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SIGNAL scoring system for river bio-assessment by community groups

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Abstract

The SIGNAL biotic index for river macroinvertebrates, originally developed at tested in eastern Australia, was revised for application to the entire continent. Macroinvertebrate survey data from the National River Health Program were used to set grade numbers between 1 and 10 to represent the sensitivities of over 200 taxa of river macroinvertebrates to water and habitat quality. Initially, grades were derived separately for 24 geographic regions. However, cluster analysis showed no clear spatial pattern, indicating that taxon sensitivities were essentially homogeneous. Accordingly, a single set of nationwide grades was produced. Grades were assigned at the taxonomic levels customarily used by State and Territory agency staff (predominantly family level) and by community groups (mainly order). A new index version using these grades, termed SIGNAL 2, was significantly and often strongly correlated with habitat quality indices, several water quality variables (especially electrical conductivity and total nitrogen) and physiographic variables such as slope and altitude. Because of natural spatial variation, index scores need to be interpreted in a local context or against site-specific predictions generated by the Australian River Assessment Scheme (AUSRIVAS). A general scheme was developed for evaluation of SIGNAL 2 scores in conjunction with taxonomic richness. SIGNAL 2 and its use are described in a User Manual.

Introduction

SIGNAL (Stream Invertebrate Grade Number – Average Level) is a simple biotic index for Australian river macroinvertebrates. It was developed by Chessman (1994, 1995) as a modification of the ASPT (Average Score Per Taxon) version of the British BMWP (Biological Monitoring Working Party) score system. Chessman assigned 'grade numbers' between 1 and 10 to 110 common families of Australian river macroinvertebrates. These numbers reflected his estimates of the sensitivities of these families to common types of stream pollution. The families considered most sensitive were awarded grade numbers of 10 and those regarded as most tolerant were given grades of 1. The rest were arranged in between.

Chessman (1995) gave instructions on collecting standard samples from defined mesohabitats such as riffles and edgewater. SIGNAL scores were calculated for these samples as the weighted or unweighted averages of the sensitivity grades of the families collected in the standard samples (the 'Average Level' in the acronym). Chessman (1995) also provided indicative ranges of SIGNAL scores that he considered to be associated with particular levels of water quality in the Hawkesbury-Nepean river system (clean water, possible mild pollution, probable moderate pollution and probable severe pollution).

The sampling methods described by Chessman (1994, 1995) were incorporated into the standardised national bioassessment protocol developed under the National River Health Program (Anonymous 1994). Later, following the recommendations of Barmuta *et al.* (1998), SIGNAL was incorporated in the Australian River Assessment Scheme (AUSRIVAS), a computer-based analysis package developed to process the data collected in the National River Health Program (Coysh *et al.* 2000). The AUSRIVAS computer models were designed to use data from reference sites to calculate an 'expected' SIGNAL score for each standard sample from a study site. Each expected score is compared with the corresponding actual ('observed') score and their relativity is expressed as observed-to-expected (O/E) ratio. This ratio constitutes one of the two outputs currently generated by AUSRIVAS, the other being the ratio of observed and expected numbers of taxa.

The use of SIGNAL has been hampered by the east-coast focus and preliminary nature of the original version. Chessman (1995) and Growns *et al.* (1995) identified several aspects of

SIGNAL that required further development and testing, and cautioned particularly against its application to other parts of Australia with different macroinvertebrate faunas and environmental characteristics. Nevertheless, attempts have been made to apply Chessman's (1995) scheme without modification to northern, western and inland Australia, and have sometimes been used as a basis for criticism (e.g., Bunn and Davies 2000).

In parallel with the development of SIGNAL and AUSRIVAS during the 1990s, the NSW Streamwatch program developed a macroinvertebrate-based stream assessment protocol for community groups in the Sydney region. This protocol incorporated an index in some ways similar to SIGNAL, but based on the level of taxonomic discrimination that could be achieved by most community groups, ranging from phylum to family according to the type of invertebrate. The Streamwatch index was calculated as a total of the grades of the taxa captured, rather than as an average as for SIGNAL. Consequently, it was substantially affected by sampling effort and efficiency. Following the publication of this method in a four-page brochure (the 'Water Bug Detective Guide'), it was widely applied throughout Australia. Subsequently the index was modified as an abundance-weighted average more similar to SIGNAL. The Streamwatch index has been beset by the same problems as SIGNAL, particularly the appropriateness of the current sensitivity grades and the difficulty of applying a single rating scheme to a country as large and diverse as Australia.

This present project was commissioned as part of the National River Health Program, in order to develop a second-generation SIGNAL index and rating scheme appropriate to both AUSRIVAS and community groups, and applicable to the whole of Australia. Its objectives were as follows:

- to adapt the SIGNAL biotic index for river macroinvertebrates to suit order-level identification by community groups, and
- to develop a manual for community and agency use describing the SIGNAL system at order and family levels, and associated material for incorporation into AUSRIVAS printed and software resources.

As part of the project the original sensitivity grades for individual families were revised, and grades were extended to families and other taxa (predominantly orders) not graded by Chessman (1995). Chessman's rating system was replaced with a more general interpretation scheme based on both SIGNAL scores and number of taxa. The new system is termed SIGNAL 2.

The following sections of this final report provide a brief overview of the methods used and results obtained, and the strategies for adoption of results.

Methods

The project analysed data sets collected by State and Territory government agencies as part of the National River Health Program (NRHP), managed by Environment Australia. NRHP sample identification and data processing were not completed in all jurisdictions before data were acquired, but data from at least four sampling rounds were available in all cases. Data from over 15 000 individual macroinvertebrate samples, with associated environmental data, were used in the analysis. A summary of these data is tabulated on the next page.

State/Territory	Data sets
ACT	Autumn 1994, 1995, 1997, 1998, 1999; spring 1994, 1995, 1997, 1998, 1999

NSW	Autumn 1995, 1996, 1997, 1998, 1999, 2000; spring 1994, 1995, 1997, 1998, 1999
NT	Autumn 1995, 1996, 1998, 1999; spring 1995, 1996, 1998, 1999
Qld	Autumn 1995, 1996, 1997, 1998, 1999; spring 1994, 1995, 1997, 1998, 1999
SA	Autumn 1997, 1998; spring 1997, 1998
Tas	Autumn 1995, 1996, 1997, 1998, 1999, 2000; spring 1994, 1995, 1997, 1998, 1999
Vic	Autumn 1997, 1998, 1999; spring 1997, 1998, 1999
WA	Autumn 1998, 1999; spring 1997, 1998, 1999, 2000

SIGNAL 2 grades were derived using NRHP macroinvertebrate data, which were mainly at the taxonomic level of family. Grades were also derived for the higher-level taxa (phyla, classes and orders) considered by community groups, by amalgamating family data. Grade derivation was done using the objective procedure devised by Chessman *et al.* (1997). This procedure requires data sets in which the dominant gradients are those resulting from human disturbance rather than natural spatial and temporal variation. In order to avoid major natural gradients, analyses were done separately for specific combinations of geographic region, mesohabitat and season.

SIGNAL 2 scores were calculated for NRHP macroinvertebrate samples using the revised grades. The relationships of these scores to environmental factors were assessed by generating scatterplots and correlation coefficients. Both natural and human-influenced environmental factors were considered. Relationships between SIGNAL 2 scores and taxonomic richness were also considered.

Results

Grades derived from individual analyses were averaged to produce overall grades for each of 24 geographic regions. Cluster analysis of these regional grades showed no consistent or logical geographic pattern across Australia. Although adjacent regions sometimes clustered together, disparate regions also did so. For example, at the family level, the Victorian highlands grouped with the Queensland central coast. At the order/class/phylum level the New South Wales uplands grouped with the Northern Territory. The regional grades were therefore averaged to produce a single set of new national grades. Having a single set of grades for the whole country simplifies the potential use of SIGNAL 2 both by community groups and in AUSRIVAS.

SIGNAL 2 scores were positively correlated with altitude, slope, dissolved oxygen and habitat quality scores. The strongest negative correlation was with total nitrogen, followed by electrical conductivity, alkalinity, total phosphorus and turbidity. Correlations were weaker for the order/class/phylum version but of the same general form. Taxonomic richness showed much weaker correlations with the tested environmental variables than SIGNAL 2 did. Correlations between SIGNAL 2 scores and taxonomic richness were also weak.

The following conclusions were reached:

- SIGNAL 2 scores are sensitive to enrichment of streams by inorganic sediment, salts and nutrients,
- this sensitivity reflects both natural and human-induced variation in water and habitat quality across the continent,
- SIGNAL 2 scores for particular mesohabitats need to be interpreted in a regional context or by comparison with ‘expected’ scores generated by AUSRIVAS,

- useful results can be obtained by calculating SIGNAL at the order/class/phylum level, although sensitivity is somewhat reduced, and
- SIGNAL 2 scores and taxonomic richness provide different information and should be considered simultaneously when assessing river condition.

The successful development of an order/class/phylum version of SIGNAL meets the first objective of the project.

A user manual has been compiled for SIGNAL 2. This includes a scheme for interpretation of SIGNAL 2 scores and taxonomic richness, at both the family and order/class/phylum levels, in a regional and mesohabitat context. This manual could be used as a resource by Waterwatch and other community-based programs. Material in the manual is also suitable for incorporation into AUSRIVAS. This meets the second objective of the project.

Work has started on preparation of a scientific journal paper on SIGNAL 2.

Adoption

Oral presentations on progress in the project were made at the following forums:

- National River Health Program technical workshop, Canberra, 1 February 2000,
- Waterwatch National Conference, Brisbane, 21 November 2000, and
- NSW Streamwatch co-ordinators workshop, Sydney, 25 June 2001.

The Brisbane Waterwatch presentation took the form of a one-hour workshop. It was especially valuable in obtaining feedback from potential users of the community version of the index. Several changes to the format of the SIGNAL 2, mostly aimed at simplification, were made in consideration of this feedback.

Discussions were also held during the course of the project with the following people:

- David Cleary, Streamwatch NSW,
- Peter Davies, NRHP co-ordinator,
- Bruce Gray, Environment Australia,
- Nadia Kingham, Waterwatch/Environment Australia,
- Richard Norris, University of Canberra,
- Cherie Parmenter, Streamwatch NSW, and
- Geoffrey Smith, Waterwatch NSW.

In addition, much telephone conversation and e-mail correspondence took place with various scientists and community group members who made contact because of their interest in the project.

Valuable comments on a draft of the user manual were made by Ian Bayly and Michael Cassidy (Waterwatch Tasmania), Peter Davies, Bruce Gray and Cherie Parmenter.

The incorporation of SIGNAL 2 into AUSRIVAS requires further discussion between the principal investigator, Environment Australia and the NRHP co-ordinator. The use of the original version of SIGNAL within AUSRIVAS has been problematic, and there is uncertainty within the scientific community about the correct means of calculating expected SIGNAL scores. This question needs to be resolved, but is beyond the scope of the present project.

The scheme presented in the SIGNAL 2 user manual, involving simultaneous consideration of the SIGNAL score and taxonomic richness, resembles a scheme used by Waterwatch Victoria (based on aggregate score and number of individuals), but is a substantial departure from the scheme presently used in AUSRIVAS. The latter assigns an overall 'band' label to a site (e.g., 'similar to reference', 'poorer than reference') according to the lower of the O/E ratios for SIGNAL and number of taxa.

The following actions are suggested to further adoption:

- widespread review and testing of the SIGNAL 2 user manual by Waterwatch and professional groups,
- further development and packaging of SIGNAL 2 to support Waterwatch,
- further discussions between the principal investigator, Environment Australia and the NRHP coordinator concerning the use of SIGNAL 2 in AUSRIVAS, and
- publication of SIGNAL 2 in a suitable scientific journal.

Publication

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