11. Biological Indicators of Water Quality

P.S. Cranston  CSIRO Division of Entomology, Canberra
P. Fairweather  CSIRO Division of Water Resources, Griffith NSW
G. Clarke  CSIRO Division of Entomology, Canberra

Highlights

- Candidate biological indicators of water quality are discussed and evaluated using 11 selection criteria. They include vertebrates, plants and fungi, macroinvertebrates, deformity and asymmetry biomarkers, and bioassays.
- Macroinvertebrates are chosen to be included in a minimum set of key indicators for catchment assessment and monitoring.

Introduction

Monitoring the quality of water in a stream as an indicator of catchment health should include biological response attributes as well as physico-chemical attributes. Many within-catchment activities impinge upon and are integrated within the aquatic system. As a consequence, changes in the health of a catchment will be reflected in the aquatic biological community. The biological communities that are exposed to pollutants act as integrators of the multiple present and past environmental effects. This attribute makes them useful as indicators.

The literature on biological monitoring of aquatic environmental quality is immense, with at least three full length books being produced in the past four years. The Australian Journal of Ecology (volume 20) summarises and reviews a multiplicity of methods in the Australian context. Assessment of aquatic macroinvertebrates forms the principal method of aquatic biological environmental assessment adopted worldwide, and, in Australia, by the Federal Government’s Monitoring River Health Initiative. This diverse field is the subject of a compendious review by Rosenberg and Resh (1993). Furthermore, several scientific journals including Environmental Monitoring and Assessment, Regulated Rivers, Freshwater Biology (Applied Issues), Hydrobiologia and Environmental Pollution, devote much space to considerations of biological responses in the aquatic environment. To summarise, all organisms living in water are being studied, to a variable degree, in relation to their environmental requirements and their responses to perturbation. This tremendous breadth clearly is derived from recognition that the aquatic system integrates all within-catchment impacts.
Indicators of aquatic health is an area of ongoing research, not least under the aegis of the Land and Water Resources Research and Development Corporation R&D program funded under the Monitoring River Health Initiative. Many of the questions addressed in this manual are under current investigation because the answers are not evident or are ambiguous. These questions include identification of the best organisms for survey, the most appropriate level of identification, the stability (predictability) of populations, the specific responses to pollutants, and the most informative methods of data analysis.

Here, all the proposed major biological indicators of water quality are surveyed. The summary table using 11 selection criteria is given in Table 11–1. The advantages proposed by their advocates, and the problems that other scientists have identified are presented. The views presented derive also from consultation in recent months with scientists and lay people involved in the Federal Government's Monitoring River Health Initiative, Catchment Management groups in the Flinders, Waterwatch, Water Ecoscience, Frogwatch and several State agencies (CALM, Australian Water Technologies).

Table 11–1 Assessment of biological indicators of water quality

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criterion</th>
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<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6  7  8  9  10  11</td>
</tr>
<tr>
<td>Ideal rating</td>
<td>H  L  H  H  H  H  H  H  H  -  H</td>
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<td>Mammals</td>
<td>M  M  H  L  H  M  H  L  M  G  M</td>
</tr>
<tr>
<td>Reptiles</td>
<td>M  M  L  L  M  M  H  M  M  G  M</td>
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<tr>
<td>Amphibians</td>
<td>H  L  H  L  M  M  H  M  M  G  M</td>
</tr>
<tr>
<td>Waterbirds</td>
<td>M  M  H  M  L  L  L  L  L  G  M</td>
</tr>
<tr>
<td>Fish</td>
<td>M  M  M  M  M  M  M  M  M  GD  L</td>
</tr>
<tr>
<td>Plants</td>
<td>H  L  M  M  M  M  H  M  H  G  M</td>
</tr>
<tr>
<td>Macroinvertebrates</td>
<td>M  M  H  H  H  H  H  H  M  GD  M</td>
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<tr>
<td>Biomarkers deformity</td>
<td>H  M  H  M  H  M  H  M  M  G  L</td>
</tr>
<tr>
<td>Biomarkers asymmetry</td>
<td>H  M  H  M  H  H  H  H  M  G  L</td>
</tr>
<tr>
<td>Bioassays</td>
<td>H  H  H  M  M  H  M  M  M  D  L</td>
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Selection criteria:
1. ease of capture (High, Medium, Low)
2. total cost/ha (H,M,L)
3. standard method available (H,M,L)
4. interpretation criteria available (H,M,L)
5. significant at catchment scale (H,M,L)
6. low error associated with measurement (H,M,L)
7. response to disturbance (H,M,L)
8. stable over period of measurement (H,M,L)
9. mappable (H,M,L)
10. generic (G)/diagnostic (D) applications
11. context data available (H,M,L)

Note: Indicators selected to be included in the set of key indicators (Section Two) are shown in bold type.
The Biological Indicator Concept

What is a Biological Indicator?
The indicator concept is well founded: the commonplace observation that organisms reflect their environment is found in writings dating from as early as Aristotle. Increasing concern for the environmental impact of human activities has led to the recognition that the biota indicates changes in system function and condition. The biota frequently is used in the description and classification of ecosystems, in indicating the deleterious effects of human activities, and in monitoring the recovery of ecosystems following remediation. In this context, the biota (either a subset comprising a biological community, or individual taxa) act as surrogates for system health. Reliable indicators are taxa with narrow and specific tolerances. Organisms with wide tolerances tend to be less informative and poorer environmental health indicators (Johnson 1995). Indicators may be used to understand the response, adaptation, and recovery of ecosystems and their inhabitants to both natural and anthropogenic disturbances. In particular, Johnson argues that ideal indicators should provide an indication of status and early warning indications of change, either at the ecosystem, population, or genetic level, as well as providing insight into potential causal mechanisms.

Confusions and Errors with Biological Indicators
Several misapplications of biological indicator technique occur. Firstly, biological indicators have been used without due considerations of the questions to be addressed, particularly the magnitude of effect required to be detected (Humphrey et al. 1995; Johnson 1995). A second pitfall has been the blind selection of ‘universal’ indicators, or the application of indicators in geographic locations for which they were not designed. These misapplications have an important bearing on the search for a single or small suite of organisms to act as universal indicators of some environmental impact(s). This conflict relates to the ‘indicator species versus indicator communities’ debate. In seeking a biological indicator for a single stressor, organisms with a unimodal response should be chosen, such that the abundance of the organism directly reflects the stress level. Even if such taxa exist (and it is doubtful), the absence of the indicator could never be ascribed with certainty to the prevailing environmental conditions. For example, the general statement that the presence of nymphs (immature stages) of Plecoptera (stoneflies) indicates high water quality is correct, provided the observation is made in southern Australia. Stoneflies are predominantly cool region organisms and are intolerant of elevated water temperatures. The absence of this ‘indicator’ taxon from warmer waters bears no relation to local water quality. Although, investigations of particular ecosystems have revealed taxa that fulfil the criteria of indicator species, e.g. the species that act as positive and negative indicators of acid mine effluent input into Rock Hole Mine Creek, Northern Territory (Faith et al. 1995; Smith and Cranston 1995), the utility of these indicators on other systems in other biogeographic regions is untested. These and similar investigations have stressed the strength of multivariate responses of many taxa as a means of indicating environmental gradients.

Finally, a serious confusion exists between the use of indicators of environmental health and the use of indicators of biodiversity. The attractive concept of organismal ‘surrogates’ of biodiversity is flawed and unsubstantiated.
where sustained benevolent conditions promote long-term survival (i.e. refugia) and allow complex mutualistic associations to develop. Alternatively, low species richness across many taxa might be expected where adverse or fluctuating conditions promote community instability with high rates of species turnover and extinction. Adverse or fluctuating conditions may also provide reduced chance for co-evolutionary complexity to develop. However, Australian studies by Trueman and Cranston (1994) failed to find any groups in which the speciosity of the organisms surveyed correlated with any other. Thus the attractive concept of organismal surrogates for biodiversity appears flawed and is unsubstantiated.

**Aquatic Indicators**

The use of the indicator approach in aquatic ecosystems, in particular the use of macroinvertebrates, has received considerable attention in biomonitoring programs (see reviews by Rosenberg and Resh 1993; Johnson 1995). For a recent review of biological monitoring in Australia see Norris and Norris (1995) and for a thoughtful overview and insights into future directions see Bunn (1995).

Stressed aquatic systems often show:

- a reduction in taxon richness, with the disappearance of sensitive taxa
- a predominance of pollution-tolerant taxa
- a change in the number of individuals within a taxon, with a tendency towards becoming monospecific (Rapport 1991)

Biomonitoring of communities, with an emphasis on taxonomic richness and composition, is considered by many to be the most sensitive means of detecting alterations in aquatic ecosystems. However, an even earlier warning of stress may be provided by physiological and morphological abnormalities in some aquatic biota (e.g. Clarke 1994; Rosenberg and Resh 1993; Madden et al. 1995; Clarke et al. 1995).

A general problem with the selection of any indicator (or set thereof) of catchment health is the need to scale up site-specific measurements (point measures) to cover the total catchment. Whole catchment responses are well reflected in the aquatic system, because the water flowing from a catchment actually does the integration. Parameters measured at the bottom of the catchment integrate what goes on in the catchment per se. Thus, information obtained at a single monitoring site per catchment at its bottom-most point summarises the total catchment response. Monitoring of sites at various places within a catchment complicates matters because changes occur as water flows through the catchment (aeration, change in gradient, increased light access, filtering, deposition and primary production etc.). Examination of whole stretches of streams or rivers are necessary to pinpoint pollution sources.

**Community Structures within Aquatic Environments**

In terrestrial environmental monitoring, the structure and responses of communities are used to monitor health. Usually, the monitoring involves communities of vertebrates and flowering plants. Nevertheless, butterflies have their advocates, using a technique of a repeated walk of given time or distance. The reasons for the restriction of choice to certain groups of organisms include their ease of observation and identification. Furthermore physiological responses of these organisms are likely to be better known than for other ecosystem components.

### 3.1 Vertebrates

**Mammals**

In freshwater aquatic ecosystems, the vertebrates are much less abundant and diverse than in most terrestrial systems. There are few freshwater aquatic mammals; but these can be surveyed accurately and cost-effectively. Mammals
like water rats have some conservation interest, and their presence can be sampled by using baited hair-tubes. These tubes have food inside and double-sided sticky tape to catch some fur off whatever comes inside (Suckling 1978). Hairs are then identified using standard references (Brunner and Colman 1974). Furthermore, it may be possible to track individual animals using spool and line gear to verify the presence of nests in the area surveyed (Woolley 1989). In conjunction with Elliot trapping, and mark-and-recapture techniques, estimation of small mammal presence and density is a relatively routine matter.

**Reptiles and Amphibians**

Reptiles and amphibians may be more intimately associated with water. The presence and abundance of water dragons appears to relate to the amount of disturbance in catchments. However, studies at A.N.U. (unpublished) failed to establish a direct relationship between dragon abundance and catchment health.

Amphibians have the advantage of being very sensitive organisms, partly due to breathing through their skin. Furthermore, two aspects of amphibians have impinged on public consciousness: the world-wide loss of many amphibians and the increasing range of the introduced cane toad (*Bufo marinus*). Public concern about amphibians lies behind the establishment of the successful community-based monitoring program FROGWATCH (Phil Suter, personal communication).

Amphibians, or at least the frogs and toads, are good indicators of aquatic habitat quality and are easy to monitor in a non-intrusive manner using their distinctive calls. There is a good supply of commercial tape recordings with which to make comparisons. Also, tadpoles, which tend to be readily visible in ponds and other bodies of standing water, are identifiable with practice and initial assistance.

**Waterbirds**

The most conspicuous vertebrates are the birds which can be easily counted in aquatic habitats from hides, using binoculars at dawn or dusk. There is also an enormous familiarity with the water birds amongst the non-specialist public. This familiarity has been harnessed by the Royal Australian Ornithological Union (RAOU) for their bird surveys. Local catchment health groups could easily access pre-existing information; in fact some of the personnel are likely to belong to both groups. Protocols for estimation of bird numbers and diversity tend to be either expensive (air time, with skills in identification at height and speed at a premium), or timed observations on single bodies of water by several investigators.

Despite the ease of bird observation, identification, and estimation of abundance, there are problems with monitoring either the diversity or number of individual birds as indicators of catchment health. The first and most obvious is that there is no well-established correlation with water quality. For example, organically enriched (eutrophicated) standing waters such as sewage lagoons can harbour enormous numbers of birds, often with high diversity. This follows from the well-known phenomenon of the enormously enhanced abundance of a few species of tolerant macroinvertebrates (e.g. Tubificids and *Chironomus* spp.) associated with organic enrichment. Secondly, birds tend to be highly seasonal, and surveys must take regard of the species behaviour. In Australia, with stochastic patterns of rainfall, there are massive and as yet poorly understood intra-continental movements (Stuart Halse, personal communication). Indeed, migratory bird abundance may relate more to events during the period when they are absent from the monitored catchment (i.e. losses during migration including losses in the non-Australian sector) than to actual catchment conditions. Nonetheless, since bird data are being acquired by a substantial group of individuals, it ought to be possible to harness some of this
knowledge to assess changes within catchments.

Fish
Fish are the dominant aquatic vertebrates, in terms of diversity, abundance and probably also in human perception. Fishing is the major outdoor recreational activity in Australia, with some estimates suggesting that as much as 25% of the adult population participate at some time. Although many of the targets for these individuals are alien (introduced) species such as trout, redfin and carp, anglers are an important group of stakeholders in catchment health.

To some extent alterations in fish community structure are used to assess environmental conditions. Generally, native fish may be quite tolerant of what we perceive to be reduced habitat quality (for example, oxygen reduction, elevated temperatures, increased siltation). Some of these factors such as ponding during drought, are common across Australia, but are caused by natural phenomena. Certain introduced fish such as carp and gambusia may thrive and possibly even displace native fish under anthropogenically stressed conditions; others, such as trout, are ‘fragile invaders’ unable to cope with warm, silty water that most native fish have to tolerate at some stage in their lifecycle (Cadwallader and Lawrence 1990).

There is a developing Australian literature concerning fish responses to environmental perturbations (reviewed by Harris 1995). Another use of fish in assessment of stream health is the documentation of fish kills. These sporadic events occur frequently enough, and are generally noted by the general community, such that the environmental conditions leading to the kills can be investigated. Furthermore, fish (e.g. carp which disturb bottom sediments) have been implicated in the advent of algal blooms, another popularly observed water quality phenomenon (Gehrke and Harris 1994).

The use of fish in ecotoxicological and bioaccumulation studies is now well advanced. The benefits of using fish in monitoring studies include:

- ease of identification and interpretation by novices including the non-specialist public
- almost universal presence of certain fish in every habitat
- their longevity which leads to temporal integration of varying conditions (Karr 1987)

To this might be added the potential for fish to avoid unfavourable conditions, and the potential use of fish in asymmetry studies (see below).

It must also be recognised that there are several difficulties in using fish to monitor water quality in catchments:

- fish are highly mobile and may often be migratory, and therefore may be able to avoid exposure to adverse environmental conditions
- protocols for quantitative sampling of fish populations are still being developed
- water quality tolerances are poorly known for most Australian species
- there are ethical problems with any destructive sampling of fish populations
- the low diversity of fish in Australian waters means that few species are expected in any given river, reach or habitat

In Australia, reliable quantitative sampling techniques are being developed by the CRC for Freshwater Ecology in the form of their electrofishing apparatus.

Furthermore, there is a relatively well-established approach to examining sublethal effects induced by poor water quality based on histopathology of skin lesions, erosional deformities, liver and other internal organ malformations, and toxin accumulation. The latter has been used to examine contamination by pesticides and other organic toxins. The loss of native fish and increases in exotic species is a readily measured broad
indicator of something being ‘wrong’ with the system.

The list of techniques used in the Alligator Rivers Region to monitor fish should be consulted (Bishop et al. 1995).

**Plants (Macrophytes, Algae, Diatoms) and Fungi**

Aquatic plants form discrete communities of readily identifiable taxa. However, use of plant community floristic structure as a means of monitoring changes in ecological conditions is not well developed in Australia, compared to the northern hemisphere. Plant communities are open to modification by periodic floods and droughts which are common in Australia, and an equilibrium condition can take some time to become established. Even so, macrophytes respond to changes in water quality such as alteration in salinity and turbidity, in a predictable way. In Australia, many native fish (e.g. golden and silver perches and cod species) and introduced sports fish (e.g. redfin) require the cover provided by macrophytes, or more usually by large woody debris (snags). The availability of vegetated habitats has been shown to be important for the larvae of native fish (Peter Gehrke, NSW Fisheries, personal communication).

Algae, diatoms and fungi show variation in their species composition and abundance which can be linked to changes in water quality. Amongst the most dramatic and well-known of these responses are algal blooms and the visible dominance of sewage fungus in running waters downstream of sewage input, or in standing waters subjected to the same pollution. Algal blooms have been the focus of considerable study over the past decade. They certainly indicate the poor health of a river system, but the causality is usually multi-factor and a regional rather than a catchment problem. Aside from these extreme conditions, algae and diatoms occur in biological communities whose components reflect environmental conditions. Diatoms in particular have been used in reconstruction of palaeoclimates from fossil and subfossil remains in sediment. Despite this use, neither taxonomic grouping is regularly used in any major monitoring program, because of problems with methods of sampling and a lack of identification skills. Perhaps they respond too rapidly to environmental fluctuations which are much shorter than conventional sampling intervals.

In summary, plants have the potential to play a greater role in biomonitoring. They have the advantage that certain assessments can be made by non-specialists. For example, estimation of cover of sewage fungus, or the extent of cover and lushness of macrophytes, allows some estimate of biomass, especially in riparian zones. However, in Australian waters the prevailing low nutrient levels mean that macrophyte abundance generally is low except in nutrient-enriched (naturally or otherwise) waters. Furthermore, in many of our waterways alien macrophytes dominate, and are the subject of control attempts e.g. Salvinia, Eichhornia, Alternanthera (Sainty and Jacobs 1988). The relationship between a lush growth of alien macrophytes, like Ludwigia, and catchment activities remains tenuous. Furthermore, even native species such as Typha can be problematic when becoming invasive (Jane Roberts, personal communication).

**Macroinvertebrates**

Macroinvertebrates are conventionally defined as those invertebrates that are retained by a 500 μm mesh-sized sieve. This eliminates most organisms that require specialised microscopic techniques for their identification, although this doesn't imply all remaining invertebrates can be recognised without magnification. Some need specialised preparation techniques.

Amongst the macroinvertebrates that fall below this size range, there are many organisms that are known or suggested to be valuable in aquatic biomonitoring (Russell Sheill, personal communication). However, the techniques are too difficult
Aquatic macroinvertebrates conventionally used in monitoring activities usually comprise the immature stages of insects.

and poorly investigated to advocate their use by non-specialist community groups.

The aquatic macroinvertebrates conventionally used in monitoring activities usually comprise the immature stages of insects such as dragon- and damselflies, mayflies, stoneflies, bugs, beetles and true flies. Under certain conditions, nematodes and oligochaete worms attain high abundance and these species have been advocated in biomonitoring programs. Waterwatch provides training for community groups in identifying certain macroinvertebrates common in their area. CD-ROMs are available to schools e.g. Chiron Media’s StreamScan which allows students to identify macroinvertebrates using an interactive taxonomic key and then generate indexes of water quality.

The advantages of using macroinvertebrates in biological monitoring of aquatic environments include (Gullan and Cranston 1994):

- the ability to select amongst the many macroinvertebrate taxa in any aquatic system, according to the resolution required
- the availability of many ubiquitous or widely distributed taxa, allowing elimination of non-ecological reasons why a taxon might be missing from an area
- the functional importance of macroinvertebrates in aquatic ecosystems, ranging from secondary producers to top predators
- the ease and lack of ethical constraints in sampling aquatic macroinvertebrates, giving numbers of individuals and taxa that can be handled, yet be informative
- the ability to identify most aquatic macroinvertebrates to a meaningful level
- the predictable, and easily detectable, responses of many aquatic macroinvertebrates to disturbances, such as particular types of pollution

When combined with sampling and identification protocols such as those suggested by ANZECC (1992) and implemented by the Federal Government’s Monitoring River Health Initiative (MRHI), better repeatability is introduced.

Typical responses observed when aquatic macroinvertebrate communities are disturbed include:

- increased abundance of certain mayflies, (e.g. Caenidae with protected abdominal gills), and caddisflies (e.g. filter-feeders such as Hydropsychidae), as sediment levels increase
- increase in numbers of haemoglobin possessing bloodworms (Chironomidae) and oligochaetes as dissolved oxygen is reduced
- loss of stonefly nymphs (Plecoptera) as water temperatures increase
- potentially reduced diversity with pesticide load
- increased abundance of a few species but general loss of diversity with elevated nutrient levels (organic enrichment, or eutrophication)

More subtle community changes can be observed in response to less overt pollution sources, but it can be difficult to separate environmentally-induced changes from natural variations in community structure.

**Use and Interpretation of Macroinvertebrate Indicators**

There is a multiplicity of summary statistics (indices) that can be derived from macroinvertebrate monitoring programs (see for example, Resh and Jackson 1993; Resh and McElravy 1993; Table 3 in Resh et al. 1995). The differences between these indices include simplicity of calculation, tolerance of suboptimal identifications and inclusion/exclusion of abundance data. In rapid assessment techniques, the intention is to provide simple numerical indices for water managers; but their scientific veracity is little tested so far.
Bunn’s (1995: 225) perceptive views on this matter bear repetition in detail:

no single biological measurement will suffice to indicate the effects of pollution in aquatic systems and it is unrealistic to expect to find an all embracing, cheap and sensitive method. .. Monitoring agencies should use a range of approaches that vary in sensitivity…

Of far greater interest in the current context is the utilisation of macroinvertebrate data in a predictive mode with tools such as RIVPACS (Wright et al. 1989). This package was developed in the UK and is being used by the Monitoring River Health Initiative in Australia. This combines numerical classifications of indicator organisms found at survey sites and a correlation analysis with environmental variables, including pollution. The indication obtained from these analyses are indices of differences between the observed biota and that which is predicted by physico-chemical parameters and reference to unimpacted sites. RIVPACS and similar packages can be predictive tools, rather than simply providing retrospective confirmation that a stress has taken place.

**Biomarkers: Deformities and Asymmetry**

A general criticism of biological monitoring (with the exception of predictive schemes such as RIVPACS (above)) is that it picks up trends too late. By the time a shift in community composition is detected, the health of the system has deteriorated to the extent that irreversible damage may have been caused. Under these circumstances, early-warning indicators might allow remedial action to be undertaken earlier. Some early-warning approaches using biological indicators have been proposed: biomarkers and bioassays.

Biomarker techniques rely on organisms living in the ecosystem of interest detecting low-level contaminants prior to subsequent impacts on the ecosystem.

Techniques include:

- measurement of developmental asymmetry
- measurement of deformity of morphological features
- a suite of genetic, biochemical and physiological biomarkers

These latter techniques are laboratory-based, and are poorly suited for routine community-based use.

It is a frequent observation that organisms living in stressed environments can suffer from sub-lethal effects that include developmental abnormalities and asymmetry of development. Observations on the incidence of morphological deformities have been made in natural systems contaminated by pesticides, and in experimental channels (mesocosms) in which insecticide has been added under controlled conditions. Field estimation of deformities in chironomid larvae in pesticide-exposed rice paddies, have been reported recently by Pettigrove et al. (1995). Furthermore, laboratory cultures of appropriate Australian organisms such as Chironomus maddeni have been subjected experimentally to known concentrations of pollutants to induce quantifiable deformities (Madden et al. 1995).

However, the dose–response is not linear, and there have been some problems in reconciling natural incidence with laboratory induction. The techniques of scoring deformities involve some easily acquired skills, and perhaps the optimal value of the observations is in detection of deformities in immature macroinvertebrates collected in community-based survey. Under these circumstances the frequency of deformities acts as an early warning signal.

Deleterious effects on development perhaps can best be quantified by use of an internal control, namely the alternate sides of bilaterally symmetrical organisms. Asymmetry analysis provides another early-warning system of ecosystem deterioration and changes in life history parameters. It can also be used to assess efficacy of remedial actions. The science
of bilateral asymmetry is quite well developed, and the theoretical framework is robust.

Routine monitoring of a subset of aquatic organisms (the selected indicators) and the relative ease of scoring and analysing deformities or asymmetrical features by non-specialists seem to obviate many of the difficulties inherent in analysis of community structure. The tests can be used for in-situ monitoring at stream side. It is important to stress that these techniques are not taxon-specific, but are applicable across a wide range of taxa. Therefore the investigator can use organisms present in the system under scrutiny.

Bioassays

Bioassays involve the exposure of an indicator organism to a test material, and measurement of a response. Toxicity tests measure effects such as mortality and life history changes, whilst bioaccumulation tests measure uptake of contaminants into tissues. Bioassays have been by far the most common monitoring technique used in the past decades, notably the specific measurement of heavy metal concentrations in tissues.

P.M. Chapman (1995) reviews methods and protocols for bioassays, providing some details of Australian investigations, which are elaborated upon by J.C. Chapman (1995), in considering the role of ecotoxicology in water assessment.

The main argument for the primacy of bioassays over other indicators is that chemistry fails to provide information on biological effects. However, as J.C. Chapman observes, a combination of laboratory- and field-based ecotoxicology studies are required to give full understanding to the effects of chemicals on ecosystems. An additional problem is that synergistic effects of catchment chemicals are difficult to determine. Furthermore, most bioassays are extremely taxon-specific and stressor-specific, thereby limiting their generality and universality.

Conclusions

In this review of biological monitoring techniques to assess catchment health, the focus has been on identifying indicators that are appropriate for community catchment groups, for routine monitoring and for assessment of specific stressors. In parallel with this, the scientific knowledge associated with each technique has been identified. There are advocates of every technique outlined above.

It is notable that the Federal Government’s Monitoring River Health Initiative (MRHI) has adopted the use of aquatic macroinvertebrates, identified to family level, as their baseline source for biomonitoring data. This program has indicated a requirement for ‘control’ or reference sites/populations against which biological community changes being monitored are calibrated. Difficulties in addressing these issues lead naturally to advocacy of a BACIP (Before–After–Control–Impact paired-differences) design in biological monitoring, for which readers should consult Humphrey et al. (1995) and Faith et al. (1995). Only with such designs can the response of any proposed indicators to anthropogenic factors be quantified and standardised against ‘background noise’ i.e. the natural variation in communities through time and space. Even with the best designs, properly analysed, it must be stressed that it may not always be possible to ascribe cause to each and every ‘significant’ indicator response.

References Cited


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