ASSESSING THE BIOLOGICAL QUALITY OF FRESH WATERS:

RIVPACS AND OTHER TECHNIQUES

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CHAPTER 23

Using RIVPACS for studies on conservation and biodiversity

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Summary

Invertebrate conservation relies not only on public support and political will, but also on possessing an adequate understanding of the distribution and ecology of invertebrate species and communities. In the UK, RIVPACS is making an important contribution to assessing the conservation importance of river invertebrate assemblages. So far, work has largely centred on using RIVPACS as an integral part of SERCON (System for Evaluating Rivers for Conservation), in which data collected using the standard RIVPACS method are interpreted with reference to conservation criteria such as species richness and representativeness. Applications of RIVPACS to other areas of conservation – whether providing information on the ecological requirements of rare species, monitoring the success of river restoration projects, or making broader assessments of sustainability – are probably more limited, but merit further examination. It is important to develop closer links between RIVPACS and techniques such as SERCON and RHS (River Habitat Survey) in order to maximise the benefit each can bring to studies on conservation and biodiversity. It should also be recognised that there are limitations in transferring such systems to other countries where approaches to nature conservation may be very different.

Introduction

Until recently, strategies aimed at conserving biodiversity have centred largely on vertebrates (Hafernik 1992). This general neglect of invertebrates in conservation programmes reflects both a lack of knowledge of invertebrate species ecology and limited public enthusiasm for less visible, and aesthetically less attractive, species. Public perception is now beginning to change (Bratton 1991), and there is a growing awareness that invertebrates are important intrinsic components of biological communities and of ecological processes, and provide resources of direct human benefit (Wells *et al.* 1983). The problem of inadequate information, especially an understanding of the species ecology of such a large and diverse group of organisms, is likely to present the more serious barrier to greater efforts in conserving invertebrates.

Nonetheless, over the past five to ten years, national and international conventions and statutes have begun to address the conservation needs of invertebrates. For example, the EC Directive on the conservation of natural habitats and of wild fauna and flora (otherwise known as the Habitats Directive) lists 59 invertebrates out of 625 species (*ca* 10%) of plants and animals on Annex II (whose conservation requires the designation of Special Areas of Conservation). In the UK, the Biodiversity Action Plan (BAP) (Biodiversity Steering Group, 1995) contains 638 invertebrate species out of a total of 1659 (*ca* 38%) species of plants and animals described as "globally threatened" or "declining", some of which will have BAPs produced in response to the agreements reached at the international Rio Convention in 1992.

Nevertheless, despite the higher profile of invertebrates in initiatives such as these, relatively few species associated with rivers in the UK are afforded special protection or are the subject of BAPs. For example, in Great Britain (separate legislation covers Northern Ireland) only four riverine invertebrates (Atlantic stream crayfish or white-clawed crayfish *Austropotamobius pallipes,* freshwater pearl mussel *Margaritifera margaritifera,* southern damselfly *Coenagrion mercuriale,* and glutinous snail *Myxas glutinosa)* are statutorily protected under the Wildlife and Countryside Act 1981.

This chapter is not principally concerned with the *mechanisms* for protecting rivers and their invertebrate communities, nor with the problem of *public perception* of invertebrates and their conservation. Rather, it seeks to explore the information requirements and evaluation techniques needed to underpin conservation action, and the particular role that RIVPACS can play in helping to meet those needs.

Discussion topics

Evaluating sites

The relative merit of focusing river conservation efforts on habitats rather than on species is an area of lively debate. There are persuasive arguments for viewing habitat conservation as the most cost-effective means of protecting populations of individual species or entire communities: indeed, an approach which divorces species from their habitats is to some extent artificial and less likely to succeed.

In Britain, some rivers are protected under the Wildlife and Countryside Act as Sites of Special Scientific Interest (Boon 1991, 1995), most of which are selected not for the presence of a single rare species, but rather for a wider range of biological features (Nature Conservancy Council 1989). In recent years, increasing attention has been given to the way in which the conservation value of rivers is assessed, across the full spectrum of river "quality". This has led to the development of SERCON (System for Evaluating Rivers for Conservation) which aims to provide a more rigorous and repeatable method for river conservation evaluations (Boon, Holmes *et al.* 1996, 1997). SERCON is essentially a scoring system, and requires information both on physical habitat features (derived from River Habitat Survey (RHS): Raven, Fox *et al.* 1997; Raven, Holmes *et al.* 1998), and on a wide range of biological data, to produce a comprehensive assessment of conservation value in terms of accepted criteria such as naturalness, species richness, representativeness and rarity (Ratcliffe 1977). At present, RIVPACS is used in two ways to assist SERCON evaluations.

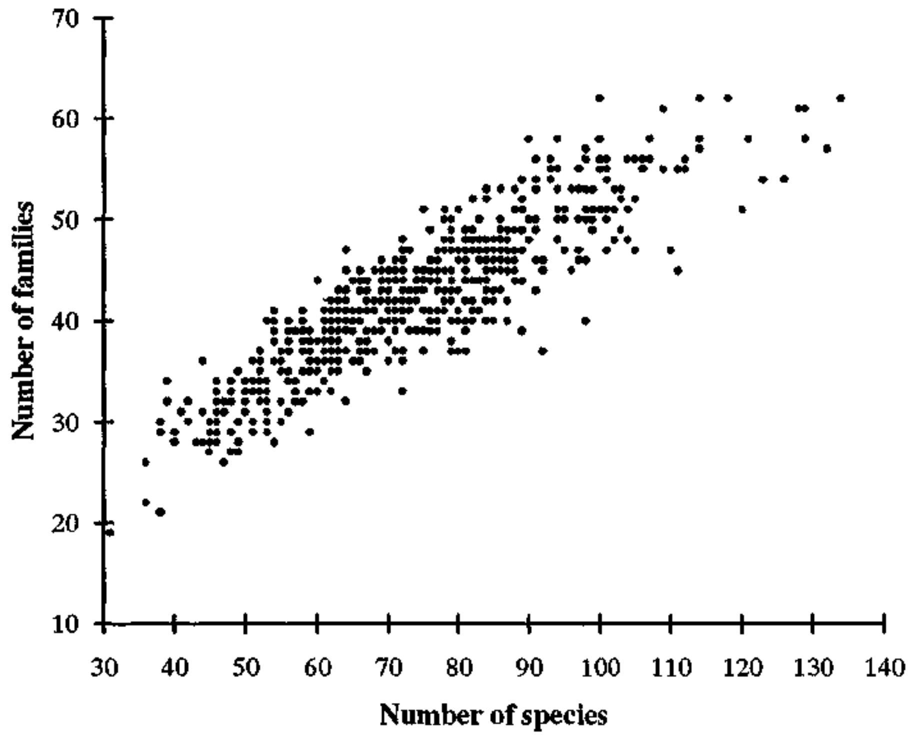
First, the taxon list in RIVPACS III (Wright, Blackburn *et al.* 1996) provides a standard reference against which to assess the criterion of species richness, although caution is needed in evaluations of this type. The high profile of biodiversity issues has led, perhaps, to an undue focus on species richness, under the misapprehension that the word "biodiversity" is synonymous with "species richness", and that rivers with high species richness are therefore necessarily important for conservation (and *vice versa*). Relatively natural rivers in some locations (e.g. on resistant geology, and with harsh flow regimes) will invariably be species-poor, yet may be important for conservation for other reasons; conversely, species richness may sometimes increase as a consequence of human impact (e.g. through nutrient enrichment). In other words, assessments of species richness for the purposes of conservation evaluation must always be interpreted in the light of the naturalness and representativeness (or typicalness) of the system. Nevertheless, rivers that harbour a wide diversity of species are likely to be considered more valuable than those of a similar type with fewer species, and this basic descriptor of river invertebrate communities will continue to feature in most conservation evaluation systems.

This raises the fundamental question of the taxonomic level at which evaluations should be carried out. In SERCON, assessments of invertebrate species richness derived from family-level data are given a lower weighting than those based on species-level data (Boon *et al.* 1996). In RIVPACS, data at species level and at family level are used to generate predictions of the probability of occurrence, although site classification using RIVPACS operates satisfactorily only with data at species level. Herein lies a dilemma: the concept of conserving *invertebrate families* is comparatively meaningless, yet the time and expense of gathering data at the species level is often prohibitive – at least for an extensive programme. One approach is to explore the relationship between invertebrate family richness and species richness to see whether the former might act as a surrogate for the latter. Recent work by the Institute of Freshwater Ecology (Wright *et al.* 1998b) has shown a close correlation between family richness and species richness, and between BMWP family richness and species richness (Fig. 23.1). This opens up the possibility of carrying out extensive invertebrate surveys at the family (or BMWP family) level, and using them as a means of targeting more intensive, species-level surveys for rivers shown to be family-rich. Moreover, careful preservation of samples identified to family level provides future opportunities for species-level identification should resources (time, money, identification keys) become available.

The second application of RIVPACS in SERCON evaluations concerns the criterion of "representativeness". Assessments of invertebrate representativeness in SERCON (which are more complex than those of species richness) aim to assess whether a site is a good example of its "type", and thereby deemed to be of conservation value (Boon, Holmes *et al.* 1996). A list of predicted BMWP families is generated for each site, and divided into four groups falling within four bands of probability of occurrence. A composite list of taxa is compiled for the site from samples taken in three seasons (spring, summer, autumn) following the standard RIVPACS protocol. The similarity of the observed and expected fauna is compared using a chi-squared test, with higher chi-squared values indicating extremely unrepresentative sites. The unit of evaluation in SERCON is a river reach (usually 10–30 km long) termed an Evaluated Catchment Section (ECS); thus, representativeness scores for all sampling sites within an ECS are summed and the final assessment is given by the mean.

Of course, in other ways the *unrepresentativeness* of a site or a stretch of river may be considered an important conservation feature, provided that the unusual or atypical variant is not a reflection of human impact. Such rare or unusual habitat types may require a particular type of management to ensure their conservation. These sites may be identified using RIVPACS, by first discarding any with high O/E ratios caused by human impact (e.g. nutrient-poor streams subject to minor effluent input, resulting in a modest increase in taxon richness), and then trying to establish what it is that makes the remaining sites atypical.

As river evaluation methods such as SERCON and RHS are further refined, it is important to strengthen existing links with RIVPACS, and to develop new approaches. For example, some of the assumptions in RHS concerning the importance of physical habitat features for invertebrates merit further testing, and an integration of RHS and RIVPACS data from the same sites would be a useful step forward. Setting RIVPACS alongside other systems for habitat assessment or more general conservation assessment may also assist river management decisions. For example, are there correlations between rivers in the highest class for biological



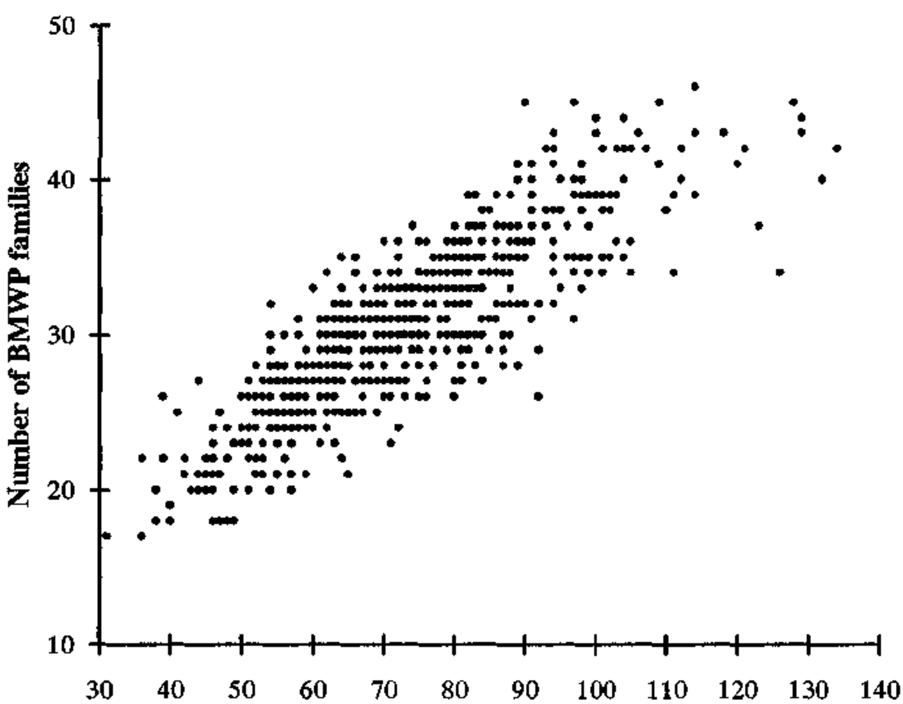


Figure 23.1. Relationships between the number of families (and BMWP families) and the number of "species" of macroinvertebrates at 614 sites. Correlation coefficient $r = 0.890$ for families and 0.854 for BMWP families. (Reproduced from Wright *et al.* 1998b, with permission of the publishers).

quality (assessed by RIVPACS) and those in the highest class in terms of habitat quality (assessed by RHS) or for overall conservation value (assessed by SERCON)? Whilst correlations might be expected in some cases, it is likely that in others the distinctiveness in outputs from each assessment system will help to determine priorities for river management by highlighting different aspects of "quality" within the same river (Boon & Howell 1997a).

Despite the fact that RIVPACS was not created as a conservation tool for site evaluation, both the RIVPACS *method* and the RIVPACS *dataset* could be applied in other ways to make full use of their potential in conservation assessment. For example, recording the range of RIVPACS classification end-groups in a river might add another dimension to assessments of invertebrate "richness", and this could be supplemented by a similar procedure for aquatic macrophyte communities, using the botanical classification of British rivers (Holmes 1989; Holmes *et al.* 1998). Evaluations of "rarity" might be extended by noting the presence, within a river, of particular RIVPACS end-groups less commonly encountered within the entire RIVPACS database.

Evaluation procedures are needed not only for high quality rivers important for conservation, but also for those which are degraded and have the potential for rehabilitation or restoration (Boon 1992). As developed countries have succeeded in tackling the worst excesses of water pollution, so attention is now being given to restoring some of the physical habitat features lost through past engineering practices (Iversen, Kronvang *et al.* 1993; Nielsen 1996; Hansen, Boon *et al.* 1998). Many such schemes have as their objective the restoration of semi-natural animal and plant communities, and several have included surveys of river invertebrates (e.g. Biggs, Corfield *et al.* 1998 (UK); Friberg, Kronvang *et al.* 1998 (Denmark); Laasonen *et al.* 1998 (Finland)). However, most studies tend to concentrate on recording changes in species composition, species richness and abundance following restoration (or in restored and control sections), but they rely on inference from the observed species complement rather than using a predictive approach such as RIVPACS to compare observed (O) and expected (E) species assemblages. In fact, RIVPACS may prove to be of limited value for predicting the impact of restoration on invertebrates, as some of the environmental variables used in prediction (e.g. altitude, longitude, latitude, distance from source, etc.) will remain unchanged following restoration. Nevertheless, restoration schemes for degraded rivers could at present have the general aim of seeking to increase low O/E values, with the longer-term objective of expanding the reference database of RIVPACS to include a range of sites degraded through physical habitat destruction, as well as those suffering impaired water quality.

Evaluating species distribution, biodiversity, and sustainability

Despite the artificial distinction already discussed between habitat and species conservation, it may be instructive to consider the role of RIVPACS in work specifically targeted at invertebrate species and assemblages. How can RIVPACS be used, for example, in studies on rare species' distribution, ecological requirements of invertebrates, or broader assessments of biodiversity and sustainability?

Initiatives in river conservation, and studies on riverine biodiversity, inevitably require at least some information at the species level. Whilst it is possible to use surrogates such as family richness for species richness, or family/generic level invertebrate indicators to assess water quality, information is still needed on the distribution, abundance and ecology both of rare and common species. The RIVPACS database has an important role to play in this, although its limitations must be recognised. Species data are only routinely available for the RIVPACS reference sites, and while the degree of accuracy of species identifications in the reference site database was extremely high, the same level of standardisation in sampling methods was not achieved. Moreover, rare species are likely to feature only rarely in the database, so using RIVPACS to learn more about their ecological requirements may not necessarily be fruitful, especially when the standard technique of "pooling" samples from habitats representative of the reach makes it more difficult to determine microhabitat preferences.

For species that are generally believed to be rare, the RIVPACS database can assist in providing useful data on locations where those species have been recorded. However, Wright, Furse *et al.* (1992) emphasised that whereas a high frequency of occurrence may confirm that a taxon is common, a low frequency, though of interest, cannot be assumed to indicate a scarce taxon. The authors also pointed out that RIVPACS II (the version then in use, containing 438 sites) included very few headwaters or small streams. This gave an inaccurate picture of the relative rarity of species recorded in the database, some of which may be common in headwaters but uncommon elsewhere. RIVPACS III contains a better representation of small sites but, despite this, there is a strong argument for the development of a separate module for headwater streams (Chapter 6). The overall conclusion by Wright, Furse *et al.* (1992) was that the RIVPACS database could offer a valuable indication of the common and less common taxa found over the range of sites sampled, but could not be used to generate Red Data Book (RDB) or other formally defined rarity categories for taxa.

Wright, Blackburn *et al.* (1996) discuss in more detail the use of the RIVPACS III database (containing 614 reference sites), and again describe its use as complementary to, but separate from, the red list threat categories designated in the RDBs for invertebrates (Shirt 1987; Bratton 1991). Of the 637 "standardised" taxa in RIVPACS III, 369 occur at less than 5% of sites, and 15 of these species are accorded RDB status. However, the same analysis also indicates that species within certain rarity categories are in fact more widely distributed than previously thought.

The broader concept of "biodiversity" is rapidly gaining popular appeal, although when the word is used in the restricted sense of "species richness" many important aspects of its meaning are lost. The definition of biodiversity derived from the 1992 Rio Convention went some way to capturing its complexity: *"The variability among living organisms from all sources including,* inter alia, *terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"* (Department of the Environment *et al.* 1994). According to Noss (1990), however, even broad definitions such as this may be insufficient, and he suggests that a "characterisation" of biodiversity that identifies the major components at several levels of organisation is probably more useful than a definition. The characterisation proposed (developed from Franklin 1988) incorporates "composition" (including, e.g., species lists), "structure" (including, e.g., habitat complexity), and "function" (including, e.g., nutrient cycling), each one encompassing multiple levels of organisation from genes to biomes.

As it stands, RIVPACS can contribute to studies on biodiversity principally through providing information on species richness, and on the distribution of particular BAP species, although its usefulness may be enhanced by interpreting RIVPACS outputs in the light of other information, such as on functional feeding guilds. In countries such as the UK, much of the effort on conserving biodiversity is now focused on species and habitat action plans, arising from the Biodiversity Convention in Rio in 1992. Very few UK species listed in the BAP (Department of the Environment *et al.* 1994) are truly riverine, although many are associated with riverine shingle (e.g. *Rhabdomastix hilaris* (a crane-fly) and *Meotica anglica* (a beetle)). Some species that are riverine are less likely to be collected in standard RIVPACS surveys owing to their microhabitat preferences (e.g. *Margaritifera margaritifera* (freshwater pearl mussel) and *Austropotamobius pallipes* (white-clawed crayfish)). Whilst others (such as the stonefly *Brachyptera putata)* have been recorded from time to time in RIVPACS surveys, the application of RIVPACS to work on BAP species may be limited.

Biodiversity Action Plans cover habitats as well as species. In the UK, one of the key habitats within the broad habitat grouping of "running waters" is described as "chalk rivers". RIVPACS III has improved the prediction of fauna expected in rivers of this type (Wright *et al.* 1998a) and can thus add valuable information in describing, comparing, evaluating and monitoring BAP sites.

The applications of RIVPACS to studies under the broad banner of "sustainability", as opposed to rather narrower concerns about biodiversity, are less easy to document. Ecosystem sustainability is intrinsically related to concepts of sustainable development, which by definition are focused on the use that human beings make of ecosystems. For example, the First Principle of the Rio Declaration states that *"Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature"*. (Department of the Environment *et al.* 1994). Similar sentiments comprise the IUCN definition of conservation (International Union for Conservation of Nature and Natural Resources 1980), and the philosophy that natural resources should be maintained for handing on to future generations is a principle subscribed to by many individuals, organisations and governments.

Perhaps the main issue of controversy is whether the general notion of freshwater ecosystem sustainability is a valid concept at all, or whether it can only be considered in the context of specific freshwater "uses". In other words, should the question be "Does this river contain a sustainable trout fishery?", or "Is the rate of water abstraction sustainable?", or should it be "Is this river a sustainable ecosystem?" This subject lies outside the bounds of this chapter; further discussion may be found in Boon & Howell (1997a, b).

To what extent, then, can river invertebrates be used in assessing sustainability, and does RIVPACS specifically have a role to play in this? Apart from a few exceptions (e.g. some freshwater shrimps, crayfish, pearl mussel) river invertebrates are not subject to deliberate human exploitation. It is the exploitation of other parts of a river ecosystem that brings about change in invertebrate populations.

One of the problems inherent in assessing sustainability is the determination of an appropriate time-scale for measurement. For example, an apparent downward trend in the population size of a particular invertebrate species might be merely a small part of a long-term trend in population fluctuation in which numbers both increase and decrease. Nevertheless, over a specified time period, it might be feasible to plot RIVPACS-derived O/E ratios against time, and to observe the point on the graph at which a continued downward trend signals an unacceptable reduction in sustainability. This point has been termed the "Threshold of Potential Concern", and is part of an approach that has been used to define the desired state of river systems in South Africa (Rogers & Bestbier 1997). However, for some South African rivers such as the Sabie, changes in habitat features are likely to provide better indicators of sustainability than changes in invertebrate communities (Jay O'Keeffe, University of Grahamstown, personal communication). Invertebrate communities are characteristically resilient, and may often recolonise rivers rapidly after disturbance. Structural changes to habitats are likely to be more important in reducing the long-term sustainability of river systems.

Summary and recommendations

RIVPACS was not designed principally as a conservation tool. Nonetheless, it has already demonstrated that it has the potential to make a valuable contribution to river conservation assessments, although at present these are mainly restricted to SERCON evaluations of species richness and representativeness.

Many national and international initiatives are now focused on conserving "biodiversity". This term should be understood to include more than "species richness", although species richness is an important element. Unfortunately, the routine use of RIVPACS in river quality assessments usually entails identifications only to family level, and thus provides only limited information for biodiversity studies. The close correlations found between family (and BMWP family) richness and species richness may afford one way of targeting resources in future by focusing intensive, species-level surveys on areas found to be family-rich.

In theory, the general "RIVPACS approach" – comparing observed and expected characteristics to produce a quality index – could be extended to other habitat types and to other groups of organisms, provided that taxonomic knowledge is adequate and that sufficient is known about the variables influencing species distribution. Other RIVPACS-related systems are already planned, such as one based on aquatic macrophytes. However, further developments such as these must be monitored carefully to ensure that they fulfil a real need, rather than becoming ends in themselves.

Techniques such as RIVPACS, SERCON and RHS tend to stress the importance of "naturalness" as a criterion for assessing the quality of rivers and their value for conservation. To some extent, this may be perceived as a "first-world" rather than a "third-world" perspective (Wishart, Davies *et al.* 2000). In developing countries, especially those where factors such as climate, topography and land-use put the supply of clean, potable water at a premium, conservation objectives must be set within the wider framework of the human use of river systems. Thus, transferring UK assessment techniques such as RIVPACS, SERCON or RHS to other countries must take account not only of the physical and biological differences, and the availability of environmental information, but also the cultural context in which such systems are developed and used.

Specific recommendations

The present use of RIVPACS as an integral part of the SERCON procedure needs to be re-examined and refined. Refinements might include the use of other information generated by RIVPACS: for example, enhancing the evaluation of "richness" by assessing the diversity of RIVPACS classification end-groups within a river, or modifying assessments of "rarity" and "representativeness" by noting the presence of end-groups that are particularly unusual or uncharacteristic, respectively.

Interpretations of river "quality" using RIVPACS should be compared with outputs from RHS and SERCON. Both the presence and absence of positive correlations between quality indices for the same site may yield valuable insights for conservation management.

Consideration should be given to expanding the RIVPACS reference database to include sites where the physical habitat of the river has been degraded. This would assist in pre- and post-project appraisal of river restoration schemes.

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