sufficiently preserved in long-term data sets for there to be potential for development of predictive models based upon community structure data (Humphrey et al 1997a). Indeed, the misclassification of 1988 SAR data in the NT UPGMA classification based upon rank abundance exemplifies the pattern of high temporal variability found in macroinvertebrate communities of streams in tropical northern Australia (Humphrey et al 1997a). Moreover, the construction of models that account for rank abundance is a complex issue and only limited progress has been made worldwide on the development of such models. Even if these models were available and despite the adequate definition of groups in the NT riffle classification, the number of sites represented in this data set is regarded as too few to result in successful model construction (J Simpson, CRC for Freshwater Ecology pers. comm.).



Figure 3. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon presence-absence data. Beta set at -0.3. Site codes provided in Tables 1 and A1.

3.2.2 Presence-absence data

Advice received from the CRC for Freshwater Ecology was again to the effect that too few sites were represented in the classification based upon p-a data for predictive models to be successfully constructed (J Simpson, pers comm). The poor structure in the classification, moreover, was an additional constraining factor and even with the enforcement of sites into groups by dilation procedures there is no guarantee that discriminant function analysis could be successfully applied to the data.

A characteristic feature of the p-a classification based upon beta = -0.1 was the high inter-site similarity (Fig 1), such that this single classification was more reminiscent, to those constructing MRHI agency models, of a single *group* in any other classification derived from elsewhere in Australia (J Simpson pers comm). A similar finding has been found for the NT MRHI agency's classification based upon sand habitat communities from across the NT, derived from a data base with a greater number of sites (52). (There is the suggestion in these results of considerable uniformity of environmental conditions across stream sites of the NT.)

The high inter-site similarity of the p-a classification derived for NT riffle data implies that very minor changes in community composition between any pair of sites could result in

substantial shifts in their position relative to one another in the classification. This is presumably the reason that in the dilated classification, successive years of data for about 50% of the 15 comparable sites occurred in different classification groups, despite reasonably low interannual pairwise dissimilarity. Thus, the classification is very sensitive to temporal variation.

With little structure in numerical classifications - such as characterises macroinvertebrate community composition of sand and riffle habitat of NT sites - there is a limited basis upon which predictive models may be constructed. For sand habitat data from NT sites, the CRC for Freshwater Ecology has found no environmental variables discriminating what little structure is present in the classification (2 groups) (J Simpson, pers comm). Apart from seeking additional environmental variables for modelling (sand habitat) or combining regional data sets (eg northern WA and QLD, and NT for sand and/or riffle), the predictive basis for detecting and assessing change is reduced simply to a community composition that is altered from that observed in the original data base.

High inter-site similarity of community composition also has the potential to accentuate any temporal variability evident at a site so that even small changes in communities over time will appear as anomalous. Inter-catchment differences in temporal variability, moreover, present a different suite of problems for modelling (cf results for upper Magela Ck and SAR sites described above). Whilst BACI-type designs may provide a solution to the problems presented in the NT, options for approaches involving predictive modelling over this broad regional scale need to be canvassed and discussed amongst other experts in this field.

Acknowledgements

Unsorted macroinvertebrate samples were provided to *eriss* by Jane Suggit and Cyrus Edwards of the NT Lands, Planning and Environment Dept (NT MRHI agency). We are grateful to Justen Simpson and Andrew Storey for useful comments regarding the interpretation of the classifications derived from this study. Thanks also to Robin Galbreath who assisted with the compilation of this report.

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APPENDIX 1

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Table A1 listing NT MRHI agency sites, site codes and site locations for which macroinvertebrate samples were collected for sorting and identification by *eriss*.

Code	Site	AMG	GPS
AD 01	Margaret River	E 78 1000	S 13º 30.87'
	u/s Sandy Ck Hotel	N 849 3000	E 131° 33.40'
AD 02	Adelaide River	E 72 5000	S 13º 25.57'
	Nth of Daly R. Road nr GS	N 850 4250	E 131° 05.07'
AD 03	Adelaide River	E 72 5000	S 13º 14.70'
	u/s Adelaide R. township	N 850 4250	E 131º 05.28'
DA 01	Daly River	E 29 1000	S 14º 21.88'
	Dorisvale Crossing	N 853 2000	E 131° 33.36'
DA 03	Katherine River	E 29 1000	S 14º 19.54'
	d/s Gorge, crossing to 17 Mile Ck	N 853 2000	E 132° 24.72'
DA 04	Seventeen Mile Creek	E 22 4250	S 14º 18.05'
	crossing to Edith Falls	N 844 8750	E 132° 24.96'
DA 06	Katherine River	E 29 1000	S 14º 31.51'
	d/s Sewerage operations	N 853 2000	E 132º 13.63'
DA 09	Daly River	E 29 1000	S 14º 04.37'
	Oolloo Crossing	N 853 2000	E 131° 15.02'
DA 11	Edith River	E 21 0500	S 14º 11.31'
	u/s Mt Todd	N 844 3500	E 132° 10.23'
DA 12	Edith River	E 21 0500	S 14º 10.14'
	d/s Mt Todd	N 844 3500	E 132° 04.32'
DA 17	Green Ant Creek	E 73 1000	S 13° 44.87'
		N 850 9750	E 131º 05.75'
DA 18	Fish River	E 71 2000	S 14º 14.11'
	u/s road crossing	N 839 0500	E 130° 54.80'
DW 03	Holmes Jungie	E 71 0250	S 12º 24.67'
		N 862 6000	E 130° 55.89'
GY 02	Goyder River	E 54 7000	S 13º 01.59'
	Crossing East Arnhem Hwy	N 854 2750	E 134º 58.53'
MY 03	Mary River	E 22 2250	S 13° 16.49'
	Crossing nr old Mt Harris mine	N 847 0500	E 131° 54.60'
ML 02	Takamprimili Creek	E 70 8500	S 11º 46.94'
	Gauge station 235	N 870 2250	E 130° 46.40'
ML 03	Takamprimili Creek	E 70 8500	S 11º 46.90'
	d/s Pickertaramoor Airstrip	N 870 2250	E 130° 52.71'

Table A1. List of NT MRHI agency sites, site codes and site locations for which macroinvertebrate samples were collected for processing (sorting and identification) by *eriss*.
Table A1. Contin.

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Code	Site	AMG	GPS
RP 02	Mainoru River	E 33 8500	S 13º 58.80'
	Crossing East Arnhem Hwy	N 850 0000	E 133° 58.55'
R P 10	Roper River	E 30 4250	S 14º 44.23'
	Roper Valley Station - Rocky Bar Crossing	N 846 5750	E 134° 02.97'
RP 14	Flying Fox Creek	E 32 7000	S 14° 10.38′
	Crossing East Arnhem Hwy	N 847 2000	E 133° 44.41'
SA 01	South Alligator River	E 23 9250	S 13º 35.77'
	S-E of Coronation Hill, near Gimbat	N 848 0250	E 132° 37.20'
SA 02	South Alligator River	E 23 9250	S 13º 34.16'
	S-E of Pul Pul, near Gimbat	N 848 0250	E 132º 35.14'
SA 03	South Alligator River	E 23 9250	S 13º 29.80'
	Gunlom road crossing	N 848 0250	E 132° 28.61'
VC 05	Victoria River	E 60 3500	S 16º 19.96'
	Dashwood Crossing	N 802 6250	E 131° 06.81'
VC 07	W Baines	E 50 9250	S 15° 56.57'
	u/s Vic Hwy crossing	N 813 8750	E 129° 44.32'
VC 12	Victoria River	E 60 3500	S 15° 34.96'
	Victoria R Roadhouse	N 802 6250	E 131º 06.08'

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APPENDIX 2

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Tables A2-A4 listing taxa and relative abundances of macroinvertebrates sampled fromriffle habitat at NT MRHI agency sites in different seasons

Table A2. Taxa and relative abundances of macroinvertebrates sampled from riffle habitat at NT MRHI agency sites in late Dry season of 1994. Site codes as per Table A1.

									Sampling	Sites							
Taxa		AD02R	DA01R	DA03R	DA04R	DA06R	DA09R	GY02R	RP02R	RP10R	SA01R	SA02R	SA03R	ML02R	ML03R	VC07R	VC12R
Acarina	1																
	Acarina	15400	280	2000	2550) 200) 2000	7600	2800) 50	0 15500) 2700) 900) 167	7 150) 10) 100
Coleor	tera																
•	Dvtiscidae	0	0	0) 0) () 100	0) () () () () () 33	3 () () 51
	Elmidae	2100	2180	4050	2250	4567	7 22000	4600	4800) 550	2000	7100) 4900) 733	3 2100) 50) 50
	Gvrinidae	0	0	0	1	C) 0	0) () () () () () () () () 0
	Hvdrophilidae	0	0	Ō	0) () 0	0) () () () () () (50) () 101
	Scirtidae	Ō	0	Ō	100) (Ō) () () () () () () ())) 0
Crusta	cea	-		-				-			-					-	
	Atvidae	0	0	0) 0) 1	I 0	0) () () () () () () () () 0
	Palaemonidae	1	10	1	1) 1	1	1	1	1 1	0) 1	1	1 () () 1
	Parastacidae	0	0	0	0) ()) 0	1	C) () () () () () ())) 0
Diptera	l																
•	Ceratopogonidae	300	80	50	50) 33	3 0	400	400) () () 300) 800) 100) 50) 10) 150
	Chironomidae	7100	1240	4350	1850	1433	3 400	7600	4200) 1600	0 1500	3200) 7600) 1267	7 1600) 400	6950
	Empididae	500	50	0	0) () 0	100) () () () 300) () () 100) () 0
	Simuliidae	0	2390	2200	700	467	7 100	100) () 150	0 400) 200) 500) 1667	650) 280	6750
	Tabanidae	1	0	101	101	34	↓ 1	100) 1	1	I 100) 101	101	I 0) 50) 20) 1
	Tipulidae	0	10	0	1	C) 0	0) C) () () () () () () () 0
Ephem	eroptera																
•	Baetidae	0	580	2250	500	200) 600	200	1400) 250) 200	900) 100) 500) () 911	1650
	Caenidae	4900	1380	500	0	633	600	2700	6900	850) 700) 3300) 4900) 167	/ 100) () 2550
	Leptophlebiidae	0	0	0	8900	133	30	100	100) () 200) 100) () 1100) 3600) 470	301
Hemipt	era																
•	Naucoridae	0	0	0	0) 1	1	0) C) () () 0) () () () () 0
Lepidor	otera																
•••	Pyralidae	300	70	51	100) () 1	1	201	51	I 201	300) () () () ". 1	0
Mollusc	a																
	Corbiculidae	0	320	0	0) 34	1401	100	100) 365 1	I () () () () () () 0
	Thiaridae	0	0	0	0) () 0	1300	. C) 1	I C) () () () () () 0
Nemato	xda																
	Nematoda	0	10	0	0	33) 0	0	0) 50) () 0) 100) () () () 0
Neurop	tera																
	Sisyridae	0	0	0	50) C) 0	0	0) () (0) 200) () () () 0
::	-																
Odonat	a																
	Anisoptera	0	20	0	0	0) 0	0	0) () (400) () 133) () () 0
	Gomphidae	1	40	50	0	0) 1	0	201	1	I 100) 101	1	100) 50) () 50
	Libellulidae	1	10	151	251	C) 0	0	300) () 100) () 100) (1551	10) 0
	Zygoptera	0	0	0	0) C) 0	100	0) () (0) () () () () 0

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Table A2 cont.

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					٠			Samolina	Sitos									
Таха	AD02R	DA01R	DA03R	DA04R	DA06R	DA09R	GY02R	RP02R	RP10R	SA01R	SA02R	SA03R	ML02R	ML03R	VC07R	VC12R		
Oligochaeta																		
Oligochaeta	600	20	700	200	133	1700	500	700	1750	300	200	300	900		0 10) 650		
Trichoptera																		
Ecnomidae	300	C	50	100	67	0	200	0	500	0	300	200	33		0 O) 51		
Hydropsychidae	600	620	1051	850	67	200	0	0	550	0	0	500	0	35	0 O) - (
Hydroptilidae	300	120	750	250	33	0	400	0	0	300	2500	2500	0	20	o 0) 150		
Leptoceridae	0	0	0	50	0	100	0	0	0	0	0) 0	0	20	o 0) 0		
Philopotamidae	100	220	200	1150	0	1700	0	0	0	100	200	500	67	55	0 C) 100		

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Table A3. Taxa and relative abundances of macroinvertebrates sampled from riffle habitat at NT MRHI agency sites in early Dry season of 1995. Site codes as per Table A1.

•		•					•				Samplin	ig Sites										
Taxa	AD01R	AD02R	AD03R	DA01R	DA04R	DA09R	DA11R	DA12R	DA17R	DA18R	DW03R	GY02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	VC05R	VC12R
Acarina																						
Acarina	367	5900	1250	140	500	200	380	200	143	1233	50	850	92	50	200	300	600	700	233	267	133	300
Coleoptera																						
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Elmidae	67	1800	1600	200	400	433	200	367	529	167	50	450	250	600	450	700	167	1350	933	567	0	43
Gvrinidae	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0
Hydrophilidae	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	14
Scirtidae	0	Ō	Ō	Ō	Ō	Ō	20	Ō	Ō	Ō	Ō	Ō	50	Ō	Ō	Ō	0	Ō	Ō	0	0	0
Crustacea	-	-	-		-	-																
Atvidae	0	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	ō	0	ō	Ō	Ō	ŏ	Ō	Ō	Ō	17	Ō	Ō	Ō	Ō	ō	Ō	Ō	Ō	Ō	Ō	Ō	Ō
Palaemonidae	1	1	ŏ	21	1	1	1	1	1	0	Ō	1	1	1	1	1	34	1	Ō	1	1	1
Dintera	•	•	Ŭ		•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Ceretononidae	267	٥	100	140	100	67	0	33	20	117	25	200	25	350	25	0	133	100	133	233	0	14
Chimnomidae	2167	5600	3050	620	525	1300	260	1433	1472	1650	475	2850	200	5050	300	600	867	1150	367	900	1167	320
Empididae	100	100	250	140	525	300	200	0	14	33	-,,,	50	25	0000	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	007	50	33	67	0	14
Simulidae	400	200	200	1620	225	000	1120	333	17	687	1 100	500	100	50	350	2200	100	1600	567	1700	4600	671
Tabanidae		300	500	1020	325		1120	101	0	17	1100	100	100	1		22.00	001	1000	100	1/00	1	1
Tipulidao			201	1	20	0		101	0	17	14	100	1		ŏ		1	51	69			
Enhomoroptom	1	U	301			U	0		U	17	14	U			0	0		51			U	0
Bactida a	407	•	150	400		500	100	400	040	•	175	1450	17	750	0050	1050	2124	1150	1000	1222	687	57
	40/	~~~	150	420	200	500	100	400	243	433	1/5	0050	17	1050	2200	700	200	100	2000	1007	707	37
	501	2200	300	340	20	200	00	1000	129	133	0	2230	040	1250	11/5	/00	167	0701	200	120/	/33	40
	U	200	50	U	1020	U	020	1000	U	0	U	50	242	U	/0	0	10/	2/01	000	000	07	114
	•	•	•	~	•	•	•	•	~	•		~	•	•	•	~	~	•	•	•	•	•
Conxidae	0	0	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	0	0	0
Naucondae	0	0	0	1	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	_												-	-			~ ~ ~		~-	*		
Pyralidae	0	401	150	1	25	33	120	33	144	0	/5	151	8	0	1	251	34	0	67	0	67	43
Mollusca		-			_	_		-		_	-	-			-			-	-		•	-
Corbiculidae	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	4401	0	0	0	0	0	0
Thiaridae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	51	0	0	0	0	0	0
Viviparidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
::																						
Nematoda																						
Nematoda	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	67	0	0	0	0	0
Odonata																						
Anisoptera	0	0	100	20	0	33	0	0	0	67	38	0	42	0	0	50	0	100	0	33	0	0
Cordulildae	1	1	1	0	0	0	1	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Gomphidae	0	1	0	20	26	1	1	1	0	0	0	51	0	100	1	1	1	51	0	1	0	14
Libeliulidae	33	501	1	0	0	0	21	0	0	0	1	1	68	51	26	1	68	101	100	34	0	0
Zygoptera	0	0	Ó	Ō	0	Ō	0	0	Ō	0	0	0	0	0	0	0	0	0	33	0	0	0
	-	-		-	-	-	-		-				-	-								

Table A3 cont.

•			1					•														
Taxa	AD01R	AD02R	AD03R	DA01R	DA04R	DA09R	DA11R	DA12R	DA17R	DA18R	DW03R	GY02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	VC05R	VC12R
Oligochaeta																						
Oiigochaeta	733	0	0) C	25	67	0	533	229	167	0	101	33	0	0	101	34	0	33	0	67	129
Trichoptera																						
Ecnomidae	167	100	1000	60	325	0	140	133	14	0	100	0	58	950	0	351	33	201	400	733	233	86
Hydropsychidae	100	901	2400	40	626	i 100	501	534	115	17	289	601	275	750	26	2201	134	1951	434	1001	- 1033	757
Hydroptilidae	0	1800	150	20	275	33	80	367	143	17	13	200	58	50	0	51	300	150	568	233	33	29
Leptoceridae	0	0	50	20	25	0	0	0	29	0	38	0	17	0	0) 0	0	0	33	0	0	0
Philopotamidae	1334	2901	5851	421	325	2134	540	667	0	0	0	1101	33	1400	201	300	333	2301	3500	1734	567	100

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Table A4. Taxa and relative abundances of macroinvertebrates sampled from riffle habitat at NT MRHi agency sites in late Dry season of 1995. Site codes in Tables A1 & Table 1.

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Taxa ADOCR ADOCR DAOR DAOR DAOR DAOR DAOR DAOR MUC2R MUC2R MUC2R MUC2R MUC2R PPCAR PPCAR<					1						Sampling	Sites							•					
Acarana 1000 0 138 250 287 600 550 33 450 100 67 350 0 400 129 17 51 0 16 6 1 Dyficicias 60 0 </th <th>Taxa Acarina</th> <th>AD02R</th> <th>AD03R</th> <th>DA01R</th> <th>DA03R</th> <th>DA04R</th> <th>DA06R</th> <th>DA09R</th> <th>DA17R</th> <th>GY02R</th> <th>ML02R</th> <th>/LO3R</th> <th>MY03R</th> <th>RP02R</th> <th>RP10R</th> <th>RP14R</th> <th>SA01R</th> <th>SA02R</th> <th>SA03R</th> <th>SA03R88</th> <th>ERIS3R95</th> <th>BBRD88</th> <th>BBRD95</th> <th></th>	Taxa Acarina	AD02R	AD03R	DA01R	DA03R	DA04R	DA06R	DA09R	DA17R	GY02R	ML02R	/LO3R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	SA03R88	ERIS3R95	BBRD88	BBRD95	
Consistential Consiste	Acarina	1000	0	1000	138	250	267	600	550	33	450	100	67	350	0	400	129	17	51	0	16	6	, 1	ł.
Dipticade 0 0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1 1 0	Coleoptera		-																					
Emindae eso 1066 2700 700 575 307 1250 2450 5233 100 14 1583 100 14 1583 100 14 1583 100 0 </td <td>Dytiscidae</td> <td>0</td> <td>17</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>/ 1</td> <td>J</td>	Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	1	0	0	/ 1	J
Cyrindiae III IIII IIII IIIIIIII IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Fimidae	650	1086	2700	700	575	3067	1250	2450	5233	100	114	1583	1050	1633	50	1229	1067	574	744	1086	32	11	
Hydrophildae 0 <t< td=""><td>Gyrinidae</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>100</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>) O</td><td>)</td></t<>	Gyrinidae	1	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	1	0	0) O)
Schriftsenande 0	Hydrophilidae	ò	0	Ō	ō	ō	ō	ō	Ō	Ō	0	0	0	0	0	0	0	0	0	2	1	0) O)
Crusteria Crusteria <t< td=""><td>Scirtidae</td><td>ō</td><td>Ō</td><td>Ō</td><td>ō</td><td>Ō</td><td>Ō</td><td>Ō</td><td>Ō</td><td>Ō</td><td>Ō</td><td>171</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>) 0</td><td>)</td></t<>	Scirtidae	ō	Ō	Ō	ō	Ō	Ō	Ō	Ō	Ō	Ō	171	0	0	0	0	0	0	0	0	0	0) 0)
Barry Gale 0 1 0	Crustacea	•	•	-	-	-	-	-	-	-	-		-	-										
Obstraceda 0 <th0< td=""><td>Atvidae</td><td>0</td><td>15</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>) O</td><td>)</td></th0<>	Atvidae	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0) O)
Palaemonidae 1 44 1 14 1 0 1 0 1 1 1 1 1 0 1 1 1 1 0 1 <th1< th=""> 1 1 <</th1<>	Ostracoda	ō	0	Ō	ŏ	ō	Ō	ō	Ō	Ō	Ō	Ō	Ō	Ō	Ō	0	0	0	8	0	0	0) 0)
Optical attraction attractra attractra<	Palaemonidae	1	44	1	14	1	1	ō	1	1	Ō	Ō	1	1	1	1	1	1	2	0	1	0) 1	i
Caratopogonidae 0 14 0 25 50 200 0 0 150 0 17 100 0 50 14 50 31 108 67 2 0 Chinomidae 3100 1020 200 100 0 286 53 210 315 937 277 19 Empldidae 1050 86 125 67 1650 0 67 6850 357 400 400 100 51 1 12 21 71 27 19 Tabanidae 1 15 3 51 0	Diptera	•		•	• •	•	•	-	-	-	-													
Chronomidae 3400 1029 1800 550 775 1367 900 3200 1200 500 866 167 3300 1187 3300 286 533 210 315 937 27 19 Empldidae 150 0 200 0	Ceratopogonidae	0	14	0	25	50	200	0	0	100	150	0	17	100	0	50	14	50	31	108	67	2	0)
Empididae 150 0 200 <	ChironomIdae	3400	1029	1600	550	775	1367	800	3200	1200	500	86	167	3050	1167	3300	286	533	210	315	937	27	19)
Simulicidae 1050 86 2200 86 125 77 1650 0 67 6650 357 0 400 1400 571 17 12 4 21 71 27 Tabanidae 1 15 1 151 33 51 0 0 0 1 34 0 1 118 40 21 62 0 0 Ephemeroptera	Emoldidae	150	0	200	0	0	200	100	0	0	0	29	0	0	0	0	0	0	3	2	38	0) 0)
Tabandae 1 15 1 1 51 33 51 0 0 0 0 1 34 0 1 118 40 21 62 0 0 Tipulidae 0 14 0<	Simuliidae	1050	86	2200	88	125	67	1650	Ō	67	6850	357	0	400	400	1400	571	17	12	4	21	71	27	1
Tipulidae 0 14 0 0 0 0 0 0 0 0 0 0 31 3 0 0 Ephemeroptera Baedidae 0 233 0 14 1433 500 2850 286 300 31 55 29 5 1 Caenidae 400 200 2600 88 25 400 1100 300 233 0 14 1433 500 300 450 200 767 642 165 1278 21 6 Leptophebidiae 0 0 0 33 0 0 0 0 0 0 1 0	Tabanidae	1	15	1	1	51	33	51	Ō	0	0	0	0	1	34	0	1	118	40	21	62	0) 0)
Ephemeroptara 0 43 700 388 375 67 1000 700 0 43 0 2550 700 2850 286 300 31 55 29 5 1 Caenidae 400 200 280 2850 200 767 642 165 1278 21 6 Leptophlebildae 0 0 0 1976 0 0 0 4550 886 0 1900 0 50 57 83 1 1908 2 15 19 Iminitian Corixidae 0 <td>Tipulidae</td> <td>Ó</td> <td>14</td> <td>Ó</td> <td>Ó</td> <td>0</td> <td>0</td> <td>0</td> <td>Ō</td> <td>Ō</td> <td>Ō</td> <td>14</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>31</td> <td>3</td> <td>0</td> <td>) 0</td> <td>J</td>	Tipulidae	Ó	14	Ó	Ó	0	0	0	Ō	Ō	Ō	14	0	0	0	0	0	0	0	31	3	0) 0	J
Bacilidae 0 43 700 388 375 67 1000 700 0 0 43 0 2550 700 2863 200 31 55 29 5 1 Caenidae 400 200 2800 88 25 400 1100 300 233 0 14 1433 500 300 450 200 767 642 165 1278 21 6 Leptophiebidicae 0 0 0 0 0 0 0 0 0 0 0 0 1 0	Ephemeroptera	•	• •	-	-	-	-	-	-	-	-													
Caenidae 400 200 288 25 400 1100 300 233 0 14 1433 500 300 450 200 767 642 165 1278 21 6 Leptophilebilidae 0 0 0 1978 0 0 0 4550 888 0 1900 0 50 57 83 1 1908 2 15 19 Hemiotera Cotixidae 0 0 0 0 0 0 0 0 0 0 0 0 1 0	Baetidae	0	43	700	388	375	67	1000	700	0	0	43	. 0	2550	700	2650	286	300	31	55	29	5	, 1	l
Leptophlebildae 0 0 0 0 0 0 0 4550 886 0 1900 0 50 57 63 1 1908 2 15 19 Heinighera 0	Caenidae	400	200	2600	88	25	400	1100	300	233	0	14	1433	500	300	450	200	767	642	165	1278	21	6	\$
Hemiptera Control dae 0	l entophieblidae	0	0	0	0	1976	0	0	0	0	4550	886	0	1900	0	50	57	83	1	1908	2	15	, 19)
Contxidae 0 0 0 33 0 <th0< td=""><td>Hemiptera</td><td>-</td><td>-</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th0<>	Hemiptera	-	-																					
Gerridae 0<	Corixidae	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	, O)
Naucoridae 0	Gerridae	Ō	Ō	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	i O)
Lepidoptera	Naucoridae	Ō	Ō	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0)
Pyralidae 0 14 301 38 75 33 201 250 68 0 0 200 167 51 14 50 2 18 48 0 2 Mollusca Corbiculidae 0	Lepidoptera																				# ·			
Mollusca Corbiculidae 0 0 0 0 0 0 0 2768 0 0 0 1 0 0 0 0 Hyrildae 0 0 0 0 0 0 1 0	Pyralidae	0	14	301	38	75	33	201	250	68	0	0	0	200	167	51	14	50	2	18	48	0	; 2	2
Corbiculidae 0 0 0 0 1 0 0 0 0 2768 0	Mollusca																							
Hyridae 0 0 0 0 0 1 0 0 0 1 0 </td <td>Corbiculidae</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>2768</td> <td>0</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>i 0</td> <td>)</td>	Corbiculidae	0	0	0	0	0	0	1	0	0	0	0	0	0	2768	0	0	0	0	1	0	0	i 0)
Thiandae 0<	Hyrlidae	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	i 0)
Viviparidae 0 0 0 0 0 1 0 <th< td=""><td>Thlaridae</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>68</td><td>0</td><td>0</td><td>0</td><td>1</td><td>167</td><td>' O</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>i 0</td><td>)</td></th<>	Thlaridae	0	0	0	0	0	0	0	0	68	0	0	0	1	167	' O	0	0	0	0	0	0	i 0)
Nematoda Nematoda 0	Viviparidae	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0) O)
Nematoda 0<	Nematoda																							
Neuroptera Sisyridae 0	Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	. 10	0	0) O)
Sisyridae 0	Neuroptera																							
Odonata Anisoptera 0 0 100 38 0 50 250 0 50 100 0 14 17 0	Sisyridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	i 0)
Anisoptera 0 0 100 38 0 50 250 0 50 100 0 14 17 0	Odonata																							
Corduliidae 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 33 0 <t< td=""><td>Anisoptera</td><td>0</td><td>0</td><td>100</td><td>38</td><td>0</td><td>0</td><td>50</td><td>250</td><td>0</td><td>50</td><td>100</td><td>0</td><td>50</td><td>0</td><td>0</td><td>14</td><td>17</td><td>0</td><td>0</td><td>0</td><td>0</td><td>) O</td><td>)</td></t<>	Anisoptera	0	0	100	38	0	0	50	250	0	50	100	0	50	0	0	14	17	0	0	0	0) O)
Gomphidae 0 0 1 1 0 0 0 1 33 0 0 0 0 0 0 0 3 0 0 0 0	Corduliidae	1	Ō	0	1	0	0	50	0	0	0	1	0	0	0) 0	0	0	0	9	0	C) 1	ł
Libelluildae 5000000051510130010101012183000	Gomphidae	Ó	Ō	1	1	0	0	0	1	33	0	0	0	0	0	0	0	0	3	0	0	C) 0)
	Libelluildae	50	0	· 0	0	0	0	51	51	0	1	30	0	101	C) 1	0	1	21	8	3	C) 0)

Table A4 cont.

					•					Samplin	a Sites			•									
Taxa	AD02R	AD03R	DA01R	DA03R	DA04R	DA06R	DA09R	DA17R	GY02R	ML02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	SA03R88	ERIS3R95	BBRD88	BBRD	195
Oligochaeta																							
Oligochaeta	0	157	0	75	200	1200	50	0	33	0	0	117	100	267	0) 71	17	19	13	12	2 (3	0
Trichoptera																							
Ecnomidae	350	0	0	25	25	33	200	201	33	100	71	0	100	500	250) 14	100	7	20	2	2 (3	1
Hydropsychidae	1550	300	4001	325	125	100	1200	751	100	150	429	17	501	1367	850) 43	33	39	260	19)	4	33
Hydroptilidae	750	0	100	125	225	100	650	450	0	50	14	17	150	0	1100	29	83	115	109	11	10)	1
Leptoceridae	50	0	100	38	25	0	50	50	0	0	57	67	100	0	200) 0	0	0	34	0) :	3	2
Philopotamidae	1200	0	4101	50	700	167	2450	1151	33	600	743	0	600	0	50	114	50	102	229	43	3	1	8

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