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LWRRDC Milestone Report 2 - Monitoring River Health Initiative, Project ARR1. Temporal variability of macroinvertebrate communities in Australian steams

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supervising scientist

LWRRDC Milestone Report 2
Monitoring River Health Initiative, Project ARR1

Temporal variability of macroinvertebrate communities in Australian streams

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Humphrey CL, Klessa BA, Norton D, Galbreath RW & Walden DJ (1997b). Benthic macroinvertebrate communities in riffle substrates of the upper South Alligator River, NT. Phase 3 - Review of data from May and October samples 1994-1996. Internal Report 251, Supervising Scientist for the Alligator Rivers Region.

LWRRDC Milestone Report 2

LWRRDC project reference no.: ARR1

Project title: Temporal variability of macroinvertebrate communities in Australian streams

Principal investigators: Dr Chris Humphrey, ERISS

Project duration: 1 January 1995 to September 1997

Due date for milestone report: May 1997

Project objectives

- Access long-term macroinvertebrate data-sets from selected (reference) streams across Australia. Where necessary, extend sampling in streams so that data-sets are sufficiently 'long-term' in nature as to allow long term comparisons to be made for relevant old data-sets.
- Measure 'persistence' of macroinvertebrate community composition using appropriate statistical analyses of the data.

Where lack of persistence is observed:

- 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.
- Where data-sets allow, seek environmental correlates that may account for any year-to-year variation in community composition and input these variables to the MRH predictive models.
- Make appropriate recommendations to the developers of MRH predictive models according to different climatic/hydrological regions of Australia.

Alteration to original objectives: Through the course of this study, it has become apparent that the original approaches to be used to assess the implications of any lack of persistence and to redress this problem - ie second and third-last objectives listed above - are now either not viable or are largely unsuitable given additional information that has come to light since the project was initiated. A more pertinent and better targeted approach to this important issue is discussed in the sections below.

Milestones and achievement criteria

<u>Milestone 2, 31 May 1996</u>

a) Compile SAR data from October 1994 - May 1996 and perform analysis on full seven year data set.

b) Complete analyses of community persistence and modelling for other long-term data sets.

c) Continue sampling of existing SAR sites for macroinvertebrates; process and identify all samples; compile data.

d) Liaise with members of related NRHP-commissioned projects to ensure integration.

e) Attend the third NRHP workshop (October 1996) and report on project scope and progress.

f) Sort and identify samples from riffle habitat collected by NT Dept LP&E (formerly PAWA) in the NT MRHI program.

Achievement criteria

a) Summary of SAR sampling conducted;

b) Summary of results of further analyses of long term data sets, including that of SAR;

c) From riffle habitat data, interpret the significance of temporal variability of macroinvertebrate communities in NT streams;

d) Liaison with other NRHP project leaders and assessment of project integration.

Achievement of milestone criteria 1

Summary of SAR sampling conducted

Early and late Dry season data (April/May and October respectively) from the 8 SAR sites are now available for the period October 1987 to May 1996. Data for the seven year period 1987-1993 were presented to LWRRDC in Milestone 1 (December 1995, Attachment 3) whilst data for the two-year period October 1994 to May 1996 are contained in Attachment 3 of the current report. Both reports contain, for the relevant period of sampling, lists and abundances of all invertebrate families present at SAR sites in addition to associated environmental data. Environmental data include values of habitat structural variables, and physico-chemistry and hydrology of South Alligator River waters. Additional sampling was also conducted in October 1996. This sampling was not funded under the current LWRRDC project though data from this late Dry season sampling period were analysed in the study of persistence and temporal variability (Attachment 1 of current report).

Achievement of milestone criteria 2

Summary of results of further analyses of long term data sets, including that of SAR

(Degree and extent of temporal variability)

A comprehensive summary of results of temporal variability and degree of persistence of macroinvertebrate communities in Australian streams is presented in Attachment 1. Data from 9 bioregions, from tropical northern Australia to cool temperate Australia and representing 14 catchments and 37 individual sites, were compiled for analysis of temporal variability. Results may be summarised as follows:

- Persistence of macroinvertebrate communities, based upon presence-absence (p-a) data, is significantly and positively correlated with permanence of stream flow and latitude, and negatively correlated with interannual variability of annual stream discharge.
- For the streams of tropical northern Australia, community composition (p-a) and structure (rank abundance) 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).
- 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 there was evidence of a rapid return to a pre-disturbance community structure following a discrete disturbance event.

- 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.
- Measures of temporal variability averaged across the seasons, indicated relatively high persistence for all but one or two bioregions represented. 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.

Achievement of milestone criteria 3

From riffle habitat data, interpret the significance of temporal variability of macroinvertebrate communities in NT streams.

(Some possible implications for predictive modelling of lack of persistence in macroinvertebrate communities)

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. Such an exercise was conducted for the SAR communities, results being reported in the first milestone report submitted to LWRRDC in December 1995 (Attachment 2 of the report). 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 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, 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.

As part of the current project, LWRRDC provided funds to ***eriss*** to sort and identify the NT agency samples gathered from riffle habitat throughout the NT. This enabled the incorporation of long-term SAR data into the NT MRHI agency classification based upon riffle samples with an assessment then made of the severity of lack of persistence in the SAR data. The results of this study are reported in Attachment 2. 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.

Achievement of milestone criteria 4

Liaison with other NRHP project leaders and assessment of project integration

Results of the project have been reported progressively at the various MRHI TAC meetings and at the October 1996 NRHP Workshop (Canberra). The most significant and important of these meetings, however, was the MRHI TAC meeting convened in May 1997 to set priorities for further R&D for the next NHT-funded round of the NRHP. At the May 1997 meeting, the concept of, and need for, a "sensitivity analysis" was discussed. This would involve an integrated assessment of the implications to predictive model sensitivity arising from operator error and sources of environmental variability, particularly temporal variability. This sensitivity analysis would supersede a complete assessment of the impact of temporal variability upon model development and sensitivity that could be conducted in the course and remaining time frame of the current project.

There are two factors that justify incorporating this assessment into a new and more expansive R&D project: Firstly, the proposed method for assessing the implications of high temporal variability on model development and performance has come empirically with data analysis of this and other related MRHI R&D projects. Incorporating temporal variability into actual agency models is now deemed the best 'yardstick' for the assessment as opposed to methods originally proposed for this project (see original objectives above). Agency models are only now becoming available for use in MRHI research support. Secondly, temporal variability is only one source of "noise" in predictive models. *Collective* (operator) error and environmental variability must be studied to determine the full implications of such error and variability to model sensitivity. Thus an integrated approach is required that uses the information generated from the current project and those from the external QA/QC projects.

The NRHP committee has recently (July 1997) endorsed the need for such a sensitivity analysis and has approved the advertising of such a study to interested research parties (P Davies, pers comm).

Variations required to future milestones

On the proviso that a complete assessment of the implications to predictive model sensitivity arising from temporal variability is not feasible as a final achievement criterion - nor warranted in isolation of other sources of variability and operator errors - no significant variations will be required to the final report.

Financial issues

In April 1996, the NRHP committee approved a request from ***eriss*** for $8,000 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 (3 sampling rounds). 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. This aspect of the project has been successfully completed and results are reported in Attachment 2.

Human resource issues

There are no human resource issues to raise.

Communication achievements

Communication has centred on NRHP fora, namely workshops and technical committee meetings, as well as presentation of conference papers (Aust Soc Limnology annual conference, 1995, and International Workshop on RIVPACS to be held at Oxford, UK in September 1997).

Listing of attachments

Attachment 1

Humphrey C, Doig L, Macfarlane W, Galbreath R & Masiero M (1997a). Degree of temporal variability of macroinvertebrate communities in Australian streams.

Attachment 2

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.

Attachment 3

Humphrey CL, Klessa BA, Norton D, Galbreath RW & Walden DJ (1997b). Benthic macroinvertebrate communities in riffle substrates of the upper South Alligator River, NT. Phase 3 - Review of data from May and October samples 1994-1996.

Other comments

Nil.

Summary

The degree and extent of temporal variability of stream macroinvertebrate communities has being 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 latitude, and negatively correlated with interannual variability of annual stream discharge. 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.

An important MRHI topic approved by the NRHP committee for further R&D is a complete assessment of the implications to predictive model sensitivity arising from temporal (and if possible, spatial) variability and operator errors. The extent to which the current project has been able to assess implications of high temporal variability upon model performance has been limited. Nevertheless, data on temporal variability arising from the current study will provide an important information base upon which such an assessment can proceed. Moreover, future R&D needs that will assist in this 'sensitivity analysis' have been identified in the summary (section 5) of Attachment 1.

The current project is well advanced in formulating approaches to pursue in relation to temporal variability and predictive modelling. This includes approaches to apply in assessing implications to predictive model sensitivity arising from temporal variability, as well as approaches that might be used to account for such variability. These approaches are

discussed and appraised at length in Attachment 1 and include: (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 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 bioregions and stream types susceptible to high temporal variability is in itself informative and valuable for management. The magnitude of persistence indices calculated in this study (Attachment 1) and modelled according to different bioregions and stream types, may eventually be related to some measure of AUSRIVAS model 'noise' and variability and, consequently, to predictive failures from model outcomes. Hence, for a particular location in Australia, there would be some indication 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 error and probability statements around predictions, or recommend alternative monitoring approaches.

ATTACHMENT 1

Degree of temporal variability of macroinvertebrate communities in Australian streams

(Results to 30 June 1997)

by

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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. 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. 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 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. These custodians for respective bioregions 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);
- Assoc. Prof. Angela Arthington, Centre for Catchment and In-stream Research, Griffith Uni (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 and the Thredbo River in (sub-alpine) NSW, and custodians of data sets from these regions provided data for no charge. The data presented in this report meet one of the achievement criteria of the milestone report for May 1997 (an extended deadline on Milestone 2, December 1996), namely, a summary of results of analyses of long-term data sets. Results are also used in a preliminary assessment of the implications for MRHI predictive modelling. Analyses comprise, for each season separately, pairwise, year-to-year comparisons of macroinvertebrate structure and composition by way of multivariate dissimilarity measures.

2. Study sites and data analysis procedures

2.1 Location of study sites and data-set custodian

Data from 9 bioregions representing 14 catchments and 37 individual sites were compiled for analysis of temporal variability (Table 1). The extent of permanence of stream flow and surface water availability at the sites is indicated in Table 1.

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

Bioregion	Catchment	Flow regime	No. of sites
Dry tropical (Pilbara, WA)	Robe R	Seasonal (permanent pools)	1
Wet-dry tropical (Alligator Rivers Region, NT)	South Alligator R	Permanent	3
	Magela Ck	Seasonal (little or no surface water by end of dry season)	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 (coastal [LR] and inland [WR] VIC)	Latrobe R	Permanent	9
	Wimmera R	Seasonal	2
Temperate cool (TAS)	Musselboro-Coquet Cks	Permanent	2
Temperate semi-arid (Flinders Ranges, SA)	Brachina Ck	Permanent	1
	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, perennially-flowing 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.

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 situated 1 km upstream of the Ranger Uranium Mine release pipe and the other 5 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).

Stony Creek. Two upland sites in this bioregion 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. 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)).

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 (1990). 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.

Table 2. Sampling and sample processing methods adopted in each of the long-term studies according to year of sampling.

Bioregion	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 Rivers Region, NT)	South Alligator R	1987-96: 4 x 0.063 m^2 Surber samples; 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 m^2 Surber samples; 500 μm mesh 1995: 4 x 0.04 m^2 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 1990-94: 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 μm mesh *Lower*, 1979-81: 30 x 0.02 m^2 airlift samples; 150 μm 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 μm 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 μm 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 μm mesh. 1994-95: Dip net (single replicate) MRHI sampling, quantitative laboratory sample processing; 250 μm mesh.
Temperate mild (south-west WA)	Canning & North Dandalup Rivers	1985-89: 6 x 0.063 m^2 Surber samples; 250 μm mesh.

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, Tables A1-A11). 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.

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.

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. 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), Magela Creek. Early Dry season sampling (recessional flow, Apr/May) of two sites has been conducted in each of 8 years (Table 2). 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, $MgSO_4$). As of 1994, the downstream site was re-located a further 700 m 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 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 period 1988-95. 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, 3 years: Sept 1988-89, Sept 1995.

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 A5) 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, 8 years: Nov 1982, 1990-96.

Summer, 6 years: Feb 1982, Jan 1983, Feb 1992-93, Jan 1994, Feb 1995.

Data for the period 1982-83 were derived from McKaige (1986) whilst other data were collected 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 collected from each site per sampling occasion generally comprised 5 samples each from riffle and pool. 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 m^2 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 live-sorted taxa abundances for each of the sites, separated according to habitat (edge and riffle-kick) 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 m^2 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 m^2 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 seasons and habitat (for comparison with 1979-81 data). The actual interannual comparisons made for the period 1979-95 are described below (section???).

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 bioregion in terms of their standardised nature for interannual comparison is provided in Table 3.

Table 3. Quality of the long-term stream macroinvertebrate data sets from each bioregion in terms of their standardised nature for interannual comparison.

Bioregion	Quality of data set; other comments
Dry tropics (WA)	High quality
Wet-dry tropical (SAR, 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 used rank correlation methods (eg Spearman) to compare community structure data amongst years. These measures, however, were deemed less suitable for the analyses applied here, comparing data sets across bioregions. Rank correlation methods are sensitive to sample size in determining statistical significance. Thus, for comparing data across bioregions 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 validly compare the persistence of macroinvertebrate communities across different bioregions, 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 taxa number (eg the 20 most abundant taxa per site over time), or a proportion of the taxa number (eg the top 50% of taxa as adjudged by their overall abundance per site over time). On the surface, setting a fixed taxa 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 bioregions. Thus, the top 20 taxa in one bioregion could comprise half the taxa 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 taxa 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 taxa number as defined here. Thus in analyses conducted on data sets derived from bioregions 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 bioregions, 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 bioregional 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 (in prep) 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 QA/QC 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, in prep). 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 delimited 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 dip/sweep net sampling (as occurred with Thredbo R and Flinders Ranges streams, Table 2).

Data gathered from simultaneous sampling of 3 South Alligator River riffle sites by ***eriss***, conducting quantitative Surber sampling, and the NT MRHI agency (NT Lands, Planning and Environment Dept, LP&E), using the standard 10 m kick sample, were compared in order to assess whether different sampling methods affected results significantly. Both agencies preserved samples in the field for later laboratory subsampling and sorting. Simultaneous sampling of the 3 sites was conducted in October 1994 and 1995, and May 1995. 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 and ***eriss*** data were compared for each site and sampling occasion by way of Bray-Curtis dissimilarity measures, using presence-absence and rank abundance data. (Data from any particular site and sampling occasion were ranked by dividing taxa abundances by the maximum abundance value found for a taxon in that sample, as described above.) DLP&E data for a particular site and sampling occasion were derived from a subsample of approximately 200 invertebrates, whereas *eriss* data were average abundances of taxa present in 4 Surber replicates (Table 2), data for each replicate being derived from a subsample of approximately 200 animals. 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 μm 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. Results of the comparison are described in section 3.1 below.

3. Results

3.1 Validity of comparing data gathered by different sampling methods

The comparison of DLP&E and *eriss* data obtained from simultaneous sampling of South Alligator River sites, and derived using different sampling methods, is shown in Table 4. These results indicate generally small differences in family-level, macroinvertebrate community data derived using different sampling methods at riffle habitat in the South Alligator River, 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 (section 2.3.4).

Table 4. Dissimilarity values comparing macroinvertebrate community data derived by different agencies using different sampling methods at sites on the upper South Alligator River, NT. The '250 μm' designation refers to comparisons made between the agencies where Surber samples were retained by 250 μm mesh as opposed to 500 μm mesh for other samples.

Year and site	Bray-Curtis Dissimilarity	
	Presence-absence	Rank abundance
Oct 1994		
site 1	0.243	0.860
site 2	0.158	0.295
site 3	0.200	0.335
May 1995		
site 1	0.122	0.293
site 1 (250 μm)	0.122	0.288
site 2	0.105	0.561
site 2 (250 μm)	0.095	0.523
site 3	0.128	0.402
site 3 (250 μm)	0.073	0.304
Oct 1995		
site 1	0.177	0.250
site 2	0.143	0.277
site 3	0.077	0.177

Discrepancies in dissimilarities calculated using rank abundance data occurred for site 1 in October 1994 and sites 2 and 3 in May 1995 (Table 4). 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 micro-habitats 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 latter explanation can account for differences in Acarina abundance. Thus, although abundance data are not provided, the small 'improvement' in the results of Table 4 after DLP&E data are compared with data derived from samples retained by 250 µm 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 µm. 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 µm) 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.

These results, indicating generally little difference in family-level data derived from quantitative areal sampling and single dip/sweep net sampling - at least for presence-absence data - would appear to validate comparison of data derived from the two methods - ie within Thredbo R and Flinders Ranges stream data sets. The results also appear to suggest that data are not greatly affected by different sampling and sample processing intensities, within certain limits. Thus a single subsample of about 200 animals, derived from a larger composite sample, is sufficient to characterise macroinvertebrate community composition and structure at a site. This approach characterises the sampling and sample processing approach of some MRHI agencies (ACT, SA and NT) and is also representative of the procedures used to process samples from Musselboro and Coquet Cks, TAS (involving the pooling of Surber replicates and processing of a single subsample of about 200 animals, section 2.2). For this study, the results appear to validate temporal comparison of family-level data derived using different methods both within a site and also amongst sites and bioregions - at least for cases in which samples were taken from riffles and later subsampled and sorted in the laboratory.

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 bioregion according to season and habitat in Tables A1-A11 of the Appendix. For each season, the number of years available for comparison and total number of pairwise comparisons made, are indicated. 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. 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, for presence-absence and rank abundance data.

Where data for more than one site were analysed for a given bioregion, average values across the sites of the pairwise interannual summaries described above, are also provided in Tables A1-A11. 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 A10). The average or summary data derived for each bioregion according to season are shown in Table 5.

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

Finally, little attempt has been made at this stage to describe actual changes in taxonomic composition associated with temporal variability of macroinvertebrate communities at any of the study sites. 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 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 A1-11 and Table 5 summarise interannual variation in community rank abundance data from different bioregions, 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. For the lower Latrobe River site (Willow Grove), all interannual comparisons with data for Autumn 1995 resulted in high dissimilarity values (Tables A7 and 5) though whether this is a consequence of mild drought in 1995 or an artefact of sample processed using a live-sort method (not reliable for recovering rank abundance data, Humphrey & Thurtell (in prep.)) 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 bioregions 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 eliminations and additions. 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 bioregions may be listed:

1) Similar seasonal changes in dissimilarity (p-a) as observed for dissimilarity based upon rank abundance data

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 Autumn pairwise dissimilarity values are higher than those observed in Spring ('post wet season') (Table 5).

2) 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 flow-dependant 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 A2).
- 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. Macroinvertebrate communities were seemingly unaffected at this time at the two upland sites in Stony Ck in this same bioregion (Table A5), despite cessation of flow at the sites at the time of the Spring 1996 sampling.
- 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 A7). 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) 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, 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 5), 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 'post-event' (1990s) data are available for this season than for the late Dry season (Table 5).

- 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 is the cause of the high interannual dissimilarities observed for this site.

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 A10. 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 across Australia

To compare the long-term data further across bioregions, additional summaries and information were drawn together, restricting the comparisons this time to results based upon presence-absence data. Thus in Table 6, various 'persistence indices' are shown. These were calculated by averaging the seasonal summaries shown in Table 5 to derive annual indices. Index 1, "%dissim>0.4", is the average of the seasonal values of 'percent of interannual comparisons in which dissimilarity values exceeded 0.4 (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 6 are the coefficients of variation associated with the mean of annual flow for streams in the bioregion from which data were derived; these (CV) values were obtained from McMahon (1979).

Lower persistence index values shown in Table 6 reflect, conversely, higher persistence of macroinvertebrate communities. The overall ranking of most persistent to least persistent communities in Table 6 (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 that is a measure of model predictive failure for MRHI. For Flinders Ranges streams (SA), data for riffle and non-riffle habitat have been treated separately. Finally, the summary data shown in Table 6, 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 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 5 and those presented for individual sites in the tables of the Appendix, 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 unknown '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 5). (The high dissimilarities for the upper Latrobe R data are likely to be an artefact of the comparison of live-sort data with data derived from laboratory subsampling and sorting. Humphrey and Thurtell (in prep.) show that 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 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 bioregion (see data for NT, VIC and SW WA in Table 5).

Presence-absence data

Summary measures of persistence based on family presence-absence data and ranked according to bioregion, are provided in Table 6. Comments on persistence and possible reasons for relative lack of persistence are also provided in this table. Three summary points may be made from the results:

1. (a) Persistence of macroinvertebrate communities is generally 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.)

   (b) There appears to be a good correlation between persistence, and predictability and low interannual variation of stream discharge.

   (c) Macroinvertebrate communities of permanent streams in temperate Australia tend 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.)

   A regression approach was used to describe the relationship between summary measures of persistence, and the regime of stream hydrology, discharge variability and latitude of study sites, data for each of these variables being derived from Table 6. (Non-riffle habitat data from Flinders Ranges streams were excluded from analyses.) A variety of combinations of variables was analysed with the best predictive equations being those that used the dependent persistence index variable, 'mean threshold', and independent variables, CV of annual flow, flow status and latitude. Derived regression equations from inclusion of single to multiple independent variables were:

   (1) $\log_{10}PI = 0.273 + 0.81CV$ $R^2=0.42$, $P < 0.05$,
   (2) $\log_{10}PI = 0.219 + 0.656CV + 0.458FS$ $R^2=0.64$, $P < 0.01$,
   (3) $\log_{10}PI = 0.022 + 0.718CV + 0.392FS + 0.43LAT$ $R^2=0.86$, $P < 0.001$.

where

PI = persistence index, mean threshold,
CV = CV of annual flow (mean of range values and a value of 1.3 for CV > 1.25), and
FS = Flow status, using a dummy variable, 0 = permanent flow, 1 = seasonal flow.
LAT = Latitude, coded simply (sub)tropical vs temperate Australia using a dummy variable, 0 = temperate Australia, 1 = (sub)tropical Australia.

The three independent variables were significant for respective equations at:

(1) $P < 0.05$ (*CV*),
(2) $P < 0.05$ (*CV* and *FS*), and
(3) $P < 0.01$ (*CV* and *LAT*), $P < 0.05$ (*FS*).

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 bioregions 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. 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 bioregion and/or response to seasonal or aseasonal drought (ie Wimmera R, VIC and Barker-Barambah Cks, QLD).

Summary

Despite the different duration of study length and other limitations represented in the data sets analysed from across Australia, some generalisations drawing on the results from above, can possibly be made:

- Persistence of macroinvertebrate communities is significantly and positively correlated with permanence of stream flow and latitude, and negatively correlated with interannual variability of annual stream discharge.
- 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).

- 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.

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 A5). 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 catchment of the NT, where the fauna of Rockhole Mine Ck (RMC), a 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 (C Humphrey, unpublished observations). This is despite the fact that RMC is seasonally-flowing and all surface waters 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.

- For streams in one bioregion, persistence of macroinvertebrate communities was high in riffle habitat and low in pool and macrophyte habitat.

Table 5. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures) for stream sites located in various parts of Australia

	Bioregion																					
	NW WA	NT (SAR)		NT (Mag)	NE QLD		SE QLD		NSW		VIC (Latrobe)		VIC (Wimmera)		TAS		SA		SW WA (seasonal)		SW WA (permanent)	
Site details	-	-	-	-	-	-	-	-	-	-	upper	lower	-	-	-	-	-	-	-	-	-	-
No. of combined sites	1	3	3	2	1	1	4	4	1	1	8	1	2	2	2	2	2	2	5	5	5	5
Permanent (P) or seasonally-flowing (S)	S	P	P	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	LD	A	S	S	Su	C	C/A	A	S	A	S	W	S	W	S	W	S
Habitat (Riffle, Macrophyte, Pool, Combined)	P	R	R	R/M	R	R	R	R	R	R	C	C	P	P	R	R	C	C	R	R	R	R
No. of years (N comparisons)	6 (15)	6 (45)	10 (117)	8 (56)	5 (10)	4 (6)	5 (12)	4 (12)	8 (28)	6 (15)	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	88, 90-96	82-84, 94-95	81-83, 93	88-90, 95-96	88-89, 95-96	82, 90-96	82-83, 92-95	79/80-94/95	79/80 & 82-86, 95	85-88	85-88, 91,93, 95	92-94, 96	92-96	93-95	92-95	85-89	85-87	85-87	85-87
Between-year comparisons																						
Rank abundance																						
% dissim > 0.5 (top 50%)	27	42	39	36	50	17	67	42	68	6	100	36	50	33	11	0	6	6	17	13	7	0
Mean dissim (top 50%)	0.443	0.475	0.440	0.427	0.468	0.359	0.563	0.482	0.554	0.373	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	5	0	0	0	8	4	0	0	0	0	0	0	0	6	6	10	0	0	0
% dissim > 0.35 (top 90%)	93	13	14	21	30	0	0	42	29	0	0	9	0	39	0	15	38	45	21	27	13	0
% dissim > 0.4 (top 50%)	27	0	0	2	0	0	0	8	4	0	0	0	0	0	0	0	6	6	3	0	0	0
% dissim > 0.4 (top 90%)	93	2	4	11	20	0	0	42	21	0	0	0	0	28	0	0	25	29	17	13	0	0
Mean dissim (top 90%)	0.431	0.225	0.242	0.279	0.294	0.217	0.246	0.347	0.291	0.159	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 6. Persistence of stream macroinvertebrate communities across different bioregions of Australia, based upon family-level, presence-absence data. (See text for explanation of persistence indices.)

Bioregion	Flow status	No. of years	Persistence index (%dissim>0.4)	Persistence index (mean threshold)	Persistence index (mean dissimilarity)	CV of annual flow	Comments on persistence and mechanism for relative lack of persistence
Temperate (VIC-Latrobe)	Permanent	2 (upper) 7 (lower)	0.0	1.1	0.266	< 0.5	High persistence (to some degree an artefact of combined seasons and habitat data).
Temperate (SW WA)	Permanent	3	0.0	1.6	0.244	0.5-0.75	High persistence (predictable pattern of flow)
Temperate (TAS)	Permanent	4 or 5	0.0	1.9	0.204	< 0.5	High persistence (predictable pattern of flow)
Wet-dry tropical (SAR, NT)	Permanent	6 or 10	3.0	4.0	0.234	< 0.5	High persistence (predictable pattern of flow)
Temp. semi-arid (Flinders, SA)	Permanent (riffle)	3 or 4	8.3	8.3	0.290	> 1.25	Reasonably high persistence (sites of permanent flow)
Wet tropical (NE QLD)	Permanent	4 or 5	10.0	6.3	0.256	< 0.5	High late dry season persistence; cause of low early dry season persistence unknown (cyclonic disturbance/ opening of canopy in early 1990s?)
Sub-alpine (NSW)	Permanent	8 or 6	10.5	7.3	0.225	0.5-0.75	High summer persistence; low persistence in spring associated with snow-melt floods (eg 1992); summer fauna highly persistent.
Wet-dry tropical (Magela, NT)	Seasonal	8	11.0	9.8	0.279	< 0.5	Seasonal flow (little or no surface water by end of dry season)
Temperate-dry (VIC-Wimmera	Seasonal	4 or 7	14.0	8.3	0.257	0.75 - 1.0	Seasonal flow (pools in dry season)
Temperate (SW WA)	Seasonal	3 or 5	15.0	11.4	0.264	0.5-0.75	Seasonal flow (little or no surface water by end of summer 'dry season')
Subtropical (SE QLD)	Permanent	4 or 5	21.0	12.5	0.297	0.75-1.0	High autumn persistence; low persistence in spring associated with drought (1995)
Temp. semi-arid (Flinders, SA)	Permanent (macro, pool)	3 or 4	35.0	28.5	0.373	> 1.25	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	> 1.25	Seasonal flow. Third year of sampling [out of 6 years] followed severe cyclonic flooding with elimination of half taxa number; subsequent years have documented slow 'recovery' of the fauna following this event.

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 bioregions 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 latitude and flow regime/ variability 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, though these results were derived from combined-habitat data that would be relatively inured from such environmental change. 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 bioregion 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, a finding apparently mirrored at many other sites in QLD between 1994 and 1996 (S Choy, pers comm).

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 bioregions to flow characteristics of streams in the bioregions, 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, 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.

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 bioregions influenced by a mediterranean climate and low interannual variability of discharge - in particular, TAS, south-west WA (Table 5) and possibly parts of VIC - is there potential for development of AUSRIVAS models based upon rank abundance data. Thus water quality assessment programs applied to only a small part of Australia would benefit from development of models that are more sensitive to human disturbance (viz abundance data) than current p-a models. (As discussed above, live-sort sample processing by agencies in these states could 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 (1995) 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 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*

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). Examination of existing agency data sets would assist in redressing these 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 sampled simultaneously in time 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' for the response due to climatic variation. Analogous to the problem identified in 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.

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 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.) One disadvantage with this approach is the need to accumulate two seasons 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 turn-around 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

The magnitude of the persistence indices calculated (Table 6) and modelled in this study according to different bioregions and stream types, may eventually be related to some measure of AUSRIVAS model 'noise' and variability and, consequently, to predictive failures from model outcomes. 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 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.

5. Overall summary and recommendations for further study

1. The degree and geographical extent of temporal variability of macroinvertebrate communities in Australian streams have been quantified and modelled according to simple measures of latitude, flow regime and flow variability characteristics.

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.

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 discussed in section 4 above.

4. Further R&D studies are required to:

   i) Assess the implications for model development of temporal variability by running long-term 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 bioregions 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 bioregional 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 models result in loss of sensitivity to detection of impact.

viii) Incorporate the above in an overall analysis of sensitivity of AUSRIVAS models.

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

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APPENDIX

Tables A1-A11 summarising results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures) for stream sites located in various parts of Australia

Table A1. 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)	P
No. of years (N comparisons)	6 (15)
Between-year comparisons	
Rank abundance	
% 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 A2. 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	COM
Permanent (P) or seasonally-flowing (S)	P	P	P	P	P	P	P	P
Season (Win, 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	**R**
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%)	0	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 A3. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for sites on Magela Creek, NT.

	Magela Ck (NT)		
Site details			
Site (#)	1	3	COM
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			
Rank abundance			
% 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 A4. 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		
Site (#)	1	1
Permanent (P) or seasonally-flowing (S)	P	P
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		
% 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

Table A5. 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.

	South-east QLD									
Site details										
Site (# and COMbined)	BB	Litz	Ston2	Ston3	COM	BB	Litz	Ston2	Ston3	COM
Permanent (P) or seasonally-flowing (S)	P	P	P	P	**P**	P	P	P	P	**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)**	3 (3)	3 (3)	3 (3)	3 (3)	**4 (12)**
Between-year comparisons										
Rank abundance										
% dissim > 0.5 (top 50%)	67	67	67	67	**67**	67	67	33	0	**42**
Mean dissim (top 50%)	0.488	0.715	0.515	0.534	**0.563**	0.566	0.602	0.495	0.265	**0.482**
Presence-absence										
% dissim > 0.35 (top 50%)	0	0	0	0	**0**	0	33	0	0	**8**
% dissim > 0.35 (top 90%)	0	0	0	0	**0**	67	100	0	0	**42**
% dissim > 0.4 (top 50%)	0	0	0	0	**0**	0	33	0	0	**8**
% dissim > 0.4 (top 90%)	0	0	0	0	**0**	67	100	0	0	**42**
Mean dissim (top 90%)	0.179	0.287	0.238	0.281	**0.246**	0.365	0.489	0.278	0.257	**0.347**

Table A6. 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)	P	P
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	S	Su
Habitat (Riffle, Macrophyte, Pool, Combined)	R	R
No. of years (N comparisons)	8 (28)	6 (15)
Between-year comparisons		
Rank abundance		
% dissim > 0.5 (top 50%)	68	6
Mean dissim (top 50%)	0.554	0.373
Presence-absence		
% dissim > 0.35 (top 50%)	4	0
% dissim > 0.35 (top 90%)	29	0
% dissim > 0.4 (top 50%)	4	0
% dissim > 0.4 (top 90%)	21	0
Mean dissim (top 90%)	0.291	0.159

Table A7. 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.

	Latrobe R (VIC)											
Site details Site (# and COMbined)	Ult4	Ult6	Ult15	Ult28	Ult41	Ult52	Ult53	Ult60	**COM**	Llt1	Llt1	**COM**
Permanent (P) or seasonally-flowing (S)	P	P	P	P	P	P	P	P	**P**	P	P	**P**
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	C	C	C	C	C	C	C	C	**C**	C	A	**C/A**
Habitat (Riffle, Macrophyte, Pool, Combined)	C	C	C	C	C	C	C	C	**C**	C	C	**C**
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**

Table A8. 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	**COM**
Permanent (P) or seasonally-flowing (S)	P	P	**P**	P	P	**P**
Season (Win, Aut, Spr, Sum, Early Dry, Late Dry, Combined)	A	A	**A**	S	S	**S**
Habitat (Riffle, Macrophyte, Pool, Combined)	P	P	**P**	P	P	**P**
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**

Table A9. Summary results for pairwise interannual comparisons of macroinvertebrate community data (viz dissimilarity measures), for a sites on Musselboro-Coquet Cks, TAS.

	Musselboro-Coquet Cks (Tas)					
Site details						
Site (# and COMbined)	Muss	Coq	COM	Muss	Coq	COM
Permanent (P) or seasonally-flowing (S)	P	P	P	P	P	P
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)	6 (13)
Between-year comparisons						
Rank abundance						
% 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	0.194	0.237	0.216

Table A10. 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	COM	OR	OR	OR	BR	BR	BR	WR	COM
Permanent (P) or seasonally-flowing (S)	P	P	P	P	P	P	P	P	P	P	P	P	P	S	P
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	M	P	R	M	P	C	R	M	P	R	M	P	P	C
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

Table A11. 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	COM	CD6	ND1	ND2	ND3	ND4	COM	CD1	CD2	CD3	CD4	CD5	COM	CD6	ND1	ND2	ND3	ND4	COM
Permanent (P) or seasonally-flowing (S)	S	S	S	S	S	S	P	P	P	P	P	P	S	S	S	S	S	S	P	P	P	P	P	P
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)	6 (29)	3 (3)	3 (3)	3 (3)	3 (3)	3 (3)	3 (15)
Between-year comparisons																								
Rank abundance																								
% 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	0.484	0.465	0.239	0.380	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	0	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	0	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	0.250	0.200	0.203	0.199	0.239	0.231	0.214	0.333	0.260	0.322	0.283	0.187	0.277	0.264	0.306	0.082	0.219	0.293	0.233

ATTACHMENT 2

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

(Results to 30 June 1997)

by

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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 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. 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 μm 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 µm 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.

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

Sample (and agency)	Code	Rationale for inclusion
Bowerbird, upper Magela, 1988 (*eriss*)	BBRD88	Macroinvertebrate communities seemed persistent over time
Bowerbird, upper Magela, 1995 (*eriss*)	BBRD95	Macroinvertebrate communities seemed persistent over time
SAR site 3, 1988 (*eriss*)	SA03R88	Lack of persistence of macroinvertebrate composition and structure evident in long-term data.
SAR site 3, 1995 (*eriss*)	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

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: Table 4) 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.

Comparison	Analysis	Pres-abs	Rank abund
BBRD88 vs BBRD95: Temporal variability	Dissimilarity	0.05	0.361
	(Mis)Classify	C	C
SA03R88 vs ERIS3R95: Temporal variability	Dissimilarity	0.256	0.676
	(Mis)Classify	M	M
SA03R95 vs ERIS3R95: Methodology	Dissimilarity	0.077	0.177
	(Mis)Classify	C	C

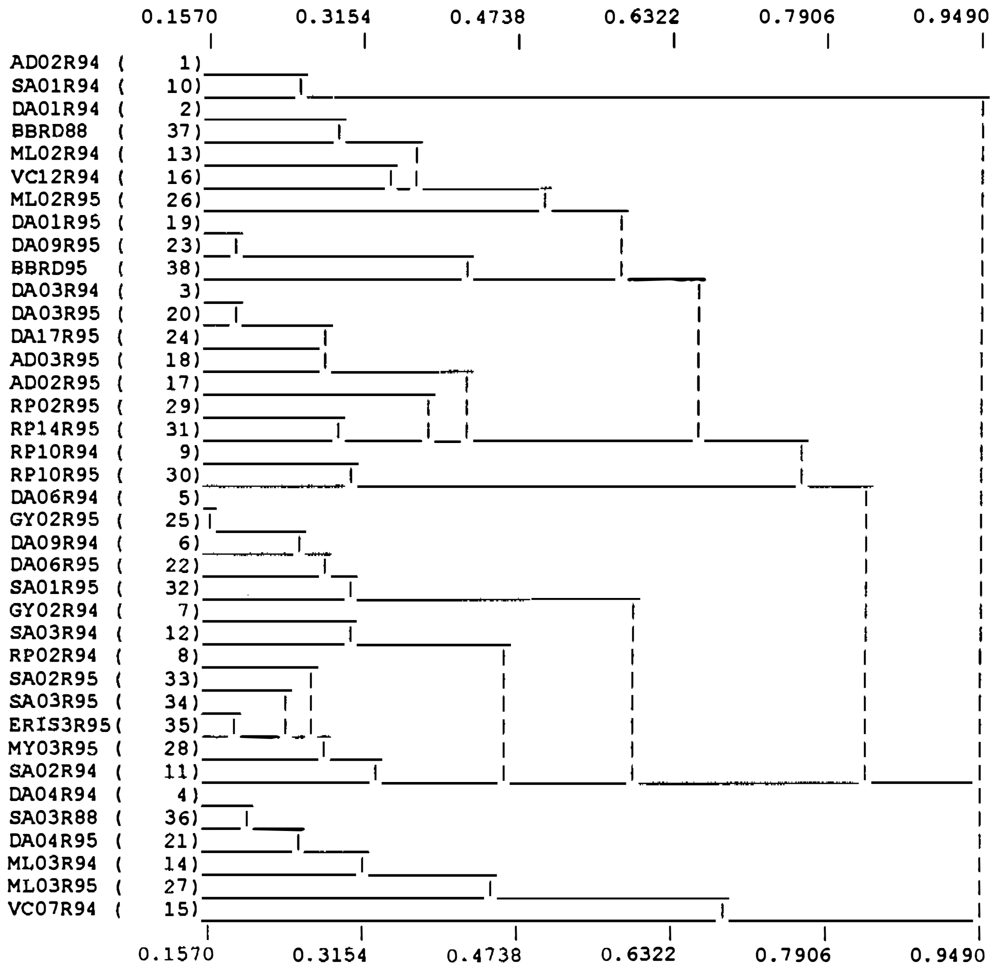

Figure 1. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon rank abundance data. Site codes provided in Tables 1 and A1.

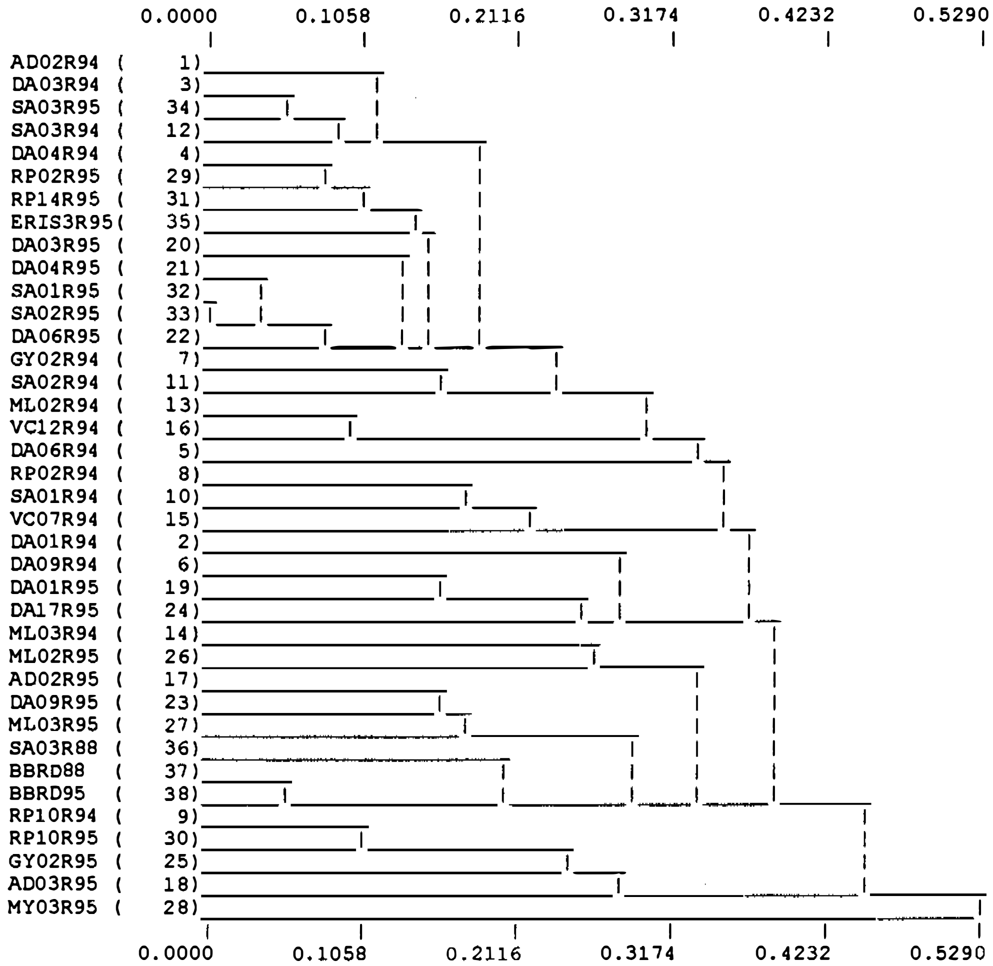

Figure 2. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon presence-absence data. Beta set at -0.1. Site codes provided in Tables 1 and A1.

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 1997). 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 1997). 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.).

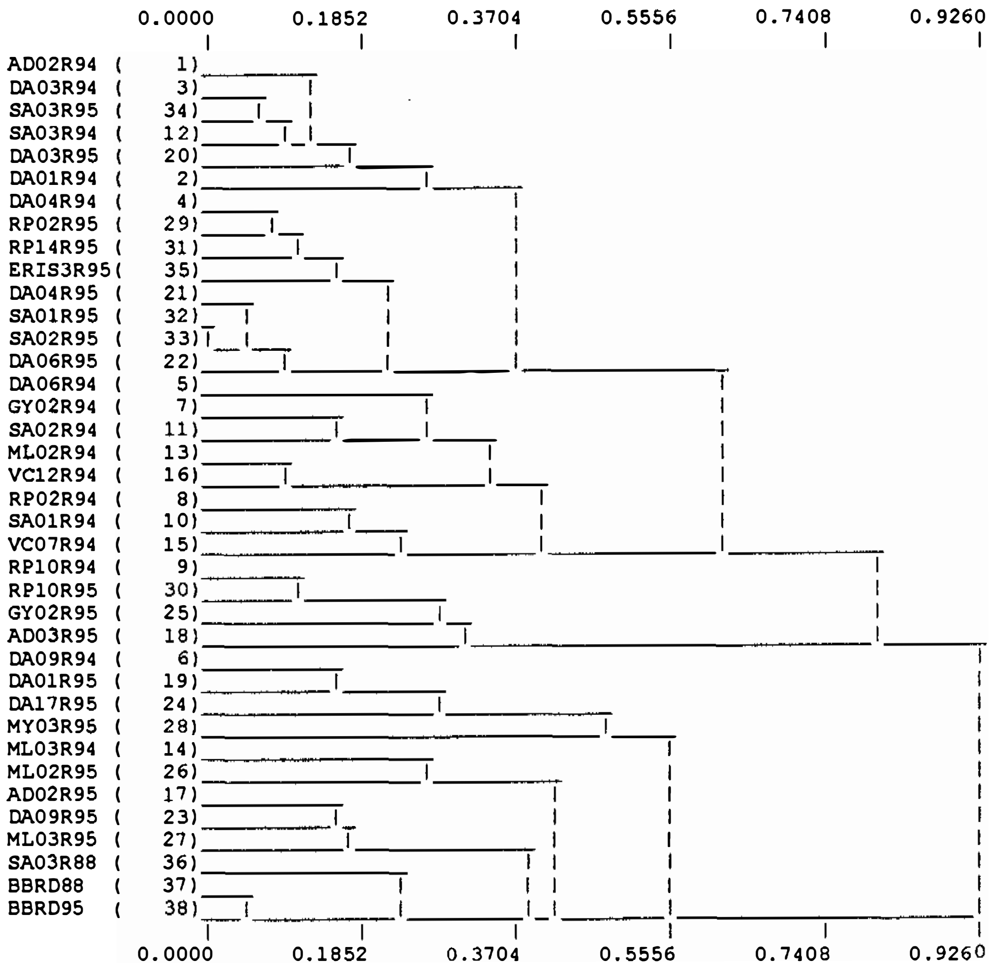

Figure 3. UPGMA classification of riffle macroinvertebrate samples for DLP&E (late Dry season 1994 & 1995) and additional ARR samples (mid-late Dry 1988 & 1995) based upon presence-absence data. Beta set at -0.3. Site codes provided in Tables 1 and A1.

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

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

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

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*.

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

Table A1. Contin.

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

APPENDIX 2

Tables A2-A4 listing taxa and relative abundances of macroinvertebrates sampled from riffle 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																
Acarina	15400	280	2000	2550	200	2000	7600	2800	50	15500	2700	900	167	150	10	100
Coleoptera																
Dytiscidae	0	0	0	0	0	100	0	0	0	0	0	0	33	0	0	51
Elmidae	2100	2180	4050	2250	4567	22000	4600	4800	550	2000	7100	4900	733	2100	50	50
Gyrinidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	101
Scirtidae	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea																
Atyidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Palaemonidae	1	10	1	1	0	1	1	1	1	1	0	1	1	0	0	1
Parastacidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Diptera																
Ceratopogonidae	300	80	50	50	33	0	400	400	0	0	300	800	100	50	10	150
Chironomidae	7100	1240	4350	1850	1433	400	7600	4200	1800	1500	3200	7800	1267	1800	400	6950
Empididae	500	50	0	0	0	0	100	0	0	0	300	0	0	100	0	0
Simuliidae	0	2390	2200	700	467	100	100	0	150	400	200	500	1667	650	280	6750
Tabanidae	1	0	101	101	34	1	100	1	1	100	101	101	0	50	20	1
Tipulidae	0	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera																
Baetidae	0	580	2250	500	200	600	200	1400	250	200	900	100	500	0	911	1650
Caenidae	4900	1380	500	0	633	800	2700	6900	850	700	3300	4900	167	100	0	2550
Leptophlebiidae	0	0	0	8900	133	0	100	100	0	200	100	0	1100	3600	470	301
Hemiptera																
Naucoridae	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Lepidoptera																
Pyralidae	300	70	51	100	0	1	1	201	51	201	300	0	0	0	1	0
Mollusca																
Corbiculidae	0	320	0	0	34	1401	100	100	3651	0	0	0	0	0	0	0
Thiaridae	0	0	0	0	0	0	1300	0	1	0	0	0	0	0	0	0
Nematoda																
Nematoda	0	10	0	0	33	0	0	0	50	0	0	100	0	0	0	0
Neuroptera																
Sisyridae	0	0	0	50	0	0	0	0	0	0	0	200	0	0	0	0

Table A2 cont.

Taxa	AD02R	DA01R	DA03R	DA04R	DA06R	DA09R	GY02R	RP02R	RP10R	SA01R	SA02R	SA03R	ML02R	ML03R	VC07R	VC12R
	Sampling Sites															
Odonata																
Anisoptera	0	20	0	0	0	0	0	0	0	0	400	0	133	0	0	0
Gomphidae	1	40	50	0	0	1	0	201	1	100	101	1	100	50	0	50
Libellulidae	1	10	151	251	0	0	0	300	0	100	0	100	0	1551	10	0
Zygoptera	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Oligochaeta																
Oligochaeta	600	20	700	200	133	1700	500	700	1750	300	200	300	900	0	10	650
Trichoptera																
Ecnomidae	300	0	50	100	67	0	200	0	500	0	300	200	33	0	0	51
Hydropsychidae	600	620	1051	850	67	200	0	0	550	0	0	500	0	350	0	0
Hydroptilidae	300	120	750	250	33	0	400	0	0	300	2500	2500	0	200	0	150
Leptoceridae	0	0	0	50	0	100	0	0	0	0	0	0	0	200	0	0
Philopotamidae	100	220	200	1150	0	1700	0	0	0	100	200	500	67	550	0	100

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.

	Sampling 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
Gyrinidae	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	0	0	0	0	0	20	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0
Crustacea																						
Atyidae	0	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0
Palaemonidae	1	1	0	21	1	1	1	1	1	0	0	1	1	1	1	1	34	1	0	1	1	1
Diptera																						
Ceratopogonidae	267	0	100	140	100	67	0	33	29	117	25	200	25	350	25	0	133	100	133	233	0	14
Chironomidae	2167	5600	3050	620	525	1300	260	1433	1472	1650	475	2850	200	5950	300	600	867	1150	367	900	1167	329
Empididae	100	100	250	140	0	300	0	0	14	33	0	50	25	0	0	0	0	50	33	67	0	14
Simuliidae	400	300	900	1620	325	900	1120	333	0	567	1100	500	100	50	350	2200	100	1600	567	1700	4600	671
Tabanidae	1	1	51	0	26	0	1	101	0	17	0	100	0	1	0	1	0	1	100	1	1	1
Tipulidae	1	0	301	1	1	0	0	1	0	17	14	0	1	1	0	0	1	51	68	1	0	0
Ephemeroptera																						
Baetidae	467	0	150	420	200	500	160	400	243	0	175	1450	17	750	2250	1950	3134	1150	1000	1333	567	57
Caenidae	501	2200	300	340	25	200	80	533	129	133	0	2250	8	1250	1175	700	200	100	200	1267	733	43
Leptophlebiidae	0	200	50	0	1626	0	820	1068	0	0	0	50	242	0	76	0	167	2701	668	668	67	114
Hemiptera																						
Corixidae	0	0	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	0	0	0
Naucoridae	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	75	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

Table A3 cont.

Taxa	AD01R	AD02R	AD03R	DA01R	DA04R	DA09R	DA11R	DA12R	DA17R	DA18R	DW03	GY02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	VC05R	VC12R
	Sampling Sites																					
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
Corduliidae	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
Libellulidae	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0
Oligochaeta																						
Oligochaeta	733	0	0	0	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	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

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 as per Tables A1 and Table 1.

	Sampling Sites																					
Taxa	AD02R	AD03R	DA01R	DA03R	DA04R	DA06R	DA09R	DA17R	GY02R	ML02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	SA03R88	ERIS3R95	BBRD88	BBRD95
Acarina																						
Acarina	1000	0	1000	138	250	267	600	550	33	450	100	67	350	0	400	129	17	51	0	16	6	1
Coleoptera																						
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	1	0	0	1
Elmidae	650	1086	2700	700	575	3067	1250	2450	5233	100	114	1583	1050	1633	50	1229	1067	574	744	1086	32	11
Gyrinidae	1	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	1	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	171	0	0	0	0	0	0	0	0	0	0	0
Crustacea																						
Atyidae	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
Palaemonidae	1	44	1	14	1	1	0	1	1	0	0	1	1	1	1	1	1	2	0	1	0	1
Diptera																						
Ceratopogonidae	0	14	0	25	50	200	0	0	100	150	0	17	100	0	50	14	50	31	108	67	2	0
Chironomidae	3400	1029	1600	550	775	1367	800	3200	1200	500	86	167	3050	1167	3300	286	533	210	315	937	27	19
Empididae	150	0	200	0	0	200	100	0	0	0	29	0	0	0	0	0	0	3	2	38	0	0
Simuliidae	1050	86	2200	88	125	67	1650	0	67	6850	357	0	400	400	1400	571	17	12	4	21	71	27
Tabanidae	1	15	1	1	51	33	51	0	0	0	0	0	1	34	0	1	118	40	21	62	0	0
Tipulidae	0	14	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	31	3	0	0
Ephemeroptera																						
Baetidae	0	43	700	388	375	67	1000	700	0	0	43	0	2550	700	2650	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
Leptophlebiidae	0	0	0	0	1976	0	0	0	0	4550	886	0	1900	0	50	57	83	1	1908	2	15	19
Hemiptera																						
Corixidae	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
Naucoridae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Lepidoptera																						
Pyralidae	0	14	301	38	75	33	201	250	68	0	0	0	200	167	51	14	50	2	18	48	0	2
Mollusca																						
Corbiculidae	0	0	0	0	0	0	1	0	0	0	0	0	0	2768	0	0	0	0	1	0	0	0
Hyriidae	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Thiaridae	0	0	0	0	0	0	0	0	68	0	0	0	1	167	0	0	0	0	0	0	0	0
Viviparidae	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table A4 cont.

Taxa	AD02R	AD03R	DA01R	DA03R	DA04R	DA06R	DA09R	DA17R	GY02R	ML02R	ML03R	MY03R	RP02R	RP10R	RP14R	SA01R	SA02R	SA03R	SA03R88	ERIS3R95	BBRD88	BBRD95
	Sampling Sites																					
Nematoda																						
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
Neuroptera																						
Sisyridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0
Odonata																						
Anisoptera	0	0	100	38	0	0	50	250	0	50	100	0	50	0	0	14	17	0	0	0	0	0
Corduliidae	1	0	0	1	0	0	50	0	0	0	1	0	0	0	0	0	0	0	9	0	0	1
Gomphidae	0	0	1	1	0	0	0	1	33	0	0	0	0	0	0	0	0	3	0	0	0	0
Libellulidae	50	0	0	0	0	0	51	51	0	1	30	0	101	0	1	0	1	21	8	3	0	0
Oligochaeta																						
Oligochaeta	0	157	0	75	200	1200	50	0	33	0	0	117	100	267	0	71	17	19	13	12	0	0
Trichoptera																						
Ecnomidae	350	0	0	25	25	33	200	201	33	100	71	0	100	500	250	14	100	7	20	2	0	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	1	8