Testing and Further Development of RIVPACS

Stage 3 Report

R&D Technical Report E1-007/TR

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Statement of Use
This report is part of the output from a project to test and further develop RIVPACS (a computer programme which predicts the river macroinvertebrate communities to be expected at high quality sites). It comprises four chapters which evaluate:

- The possible external market for RIVPACS (Package 2)
- The educational value of RIVPACS (Package 4)
- The use of RIVPACS for evaluating trophic structure (Package 8)
- The use of RIVPACS in the context of biodiversity and sustainability (Package 13)

The report is to be used by the Agency to:

- Inform biologists of the value of using RIVPACS in relation to trophic structure and biodiversity
- Advise the Agency on the use of RIVPACS in an educational context
- Guide the Agency to ensure that the most appropriate options are progressed in any future RIVPACS development

Keywords
RIVPACS; Biological monitoring; macroinvertebrates; market evaluation; educational tools; functional feeding groups; biodiversity; sustainability.

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EXECUTIVE SUMMARY

This project on the development of new RIVPACS methodologies comprises a total of ten separate work packages of which four received attention in earlier reports (Wright *et al.* 1999, Clarke and Wright 2000). The current report presents the results of a further four packages (numbers 2, 4, 8 and 13). The final two packages (9 and 12) will be reported separately in Stages 4 and 5 reports respectively.

Package 2: Market evaluation of the β-test version of RIVPACS by J F Wright

The development of a β-test version of RIVPACS III, primarily for purchase by commercial organisations, is described. The package, which included the 1995 RIVPACS III software, various manuals and software support from the Institute of Hydrology was launched in January 1997 at a cost of £2,200 + Value Added Tax (VAT).

Uptake has been minimal (2 copies sold) with most potential buyers probably being deterred by a combination of the price, the need for stringent field and laboratory protocols and the fact that the current software is not particularly user-friendly.

However, enquiries from a range of educational establishments on the availability of RIVPACS have been substantial, confirming our view that there would be a market for a simplified and user-friendly version of the system for purchase at nominal cost (see below).

Package 4: Development of educational tools based on RIVPACS by J M Winder

The overall objective of this limited desk-study is to provide the Environment Agency with the major options for future development of educational tools based on RIVPACS. The Agency now has its own Education Section and the expertise to undertake a full scoping study prior to any specific developments.

Initially, a review was undertaken of the main subjects at primary, secondary and tertiary level where educational tools based on RIVPACS could be relevant.

A more detailed assessment of the need for, and relevance of, new educational material was then obtained through liaison with the Communications Directorate of NERC and more particularly through the National Education Programme Coordinator of the Environment Agency. The procedures followed by the Agency when undertaking full scoping studies, including broad educational principles, subject-specific considerations and practical issues were all reviewed with respect to educational tools based on RIVPACS.

This was followed by an attempt to provide sound advice on potential educational products for which there is the greatest need. It is now clear that the first priority must be to develop a user-friendly Windows version of RIVPACS, initially for use by the Environment Agency, but also with the capability of being further modified. The creation of a web site would be an efficient way of making the new version accessible to the Agency but would also enable customised versions with appropriate manuals to be accessed by paying professional customers through the use of passwords.

Simplified and user-friendly versions of RIVPACS for use at the undergraduate level and within secondary schools at both A and GCSE levels, could be delivered via the same route together with ancillary products geared to the appropriate level. Below GCSE level in secondary schools and within primary schools, the emphasis should be on appropriate ancillary products aimed at National Curriculum Key Stages 1-4, with only brief reference to RIVPACS or possibly a simple 'play' version of the system.

Foremost amongst the ancillary products would be development of an interactive on-line key for identifying macroinvertebrates at Biological Monitoring Working Party (BMWP) family level based on 'LucID'. An ability to identify the fauna to the level of BMWP families is essential when using RIVPACS and is an ideal route for introducing the effects of organic pollution on stream fauna to undergraduates and school children.

A number of other ancillary products which meet the requirements of the National Curriculum are also proposed. These include downloadable information for both teachers and students relating to the habitats and life histories of macroinvertebrates, illustrative material, sampling kit lists and simplified versions of field manuals and sampling videos.

Whereas CEH would need to have major input to the development of the Windows version of RIVPACS and a number of the ancillary products, it is clear that the Environment Agency is best placed to undertake the full scoping study, interact with computer software development companies and approach potential sponsors of the educational products.

Finally, the report indicates how potential RIVPACS products would link to the policies of the Environment Agency and integrate with and complement existing Agency initiatives in the field of education.

Package 8: An appraisal of RIVPACS for evaluating trophic structure by R T Clarke, J F Wright and J Davy-Bowker

RIVPACS currently offers a procedure for predicting the taxa to be expected at a good quality site, that is, it provides information on the *structure* of the expected macroinvertebrate assemblage. Benthic invertebrates play an essential role in food webs, productivity, nutrient cycling and decomposition processes, and hence new insights may result from considering the *functioning* of these complex assemblages of organisms.

Schemes based on macroinvertebrate functional feeding groups (e.g. shredders, scrapers, collector gatherers, collector filterers and predators) have often been used alongside the 'River Continuum Concept' in an attempt to demonstrate progressive changes in the relative importance of these functional feeding groups as environmental conditions and available food resources change along the length of a river system.

The 614 reference sites in the RIVPACS dataset provide a means of examining whether there are meaningful Functional Feeding Group (FFG) patterns and downstream trends across a range of high quality sites. If clear patterns were to be found, then they would provide a baseline against which to assess FFGs from impacted sites and a new viewpoint from which to interpret the cause of the stress.

All analyses were undertaken at family level so that log abundance data could be used. Abundance data, rather than presence/absence data, is crucial to a study designed to provide insights into the functioning of the system. Following a literature review, each family in the RIVPACS dataset was assigned to one or more functional feeding groups on a proportional basis. A dominant FFG was also assigned, but only used in some preliminary analyses because the use of the proportional approach to assigning FFGs was regarded as more realistic and robust. Procedures were then devised for calculating the observed and expected relative abundance of the various FFGs by summing the log abundance categories.

When the mean relative abundances of the five FFGs were examined in relation to distance downstream using the 614 RIVPACS sites, the observed patterns were in broad agreement with the predictions of the River Continuum Concept (RCC). That is, shredders had their highest relative abundance in headwater streams (<5 km from source), whilst scrapers increased very slightly downstream, peaking in the 41-84 km downstream category. Collectors (gatherers and filterers) maintained a dominant and relatively stable role downstream, except in the 85-203 km downstream category where there was a slight increase in the gatherer filterer component. The predator category was also very stable downstream, with only a very slight rise with increasing distance downstream.

Overall, the mean relative abundances derived from the 614 RIVPACS reference sites were 10% shredders, 27% scrapers, 30% collector gatherers, 10% collector filterer and 23% predators. These average percentages were approximately the same, regardless of season.

Examination of the relative abundance of each FFG along the length of each of three contrasting rivers in England and Wales provided some evidence of longitudinal pattern, as expected in the RCC, but it also highlighted some unexpected between-site variations. These may have been the result of discontinuities along the rivers which impacted on food resources and hence FFGs. Alternatively, they could be a demonstration of the limitations of the RIVPACS sampling technique, which is designed to acquire maximum information for limited effort, without resorting to a very time-consuming quantitative sampling programme.

Differences between the observed relative abundance of each FFG in the 35 TWINSPAN groups of the RIVPACS classification were shown to be statistically highly significant. Despite this, the relative abundance of the five FFGs varied in a less consistent manner with the environmental characteristics of the sites than the BMWP indices and in particular ASPT. Hence, RIVPACS will be less effective at predicting the expected relative abundance of FFGs than the expected value of BMWP indices.

Following this appraisal of the behaviour of the FFGs across the RIVPACS sites, it was necessary to examine how the relative abundance of the FFGs varied with site quality.

The 16 BAMS study sites (Furse *et al* 1995) were particularly useful because they included different river types and also sites which differed in quality. In all cases, replicated samples were available in each of three seasons, so sampling variability in the relative abundance of the FFGs could be examined. Clearly, if sampling variability is high, it will be difficult to detect differences between sites due to site quality and/or site type.

Additional assessments of the response of the FFGs to site quality were made using 6016 General Quality Assessment (GQA) sites from the 1995 GQA survey. In both datasets, the most striking trend was an increase in the relative importance of gatherers at poor quality sites. The GQA dataset also demonstrated that there was considerable variation in the relative abundance of any given FFG amongst sites of a given biological quality.

It was therefore apparent that the relative abundance of the various FFGs varied only weakly with the environmental characteristics of a wide range of high quality sites and substantial differences in FFGs only occurred at very poor quality sites. These sites can be recognised very effectively using the existing EQI_{TAXA} and EQI_{ASPT} approach. Thus, there would be little to be gained at present by incorporating the facility to generate expected FFGs in the next version of RIVPACS.

However, the proportional approach for designating family-level FFGs for Great Britain, although relatively crude and subject to further improvement, may be of value in other studies undertaken by the Environment Agency and their contractors. In particular, the use of FFGs may have greater credibility where quantitative sampling procedures involving numerical and/or biomass data are used to investigate spatial change along a river system or temporal change at a site subject to periodic stress.

In future, there will be an increasing need to designate FFGs at the species level and make these and other attributes more easily accessible for use in conservation and river management.

Package 13: Evaluation of the use of RIVPACS in the context of biodiversity and sustainability by J F Wright

The objective of this scoping report is to assess the current role of RIVPACS in the context of biodiversity and sustainability and determine whether its value may be enhanced by minor developments within or alongside the current version of the system.

In 2001, the Environment Agency published ‘An Environmental Vision: The Environment Agency’s contribution to a sustainable environment’ which includes a consideration of nine separate themes. RIVPACS has some contribution to make to five of these themes including: ‘a better quality of life’; ‘an enhanced environment for wildlife’; ‘improved and protected inland and coastal waters’; ‘wiser, sustainable use of natural resources’; ‘limiting and adapting to climate change’. The relevance of RIVPACS to each of these themes is detailed in the current report.

The meaning of biodiversity is discussed at the genetic, species and community level and this is followed by further background information on the recording and conservation of the freshwater fauna in the UK, including progress on the implementation of the UK Biodiversity Action Plan.

RIVPACS contributes to the field of sustainability and more specifically to the topic of biodiversity in two main ways. First, by providing a system for the appraisal of site (or habitat) quality and second, by offering a listing of the observed (and expected) taxa at a site.

Since 1990, the Observed/Expected ratios derived by RIVPACS and based on BMWP family-level data have been used for the biological appraisal of site quality in national quinquennial surveys and also in local monitoring programmes. As biodiversity issues assume a higher profile, there will be an increasing need for family or species level identifications at selected sites. Hence, there will be a future need to automate the calculation of O/E ratios at family and standardized species level, in line with the procedures currently available at BMWP family level.

RIVPACS predicts taxonomic composition by providing a listing of taxa for a given site at the chosen taxonomic level (species, family or BMWP family) for comparison with the fauna observed at the site. Given that biodiversity issues require species-level data, the provision of additional information on the status of each species would be beneficial. The species level printouts could be modified to include the frequency of each species in the 614 site reference dataset (to distinguish common from infrequent lotic species) and all species with Red Data Book or Nationally Scarce status could be flagged.

Before these and other potential changes are incorporated into RIVPACS, there is an urgent need to develop a more user-friendly Windows version of the system. In future, the benefits of having RIVPACS accessible on a CD-ROM or via the World Wide Web, with access operated via a password system, may also become compelling. If these proposals are accepted, then the provision of supplementary information would be simplified. This could include dot maps giving the geographical distribution of the RIVPACS species together with information on their environmental ranges.

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1. INTRODUCTION

1.1 Programme of Work for Stages 1 and 2

Research and Development (R&D) Project E1-007, which started in January 1998, includes ten separate work packages, the majority of which are desk studies designed to investigate potential developments and improvements to RIVPACS. The time allotted to each package varied from one to two years. To date, four packages have been completed and reported as Stage 1 R&D Technical Report E71 (Wright *et al* 1999) and Stage 2 R&D Technical Report E124 (Clarke and Wright 2000).

Note that the Package numbering system is as given in the contract specification.

The Stage 1 report presented an account of progress with Packages 5 and 6 and gave the final results for two scoping studies (Packages 3 and 10).

Package 5. An International Workshop on RIVPACS, attended by approximately 60 participants from 22 countries took place at Jesus College, Oxford, in September 1997. Time was allotted within this package for editorial work by J F Wright and M T Furse on the manuscripts presented by Workshop contributors. This resulted in the publication in June 2000 of a 24 chapter book by the Freshwater Biological Association on the RIVPACS approach. Details are given below:

Wright, J F, Sutcliffe, D W and Furse M T. (2000) (Eds.) Assessing the biological quality of fresh waters: RIVPACS and other techniques. Freshwater Biological Association, Ambleside, 373pp.

Package 6. Development of the use of abundance data for biological quality assessment was undertaken over a two-year period. Interim results were presented in Wright *et al* (1999), and the package was completed and reported at the end of the second year in the Stage 2 report. Details are given below:

Clarke, R T and Wright J F (2000) Testing and Further Development of RIVPACS. Package 6. Development of the use of abundance data for biological quality assessment: Testing and assessment of new abundance-based indices. R&D Technical Report E124. Environment Agency, 95pp.

Package 3. This one-year scoping study to re-evaluate methods for collecting RIVPACS samples from deep waters was reported in Wright *et al* (1999).

Following the scoping study, the Environment Agency commissioned a separate field study to compare the effectiveness of three sampling devices for collecting macroinvertebrates in deep watercourses and recommend standard sampling protocols for deep-water sites. This project is complete and has been reported in:

Bass J A B, Wright J F, Clarke R T, Gunn R J M and Davy-Bowker J, 2001. Assessment of sampling methods for macroinvertebrates (RIVPACS) in deep watercourses. R&D Technical Report E134. Environment Agency, Bristol. 52 pp plus two Appendices.

Package 10. This one-year scoping study to consider the development of a RIVPACS methodology for canals was also reported in Wright *et al* (1999).

1.2 Stage 3 Programme of Work

Of the remaining six packages, four are presented in this report, and the other two will be issued as separate reports at a later date. The details of these packages are as follows.

First, the four packages included within this report:

Package 2. Market evaluation of the β-test version of RIVPACS (Year 3)

Package 4. Development of educational tools based on RIVPACS (Year 3)

Package 8. An appraisal of RIVPACS for evaluating trophic structure (Years 2 and 3)

Package 13. Evaluation of the use of RIVPACS in the context of biodiversity and sustainability (Year 3).

The remaining two packages (numbers 9 and 12) are as follows:

Package 9. An evaluation of procedures for acquiring environmental variables for use in RIVPACS (Years 2 and 3) Stage 4 R&D Technical Report E1-007/TR1.

Package 12. Development of a dynamic model to predict the biological consequences of changes in water quality. (Years 2 and 3) Stage 5 R&D Technical Report E1-007/TR2.

The progress of this final package has been slowed by significant difficulties relating to some datasets required for the work. These difficulties have been outside of our direct control and therefore some delay is anticipated before Package 12 appears as a separate Stage 5 report.

2. MARKET EVALUATION OF THE β-TEST VERSION OF RIVPACS III BY J F WRIGHT

2.1 Introduction

In the original specification, this package was always seen as a minor item, with just £1K allotted. In view of the fact that the market for RIVPACS III has proved to be very small, the project manager has indicated that the original specific objectives were too detailed and that a minimal report is required.

2.2 Objectives

The overall objective was as follows:

'To produce a report on the development and market evaluation of the β*-test version of RIVPACS III'.*

The specific objectives (modified from the original specification with the agreement of the nominated officer) were as follows:

1. To describe the development needed to produce the β-test version of RIVPACS III.

2. To describe the publicity material and marketing procedures used by the Institute of Hydrology in marketing the β-test version of RIVPACS III.

3. To indicate the range of organisations expressing interest in the purchase of the β-test version of RIVPACS III and the reasons why they decided not to purchase.

4. To provide basic information on the organisations which purchased RIVPACS III and on the subsequent training workshop.

2.3 Development of the β-test Version of RIVPACS III

The development of RIVPACS III was completed in late 1995, and at that time it was only available for use by the Institute of Freshwater Ecology (IFE), the Environment Agency, the Scottish Environment Protection Agency and the Department of the Environment for Northern Ireland (DOE(NI)). However, both the Institute of Freshwater Ecology and the Environment Agency were aware that there was an interest in access to the RIVPACS software from a variety of sources, including commercial organisations and educational institutions such as Universities, colleges and even schools who saw the potential of the system as a teaching aid.

Prior to the development of the β-test version of RIVPACS III, commercial organisations only had access to RIVPACS by subcontracting their requirement for RIVPACS predictions to the IFE and this had happened on a small number of occasions. Discussions took place within the IFE, more widely within NERC, and also between the IFE/NERC and the Environment Agency on possible future commercial exploitation of the RIVPACS software. In reality, the current software is somewhat dated and not particularly user-friendly, and ideally there would be merit in developing a windows version with user-friendly procedures for data-input and presentation of results. However, at that time, this was regarded as a substantial and time-consuming task and in the meantime, it was important to satisfy a perceived, if limited, need for a pre-commercial version of the RIVPACS III software for purchase by commercial firms.

By the summer of 1996 most of the work to be undertaken before release of the software had been identified and detailed discussions had taken place between the IFE and the Environment Agency. An early decision related to the inclusion or otherwise of the separate module for Northern Ireland. The DOE(NI) were consulted on this issue and decided that they did not want the module for Northern Ireland included within the package. Hence, development went ahead on the Great Britain (GB) module only.

The RIVPACS III software itself was put onto disc in a compressed form, tested and identified with appropriate logos and labels. A number of minor amendments were made to the RIVPACS III software manual and new copies were produced. The IFE also produced a booklet with practical sessions on RIVPACS III to help users get started. The procedures manual, which describes the standard methodologies for collecting and analysing RIVPACS samples, was essentially the same as the manual produced by the Environment Agency. Once copies of the software and manuals were ready, they were delivered to the Institute of Hydrology at Wallingford, who agreed to undertake the marketing of the product.

2.4 Marketing of the β-test Version of RIVPACS III

Prior to the launch of the β-test version of RIVPACS in January 1997, a number of additional actions and decisions were taken. First, a publicity leaflet advertising the availability and key features of the software and the accompanying items was produced. The format was based on that used for previous software products marketed by the Institute of Hydrology (IH). Second, the normal price for the software, accompanying manuals and one year's software support from the Institute of Hydrology was set at £2,200 plus VAT. Further copies could be purchased at a lower price, but there would not be an educational discount because, at some later date, a separate educational version would be produced. Third, a separate leaflet was produced recommending that those purchasing the software should undertake a one-day accreditation course at the IFE River Laboratory before using RIVPACS III for commercial purposes.

In January 1997, a software exhibition was held at the IH office, Wallingford, at which Mrs K Symes of the IFE River Laboratory was present to answer questions from potential customers. A number of people expressed interest in the product and took away publicity material.

Two years later, in February 1999, a mailshot, describing the availability, uses and cost of RIVPACS III was sent out to 150 Environmental Consultancies throughout Great Britain.

2.5 Uptake of the β-test Version of RIVPACS III

There has been a steady stream of enquiries regarding the availability of RIVPACS in the form of letters, e-mails and telephone calls, both before and since the launch of the β-test version of RIVPACS III. A majority of the enquiries from within the United Kingdom (UK) have come from University and College lecturers hoping to acquire or purchase the software at minimal cost for teaching purposes. Invariably, the limited size of their teaching budgets prevents them purchasing the software. However, they frequently express considerable interest in the possibility of a more user-friendly educational version of the system at a nominal cost in the future. The remaining enquires have encompassed research organisations, study centres and a range of environmental consultants. Again, some organisations have assumed that the software would be available at a nominal price, or even downloadable from the internet.

A number of additional enquiries have come from abroad, including, for example, the Netherlands, Germany, Italy and the USA. In these cases it has been important for us to point out that RIVPACS III is designed for use within the UK and although the principle of RIVPACS and the reference condition is widely applicable, each region requires information on local reference sites in order to develop an appropriate prediction system.

In practice, just two copies of RIVPACS III have been purchased since the decision to make the system more widely available. One copy was purchased by Zeneca Ltd for use by their staff based at the Brixham Environmental Laboratory. A second expression of interest in RIVPACS III came from the Freshwater Biologist at the Isle of Man Government Laboratory, who wanted to utilise the same procedures for assessing the biological quality of rivers as used throughout the UK. In this second case, it was clear that it would not be appropriate to use the GB module, as in the β-test version of RIVPACS III. Instead, permission was sought and granted, by the Environment and Heritage Service in Northern Ireland, for the Northern Ireland module to be used from the original version of RIVPACS III. Clearly, in the absence of local reference sites for the Isle of Man, the predictions cannot be expected to be as reliable as in Northern Ireland, but they will be more reliable than predictions based on the GB module, simply because both the Isle of Man and Ireland have a restricted freshwater fauna compared to Great Britain.

Staff from both Zeneca Ltd and the Isle of Man Government Laboratory attended a one-day accreditation course at the IFE River Laboratory covering field procedures, laboratory protocols and hands-on experience in the use of the RIVPACS III software.

2.6 Conclusions

In marketing the β-test version of RIVPACS III, along with the accompanying manuals, software support and accreditation course, the IFE was fulfilling what it regarded as an obligation to make the system more widely available for purchase by environmental consultants. It was accepted by both the IFE and the Agency, that this initial version had not been optimised for the commercial market and that this prototype, involving minimal change to RIVPACS III as developed for the Environment Agency in late

1995, would be used to sound out the market. The purchase price, whilst substantial, was not unreasonable when viewed in relation to the long-term development costs and the fact that an environmental consultancy with access to RIVPACS could, in theory, recoup the purchase price and make a substantial profit if it won contracts requiring the use of RIVPACS predictions. In the event, it appears that most potential buyers were probably deterred by factors which included the price, the stringent field and laboratory protocols required and the software itself which is not very user-friendly compared with most modern windows-operated systems.

The separate question of developing an educational version of RIVPACS is being addressed in chapter 3.

3. DEVELOPMENT OF EDUCATIONAL TOOLS BASED ON RIVPACS by J M WINDER

3.1 Introduction

RIVPACS (River Invertebrate Prediction and Classification System) is a software package developed by the former Institute of Freshwater Ecology (now Centre for Ecology and Hydrology). The use of communities of macroinvertebrates in surveillance and monitoring of freshwater is well-established (Cairns & Pratt 1993; Hellawell 1986; Rosenberg & Resh 1993). The primary application of RIVPACS is to assess the biological quality of rivers within the United Kingdom. RIVPACS offers site-specific predictions of the macroinvertebrate fauna to be expected in the absence of major environmental stress (Wright 2000). The expected fauna is derived by RIVPACS using a small suite of environmental characteristics. The biological evaluation is then obtained by comparing the fauna observed at the site with the expected fauna.

The RIVPACS programme could be of value, not only to professionals, but also in the wider field of education. Hence in 1995, a detailed specification for this package of the RIVPACS development programme was drawn up. At the time, the Education Section within the Environment Agency was in the process of being established and had not decided upon strategies and policies. A consequence of this set of circumstances has been that the original specification was unrealistic in terms of what was appropriate for CEH Dorset to undertake. In addition, the financial constraints on this package also limited the scope of the study. Subsequent to the production of the original specification, the Education Section developed methodologies and expertise that would enable it to routinely undertake such scoping studies as required by the Environment Agency for the development of educational tools based on RIVPACS.

In the early part of 2000, Dr R Dines took over from Mr B Hemsley-Flint as Project Manager for Phase 3 of the Testing and Further Development of RIVPACS – Development of new RIVPACS Methodologies. A Progress Meeting was held on 11 July 2000 attended by Dr R Dines and Ms P Mardon of the Environment Agency and staff from CEH Dorset. At this meeting the shortcomings of the original specification for Package 4 (Development of educational tools based on RIVPACS) were recognised. It was agreed that the specific objectives should be revised, following the main items in the schedule, together with the best, but easily available guidance to likely costs.

3.2 Objectives

The overall objective was as follows:

'To produce a desk-study report entitled 'Development of educational tools based on RIVPACS' which outlines the major options for future consideration by the Environment Agency'.

The revised specific objectives were:

1. To review the main educational subjects which could be addressed by RIVPACS from primary school to University level and the potential range of educational material which could be produced.

2. To liaise with the Education Section of the Environment Agency and the NERC and document the procedures used within the Environment Agency when undertaking full scoping studies designed to assess the need for and relevance of new educational material.

3. To make a judgement on the potential educational products for which there is the greatest need, and provide guidance on the likely costs, development times and potential developers.

4. To review the extent to which potential RIVPACS products link to the educational strategies of the Environment Agency and could be integrated with existing educational material.

3.3 Objective 1

To review the main educational subjects which could be addressed by RIVPACS from primary school to University level and the potential range of educational material which could be produced.

3.3.1 Main educational subjects

Primary and secondary level education

There are various sources where it is possible to obtain detailed information about the main educational subjects which could be addressed using RIVPACS. These include both hard copy and Internet sources. The most important source of information is the *National Curriculum*. A hard copy can be obtained from Regional Environment Agency libraries, or can be downloaded from the web site at http://www.nc.uk.net/.

The *National Curriculum* is necessarily very detailed; this means that it is not always easy to quickly look up specific areas of interest. For this reason the Environment Agency Education Section has produced *The Concise Curriculum*. These fact sheets and booklets highlight particular areas of the curriculum, which are relevant to Environment Agency work and give a brief background that enables the delivery of targetted messages to pupils, teachers and Agency staff.

The main subjects in the curriculum to which educational tools based on RIVPACS could be relevant are science, geography, information and communication technology, English and numeracy. [For further details of curriculum requirements in the main subject areas see below.]

Included with the *Concise Curriculum* is the *Simple Schools Education Guide* which provides the age groups in the different Key Stages; the types of schools; the ages in the year groups within the key stages; the examination years; the subjects studied at each key stage. It also states that 'unless specific qualifications are available and selected in environmental studies at General Certificate of School Education (GCSE) or A-level (e.g. earth sciences), the Environment does not have its own subject area in the curriculum'. At Key Stages 1, 2 and 3 Environmental topics are found predominantly in the Geography curriculum but also in Science. However, there are also opportunities for the environment to feature in other subjects such as English (e.g. through drama), Art and Design (e.g. designing sculpture from recycled materials) and Maths (e.g. through water quality sampling and data handling).

Also included with the *Concise Curriculum* is *Working with schools* by C Jones, produced by the Community Education Development Centre with the Department for Education and Employment and Marks & Spencer (ISBN 0 947607 38 2). This document aims to help busy people in industry and commerce find out about the education system quickly and easily so that they can make an effective contribution. It is a comprehensive guide to school-business partnerships for business people who want to develop effective contacts with schools and is divided into two parts: 'Understanding schools' and 'Taking Practical Action'. The first part covers what teachers do, the different types of school, how schools are organised, what schools teach, understanding school inspection, understanding qualifications, and making effective contact with schools. The second part contains a step-by-step guide to developing a policy, and sections on work experience, careers programmes, sponsorship, industrial governors, Compact*, teacher placement service, Young Enterprise and mentoring.

*A Compact agreement is one set up between a group of students, the schools they attend and local companies, in order to provide additional support to young people, especially those for whom the transition from school to the world of work is likely to be difficult.

Also included with the *Concise Curriculum* is *Supporting sustainable development through educational resources – a voluntary code of practice* by the Council for Environmental Education, Department for Education and Employment and Department of the Environment, Transport and Regions. (DfEE Crown Copyright 1999). This sets out ten principles of good practice when producing educational resources.

The National Curriculum Key Stages 1 to 4 requirements cover both primary education and secondary level education up to GCSE. The subjects to which RIVPACS could be applied include Science, Geography, Information and Communication Technology, Literacy, Numeracy and Citizenship.

At the higher level of secondary education, after the GCSE stage, and leading to the qualifications of AS and A level GCE the main subjects to which RIVPACS could be relevant include Biology, Geography, Environmental Science, Computing and Information Technology. Details of the specifications for these subjects can be found on the Qualifications Curriculum and Assessment web site http://www.qca.org.uk and as follows:

Biology	http://www.aqa.org.uk
Biology/Biology (Human) A	http://www.aqa.org.uk/qual/gceasa/bioA.html
Biology B	http://www.aqa.org.uk/qual/gceasa/bioB.html
Geography	http://www.aqa.org.uk
Geography A	http://www.aqa.org.uk/qual/gceasa/geoA.html.
Geography B	http://www.aqa.org.uk/qual/gceasa/geoB.html
Environmental science	http://www.aqa.org.uk/qual/gceasa/env.html
Computing	http://www.aqa.org.uk/qual/gceasa/comp.html
Information & technology	http://www.aqa.org.uk/qual/gceasa/inf.html

Tertiary level education

In addition to schools teaching at primary and secondary level there are about sixty Further Education Colleges in the UK. These establishments straddle the boundary between secondary and tertiary level education. They prepare students for GCSE, AS and A Level subjects as well as other more vocational qualifications including Higher National Certificates and Higher National Diplomas. These colleges are listed by the Universities and Colleges Admissions Service (UCAS) on their web site at http://www.ucas.com/**.** Further Education Colleges offer courses in Applied Environmental Science (2), Biological science (1), Biology (54), Applied Biology (15), and Ecology (30) in which subjects educational material based on the RIVPACS programme could be applied.

At the tertiary level of education there are 259 universities and university colleges. These are listed on the web site: http://www.england.thecountry.com/universities.htm.

The University prospectuses describing the courses available for study can be found on the UCAS web site at http://www.ucas.com/. Subjects to which RIVPACS might be relevant include the following (although there may be some overlap or cross-referencing in the courses: applied environmental science (87 courses); aquatic (10); biodiversity (3); biogeography (1); biological science (2631); biology (1754); biology applied (1); combined science (275); conservation (299); country (8); country planning (292); countryside (120); ecology (235); ecosystems (5); environmental (2091); environmental biology (159); environmental conservation (18); environmental management (236); environmental pollution management (2); environmental pollution science (25); environmental protection (16); environmental quality (1); environmental science (1586); environmental studies (520); environmental sustainability (2); environmental systems (5); freshwater ecology; habitat (5); and water (121).

3.3.2 Potential range of educational material

RIVPACS could be exploited to develop a diverse range of materials to meet specified educational needs at different levels. Potential products could be books, leaflets, posters, slides, videos, CD-ROMs, floppy discs, DVDs, web site, activity kits, teachers' notes and handouts, activities, and ancillary materials – e.g. a taxonomic key at BMWP family level, or combinations of materials. Details concerning those materials for which it is considered there is the greatest need, are given later in Objective 3.

3.4 Objective 2

To liaise with the Education Section of the Environment Agency and the NERC and document the procedures used within the Environment Agency when undertaking full scoping studies designed to assess the need for and relevance of new educational material.

There are three stages in assessing the need for, and relevance of, new educational material. These are:

- firstly, the broad educational principles
- secondly, the detailed subject-specific considerations and
- finally, practical issues.

3.4.1 Broad educational principles with some examples

This section covers some of the more general educational principles, particularly with regard to the application of educational material to the subjects of biodiversity and education for sustainability, which generally supersede the formerly studied area known as environmental science. Educational tools based on the RIVPACS programme would need to relate to these major concepts within subject areas such as science and geography. These subjects continue to provide opportunities for teaching and learning about environmental change alongside sustainable development as themes within Curriculum 2000. It is in these subjects that it is possible to see a role for educational tools based on RIVPACS.

TEC 2000 Conference

(Contact details for organisations mentioned below are given at the end of the section)

The importance of teaching about environmental change, and methodologies by which this might be achieved, was the subject of a conference called *TEC 2000 – Teaching Environmental Change* (http://www.nmw.ac.uk/tec2000/) held at The Royal Society in London on 27 October 2000. This conference dealt with the need to communicate and educate about environmental change, particularly through the use of electronic media. Presentations were given on assessing educational needs and describing initiatives and methodologies produced by various organisations. The conference was aimed at an audience of teachers, representatives of teaching associations, curriculum advisers and scientists with an interest in promoting the teaching of environmental change in schools. The objectives of the conference were:

- to promote the teaching of environmental change in schools;
- to demonstrate computer-based tools developed to facilitate learning about environmental change; and
- to steer the development of teaching aids by research and monitoring organisations.

Educating the public about science and environmental issues is considered an area of high priority within the Environment Agency and the Natural Environment Research Council.

Environment Agency

The Environment Agency has a network of Regional Education Officers under the guidance of a National Education Programme Co-ordinator. The Agency has also developed educational resources including a web site (http://www.environment-agency.gov.uk/education/), the Riverside Explorer CD-ROM, and the Greener Futures CD-ROM. Their Education on the Internet initiative is designed for schools, further and higher education. It provides ideas for activities, is interactive, has partnership and awards information, and is available in either English or Welsh versions.

The Riverside Explorer CD-ROM deals with how rivers shape the land, describes river wildlife habitats, allows students to practice their own survey, provides a glossary of terms and key words, and provides teacher support notes together with case studies and worksheets.

The Greener Futures CD-ROM is the result of a partnership project involving Peterborough Environment City Trust and Cambridgeshire Environment Education Service. It is a lifestyles audit, recording data by area as an indicator of key environment issues as a means of monitoring change. The lifestyle audit comprises a pupil questionnaire, family questionnaire, interactive games, and data interpreter. The results from the audit have local and national implications for shaping environmental policies.

Natural Environment Research Council

Ms S Anderson of the Communications Directorate at the Natural Environment Research Council (NERC) spoke at TEC 2000 about the role of the organisation in the public understanding of science, while B Knowles presented a poster display on the educational role of the organisation. NERC supports research on issues including biodiversity, environmental risks and hazards, global change, natural resources, and pollution. The NERC schools programme comprises three main elements: the Crest Award scheme, Researchers in Residence and the schools liaison network. The RIVPACS programme relates directly to environmental change because it is an important means of assessing water quality and monitoring change in UK rivers through an examination of the macroinvertebrate fauna in relation to environmental features. Ideas for the development of educational tools based on the RIVPACS programme (as outlined below in Objective 3) would be outside the existing educational schemes in which NERC participates but these schemes could nonetheless enhance the use of an educational RIVPACS package.

The pressure to move schools, the curriculum and communities away from environmental education towards education for sustainable development was discussed by A Reid of the University of Bath at the TEC 2000 conference.

Pupil Researcher Initiative

The Pupil Researcher Initiative (PRI) is a major UK school science curriculum project supported by the Engineering and Physical Sciences Research Council (EPSRC) and the Particle Physics and Astronomy Research Council (PPARC) and managed by the Centre for Science Education at Sheffield Hallam University. PRI aims to raise pupil motivation and achievement in science particularly in investigative and ICT skills and increase the interaction between schools and the science and engineering research community. To achieve these aims PRI has three main areas of activity: producing curriculum activities and materials; promoting events to celebrate the science achievements of pupils; and mobilising the science and engineering research community to support science education.

The components of PRI designed to achieve these aims include:

1. Curriculum materials that cover essential syllabus content but also provide motivating contexts based on real research scenarios that present pupils with a realistic image of what science and engineering is all about. Pupil research briefs (PRBs) aim to put the student in the role of researcher, to provide active learning approaches, together with context and scenario based learning, by providing opportunities for teaching investigative skills and opportunities for pupils to develop scientific capability;

2. Researchers in Residence: PhD student placements in secondary school science departments to support investigative work and the development of good scientist role models for pupils;

3. “Express Yourself” Science conferences: pupil conferences with the pupils attending poster sessions and workshops where they present investigation reports to their peers and professional researchers; and

4. PRI web site www.shu.ac.uk/pri: this contains a wealth of information about the project and its components including new learning resources, PRISM-Online (the PRI pupil journal), networking opportunities (school-to-school and school-to-researcher) and up-to-date project information.

It is possible to see how a RIVPACS educational package could be used to fulfil some of these aims and initiatives, and also to learn from the Pupil Researcher Initiative ways in which it could be used – for example, by researchers in school using RIVPACS.

British Educational Communications and Technology Agency

Information and communications technology can help pupils by enhancing enquiry skills, providing access to sources, developing understanding, providing access to perspectives, and contributing to pupil awareness of ICT in society. There is also a requirement in the National Curriculum to use information and communications technology. The British Educational Communications and Technology Agency (BECTa) is a Government Agency responsible for Information and Communications Technology in education. Development of an educational package based on the RIVPACS software thus meets needs for educating all sectors of the public about environmental concerns while affording an opportunity to familiarise with computer technology and its application in science.

Association for Science Education

The Association for Science Education is for teachers, advisers, technicians, industrialists and others contributing to science education. It promotes, supports and develops science education from primary through to tertiary levels. It is independent in its thinking and in its finance. It is a registered charity, financed by members' contributions and receives no government funding. It provides a forum for the views of members on science education issues through its regional and national committee structures. Those in authority and in government, industry and Local Education Authorities frequently and regularly consult ASE. Among its many functions it supports relevant curriculum support materials. It provides ASE Inset (In-service Training) Services 2000/2001. Inset days are a useful and recommended way in which teachers can take time out from the classroom to attend short training courses, workshops or demonstrations of new or developing educational support materials. Assessing what products teachers really need to deliver curriculum requirements, and allowing teacher input at the development stage of new educational products ensures that the educational tools are appropriate, relevant and required.

ASE also runs the on-line SciShop, which is a resource area to support teachers and students in KS3 Science. The resources are related to specific learning objectives of the KS3 National Curriculum. The Editors of SciShop will be pleased to accept ideas and new resources for inclusion in the database. There is a possibility that a wider market for educational tools based on RIVPACS could be reached by uploading material onto one of the SciShop servers.

Council for Environmental Education

Finally, the Council for Environmental Education, in collaboration with the Department for Education and Employment and the former Department of the Environment, Transport and the Regions, has written a voluntary code of practice for producing education resources entitled *Supporting sustainable development through educational resources – a voluntary code of practice* (DfEE Crown Copyright 1999). It provides ten principles of good practice, in order to 'raise standards of educational resources designed to support education for sustainable development'. These are:

Content (what resources contain)

- Principle 1: Principles of sustainable development. Resources should foster understanding of the principles of sustainable development and the aims and significance of Agenda 21 (1992).

- Principle 2: Integrity. Any information and data provided should be accurate, current and verifiable.

- Principle 3: Balance. When purporting to give a balanced account of an issue, resources should accurately reflect the broad range of informed opinion on the subject.

- Principle 4: Values and attitudes. Resources should help people to explore values and develop responsible attitudes in relation to their fellow citizens and the environment, from local to global level.

- Principle 5: Knowledge and skills. In addressing environmental and development issues, resources should help develop the knowledge, skills and competencies to enable people to participate effectively in their resolution.

- Principle 6: User-centred approach. To ensure maximum take-up, resources should be easy to use and appropriate for the intended audience.

Process (how the resources have been developed)

- Principle 7: Need. Producers should be able to demonstrate there is an identified need for the proposed resource.

- Principle 8: Development. Producers should ensure that the development of the resource is inclusive, participative and has drawn on appropriate educational expertise.

- Principle 9: Production. Producers should demonstrate that the production process has followed best sustainable practice wherever possible.

- Principle 10: Promotion and distribution. Producers should consider the implications of promotion and distribution from the outset and ensure that they are effective, appropriate and accessible.

Detailed guidance statements are provided for each principle.

CONTACTS FOR THE ABOVE MENTIONED ORGANISATIONS

Environment Agency
National Education Programme Co-ordinator, The Environment Agency, Block 1, Government Buildings, Burghill Road, Westbury-on-Trym, Bristol, BS10 6BF, Phone 0117 914 2824, Fax 0117 914 2606.
Regional Education Co-ordinator, Environment Agency, Anglian Region, Kingfisher House, Goldhay Way, Orton Goldhay, Peterborough, PE2 5ZR.

Natural Environment Research Council
Natural Environment Research Council, Communications Directorate, Polaris House, North Star Avenue, Swindon, SN2 1EU, Phone: 01793 411500, Fax: 01793 411501, www: http://www.nerc.ac.uk.

Universities
University of Bath, Department of Education, Bath, BA2 7AY; Phone: 01225 826225; Fax: 01225 826113; www: http://www.bath.ac.uk/ Departments/Education.

Pupil Researcher Initiative
Centre for Science Education, Sheffield Hallam University, City Campus, Sheffield, S1 1WB. Phone: 0114 225 4876.

British Educational Communications and Technology Agency
Head of Curriculum and Institutional Development for Schools, The British Educational Communications and Technology Agency (BECTa), Millburn Hill Road, Science Park, Coventry, CV4 7JJ; Phone: 024 7641 6994; Fax: 024 7641 1418; www: http://www.becta.org.uk.

Association for Science Education
The Association for Science Education, College Lane, Hatfield, Herts, AL10 9AA; ASE HQ Telephone: 01707 283000; www: http://www.ase.org.uk/

ASE Inset (In-service Training) Services 2000/2001 Tel: 024 7669 0053, Fax: 024 7669 0726.

Council for Environmental Education
CEE, 94 London Street, Reading, RG1 4SJ, http://www.cee.org.uk

3.4.2 Subject-specific considerations

This section indicates potential links between RIVPACS and associated ideas or materials on the one hand and primary and secondary level curricula at Key Stages 1 – 4 (including GCSE), and specifications for AS and A level GCE.

Primary and secondary education to GCSE level (age 5 to 16 years)

"It is important to ensure that the National Curriculum guidelines are referred to, and included, in any method of delivery to the formal education sector (e.g. Direct involvement, production of education resources, INSET (In-service Training) for teachers, field trips) to make most efficient use of time for teachers, and no less, for the Agency's own time and financial resources." (The Concise Curriculum - Introduction)

The *National Curriculum* states the requirements for each subject and key stage. This information is summarised in the Environment Agency's *Concise Curriculum*. Programmes of work regarding what pupils should be taught at each key stage are tabulated in the *Concise Curriculum*.

Science, for example, is an obvious area to which RIVPACS is relevant. In this particular section the requirements at each Key stage are outlined. We are told that pupils should gain knowledge, a variety of skills and understanding through the subject of science at key stages 1- 4 (5-16 years). They will:

- gain knowledge of ‘the cultural significance of science and world-wide development’; ‘phenomena and events in the world around them’ and means of ‘scientific method’;

- gain ‘questioning, developmental and evaluative’ skills as well as initiating critical and creative thought; and

- gain understanding of ‘major scientific ideas which contribute to technological change’ and how ‘issues may affect their own lives, the direction of society and the future of the world’.

Throughout all four key stages (KS 1-4) for Science, the National Curriculum states that pupils should make progress in scientific enquiry, life processes and living things, materials and their properties, and physical processes. Of these, scientific enquiry, and life processes and living things are most relevant to a RIVPACS educational package.

At all Key Stages from 1 to 4, scientific enquiry deals with ideas and evidence in science, and the development of investigative skills including planning, obtaining and presenting evidence, and considering and evaluating evidence. Similarly, under the heading of life processes and living things, pupils must examine life processes, humans and other animals, variation and classification, and living things and their environment.

Some of the specifications in the full National curriculum for Science are of particular relevance if the anticipated RIVPACS educational package incorporates a web site, CD-ROM or computer-based identification key. It should be noted in Sc2 Life processes and living things (p 24) under the heading Variation and Classification it is stated that pupils at Key Stage 2 (children 7-11 years) should be taught to make and use keys, how locally occurring animals and plants can be identified and assigned to groups, that the variety of plants and animals makes it important to identify them and assign them to groups. It is also noted that this provides an ICT opportunity where pupils could use a branching database to develop and use keys. By Key stage 3 (11-14 years) (National Curriculum p 28) pupils should be taught about environmental and inherited causes of variation within a species, and to classify living things into the major taxonomic groups.

Under the heading of *Living things in their environment* the National Curriculum says that Key Stage 2 pupils should be taught about ways in which living things and the environment need protection. Within this section pupils should learn about adaptation – about the different plants and animals found in different habitats, and how animals and plants in two different habitats are suited to their environment. This provides an ICT opportunity in which pupils could use video or CD-ROM to compare non-local habitats. By Key Stage 3, pupils should be taught about ways in which living things and the environment can be protected and the importance of sustainable development; that habitats support a diversity of plants and animals that are interdependent; how some organisms are adapted to survive daily and seasonal changes in their habitats; and how predation and competition for resources affect the size of populations.

At Key stage 4, involving children from 14 to16 years, (Science Single p 37, Science Double p 46) RIVPACS may be relevant to the curriculum in most of the Sc1 Scientific Enquiry, Sc2 Life Processes and Living Things, and some areas of Variation, Inheritance and Evolution, and of Living Things in their Environment under Adaptation and Competition but the application of RIVPACS based educational tools may be less appropriate than at earlier Key stages 1 – 3. Many of these parts of the curriculum could be developed as add-ons related to the RIVPACS package.

Similarly the curricula for the other main subjects are dealt with. However, the application of a RIVPACS educational package to other subjects such as geography, literacy, numeracy, and citizenship is less relevant and more peripheral than in the subject of science.

Secondary level education to AS and A level (age 16 to 18 years)

School education for pupils above the age of sixteen years is no longer governed by the requirements of the National Curriculum but is geared towards the acquisition of qualifications based on examination syllabi (now referred to as specifications) set out by the newly unified Examining Boards. These examinations lead to AS and A level qualifications. Details of the specifications for each subject can be found at the Qualifications Curriculum and Assessment web site http://www.qca.org.uk.

The subjects to which educational tools based on RIVPACS most readily apply are biology, geography, and environmental science.

Biology

The broad aims of the AS and A level specification in biology are to encourage students to:

- develop essential knowledge and understanding of concepts of biology, and skills needed for the use of these in new and changing situations;
- develop an understanding of scientific methods;
- be aware of advances in technology, including information technology, relevant to biology;
- recognise the value and responsible use of biology in society; and
- sustain and develop their enjoyment of, and interest in, biology.

In addition, A level specifications in biology should encourage students to:

- show an understanding of knowledge, facts, principles and concepts from different areas of biology and to make and use connections between them.

Certain AS and A level specifications in **Biology** refer to areas of study to which RIVPACS is relevant. For example, students should learn about the adaptation of species to survive in particular environmental conditions (3.11); that species are classified into groups – the principles and importance of taxonomy (3.18); the dynamic nature of ecosystems (3.20) and the ecological impact of human activities (3.21).

In the area of experiment and investigation, students are required to plan, carry out and evaluate their work using information technology where appropriate. Students should be able to understand the principles of sampling as applied to biological data and the importance of chance in interpreting data (3.23).

Specifications for the subject of Biology can be found at http://www.aqa.org.uk, and for Biology/Biology (Human) A at http://www.aqa.org.uk/qual/gceasa/bioA.html. The course is divided into modules, to some of which the application of a RIVPACS educational package would be appropriate. These include Module 5 – Inheritance, Evolution and Ecosystems (Biology and Human Biology) in which the biology of ecosystems is studied. It states that living organisms do not live in isolation but form structured communities within dynamic and well-defined ecosystems through which energy flows and in which nutrients are cycled. This module also allows consideration of some of the ways in which human activity can impose far-reaching effects on the environment. It is expected that candidates will carry out fieldwork involving the collection of quantitative data from at least one habitat and the application of elementary statistical analysis to the results. A critical appreciation is required of some of the ways in which the numbers and distribution of organisms may be investigated; and an understanding is needed of the concept of diversity in the context of ecological stability; and of the concept of succession - from pioneer species to climax community; and that changes in abiotic factors can result in a less hostile environment and increasing diversity.

Biology B specification can be found at http://www.aqa.org.uk/qual/gceasa/bioB.html. Modules in which the use of educational tools based on RIVPACS might be especially apt include Modules 5 and 6. Module 5(a) deals in a general way with the environment, energy flow through ecosystems, materials recycled in ecosystems, dynamics of ecosystems, and the impacts of human activities on the environment. Module 5 (b) is an assessment of a practical investigation.

Module 6 concerns applied ecology. It deals with the concept of diversity through a knowledge of sampling techniques including netting and trapping; diversity indices; abiotic and biotic factors; and stability of ecosystems. The effects of pollution on diversity are studied through a knowledge of pollution of aquatic ecosystems; the use of diversity indices and indicator species in monitoring freshwater pollution; the effects of organic effluents and also heavy metal ions, acid rain and oil spillage on aquatic ecosystems. Knowledge is required that organisms show structural, physiological and behavioural adaptations for survival in a given niche. Agricultural ecosystems, harvesting from a natural ecosystem, and conservation (species, nature, biological, environmental and global) are also studied.

Specifications for Geography, Geography A and Geography B can be found at web sites http://www.aqa.org.uk, http://www.aqa.org.uk/qual/gceasa/geoA.html and http://www.aqa. org.uk/qual/gceasa/geoB.html respectively. The specification contains aquatic components, such as, Water on Land, River Systems and River Regime, Channel Processes and Landforms, Flooding as a Hazard and River Basin Management. However, as all the components are related to physical systems rather than biological, it is likely that an educational package based on RIVPACS would have a limited application in A level geography.

The specification for **Environmental Science** can be found on the Web at http://www.aqa.org.uk/qual/gceasa/env.html. Various aquatic themes, to which

RIVPACS might be relevant and useful, are contained in the study modules. At AS level, Module 1 deals with Energy, the Atmosphere and Hydrosphere. This module includes the study of the need for energy and water by humans, which is linked to possible environmental consequences, for instance the 'Greenhouse Effect' and global climate change. Some of these consequences, especially pollution, are explored in greater depth in Module 5, and selected themes link to Modules 2, 3 and 4. Detailed studies are outlined in 10 especially 10.1 - Hydrological cycle, and 10.3 - Water Use. Module 3 deals with The Biosphere. It includes the productivity and dynamic nature of ecosystems and the size, density and dynamics of populations in relation to human population growth and the concept of sustainability (see Module 4). The final section deals with the need for biodiversity and indicates the methods and strategies of conservation. Detailed studies are outlined in section 12 - especially 12.3 The Ecology of Ecosystems (food chains and webs illustrated by at least one aquatic and one terrestrial ecosystem using local examples where possible); Changes in Ecosystems (changes in abiotic factors and species diversity in an ecosystem); Diversity and Ecological Stability; 12.4 Populations; 12.5 Wildlife Conservation.

Educational materials derived from RIVPACS are also applicable to A level Environmental Science modules. Module 4 - Biotic Resource Management – studies the management of biotic resources through an examination of the production processes which manipulate the biotic and abiotic components of ecosystems to satisfy the increasing demand of human population for biological resources. The module builds on principles established in the first three modules and links to Module 5 especially through the study of the impacts of the production of waste, and pollution pathways in the environment.

Module 5 - Pollution and Physical Resource Management develops concepts established in Modules 1, 2 and 3 and introduces the idea of sustainable development through a study of the management of resources. Details in section 14, especially 14.3, on Water Conservation and Pollution, deal with water pollution monitoring by the Environment Agency and water quality standards. Students should be aware of the advantages and disadvantages of assessment of water quality by physical, chemical and biological methods. Students should also know about the measurement of temperature, total suspended solids, oxygen content, nitrate, phosphate, ammonium, pH and Biochemical Oxygen Demand; and the use of Biotic Indices and Indicator Species.

3.4.3 Practical considerations

In this section we deal with the mechanisms used by the Agency to determine the need for and relevance of new educational material.

The Environment Agency's booklet entitled *Developing Education Resources – A Best Practice Guide* covers key aspects for consideration, so that the resulting educational resource production meets a need and will be used by the target audience. A pre-project checklist establishes whether or not to proceed with a project. It asks a series of questions which are listed below, together with some demonstration answers using RIVPACS as the example resource.

Name of resource

RIVPACS

Type of resource

Web site
Programme and ancillary on-line material including video footage and down-loadable teacher's notes and information sheets

Agency's key themes and issues
Managing Water Resources
Enhancing biodiversity

Target audience
Formal education (schools and colleges)
Business and industry (i.e. environmental consultants & other scientific professionals)

The need for the project
Simplified user-friendly Windows version required by professionals including EA biologists
Programme and ancillary material can fulfil many requirements of the National Curriculum, GCSE, A level and degree courses

Project checks
Need to check with EA database
Need to discuss with national and regional education co-ordinators

Working with partners
Environment Agency Education Co-ordinators
Educational consultants
CEH Dorset, River Communities Team
Programme designer/statistician and computing specialists
Software designers
External partners

Scope of the project (for adapting for wider use)
Customised versions of software

Promotional benefits to the Agency
Increased awareness of projects that the Agency undertakes
Promotion of elements of the Agency Vision
Good PR

Use of the resource
Formal education sector
Specifically targeted to meet requirements of curriculum or syllabus, and requirements of teachers and lecturers – direct consultation with users necessary
Environmental consultants, freshwater ecologists, other professionals with a concern for the environment

Method of promotion
e.g. Formal launch, press releases, local and regional events
Consultation with Environment Agency Public Relations Department needed at earliest opportunity

Distribution
How?
Cost?
Public Relations Department advice required

Method of evaluation
Have the aims and objectives of developing an educational resource been met?
Is it a useful tool?
Does it meet the needs of the target audience?

Does it need further development?
Is there scope for enhancement?
Questionnaire distributed with resource?
Follow-up survey?
Follow-up workshop?
*EA evaluation panel**

Feedback
Part of evaluation
How well or badly has the product been received?

Project costs
Actual cost
All elements of project
Funding stream
Is the Agency the sole contributor? Which function or department budget?
Other financial partners?
Accessibility of external funds or grants?

Value for money
Does the resource being developed justify its expenditure?
Is the most effective medium being used?

Timescales

Project manager

* Evaluation Panel's key tasks:

- To identify gaps in the environmental education provision within the Agency
- To identify resources which have potential for national development
- To act as a forum for assessing the potential for developing inter-regional projects
- To commission independent research that will establish best practice

The pre-project checklist is part of the assessment of the need for and relevance of new educational material. Once the checklist has been completed in full, it is possible to carry the project forwards towards potential development. The guidance manual entitled *Project Management in the Agency* Volume 14 Version 2 04/97 is used to achieve best practice in the appraisal and management of projects. The guidance must be applied to all Agency projects and it will need to be applied to the proposed development of any educational tools based on RIVPACS.

The Project Executive and Project Manager are responsible for ensuring that the needs and opinions of users of the end product are properly considered throughout the planning and appraisal process. Guidance is given on the application of appropriate appraisal methodologies. The Project Initiation Document sets out clearly why the project is being undertaken, what products and benefits it is to deliver, and to whom.

3.5 Objective 3

To make a judgement on the potential educational products for which there is the greatest need, and provide guidance on the likely costs, development times and potential developers.

3.5.1 Options

1. Professional and tertiary educational level products - user-friendly Windows version of RIVPACS, together with ancillary products geared to the appropriate level, for which there is a definite market amongst professional academics, environmental consultants and in universities and colleges.

2. Senior scholastic level products - simplified version of user-friendly RIVPACS plus ancillary products geared to the appropriate level aimed at GCSE, AS and A level students.

3. Primary and secondary educational level products - references only to RIVPACS and its capabilities and relevance – ancillary products aimed at National Curriculum Key Stages 1-3 or 4.

4. A combination of options 1, 2 and 3 introduced sequentially.

Potential educational products for which there is the greatest need:

- Revised Windows user-friendly version of the RIVPACS programme and manual (on-line information and help, and hard copy).
- Different versions of programme available for different educational levels using a built-in system permitting the required level of access and options, and appropriate manual for each level.
- Customised versions for paying professional customers accessed on the web with special passwords, including manuals.
- Creation of web site with a user-friendly version of RIVPACS.
- On-line aquatic macroinvertebrate BMWP family level key.
- Reference list of published identification guides.
- Macroinvertebrate specimen reference material.
- Illustrative material.
- Habitat and life history notes for macroinvertebrates.
- Down-loadable information for teachers and students.
- Kit list for sampling rivers.
- Simplified versions of manual instructions/sampling video.

User-friendly version of RIVPACS

There is the greatest need for educational products based on RIVPACS at a fairly high level within the educational system, that is, from perhaps GCSE, through GCE AS/A level to higher education courses in Further Education colleges and Universities. Specialist professionals in the field of freshwater ecology, including Agency biologists, would also benefit a great deal from the core product, which would be a revised user-friendly Windows version of the RIVPACS III+ programme. The production of simplified versions of the programme, aimed at more junior levels of schooling, might not be so useful as the proposed ancillary parts of the package. These would lay a foundation for understanding what RIVPACS is all about and integrate more closely with the needs of the National Curriculum 2000.

The programme needs to be altered to accept batch loading of data, reading from an Excel spreadsheet or Access Database instead of an ASCII file, as well as retaining the interactive method of data input. The core programme which does all the calculations for expected values and simulation of errors in O/E (observed over expected) ratios could remain but with a complete new Windows front and back end to make it user-friendly. The user would only work in the Windows medium for input of data, selection of run options and retrieval of output. Ralph Clarke, as the developer of the latest version of this complex statistical programme, should be responsible for modifications to the RIVPACS III+ programme and for overseeing the Windows additions. This would require assistance from another person within the CEH Dorset organisation. Modifications to the main programme could involve the incorporation of 'blocks' or pre-set restrictions which would effectively make different versions of the programme available to different groups of users.

Outside Windows programming expertise would be required to make this user-friendly version of RIVPACS visually and audibly attractive for both the professional and the educational market. Computer software designers (outside of CEH Dorset and perhaps CEH) would also be required to incorporate any additional components specifically constructed for different levels of the educational market.
Access to the full RIVPACS protocol manual would be an essential element of this part of the package. This could be available for downloading from the web site either free of charge or on payment using a password. Alternatively, the manual might be made available for purchase as hard copy. Simplified versions of the manual could be written to suit the specific requirements of each education level. These would tie-in exactly with the course material in the educational RIVPACS package.

Similarly, a sampling training video should be made available. The existing training video would need to be updated. There is also scope for a much briefer, simplified and concise version of the videotape on sampling procedures suitable for National Curriculum Key Stages 1 to 4.

Creation of web site with the user-friendly RIVPACS

The creation of a web site would be a cost-effective and efficient way of making the user-friendly version of RIVPACS, and the educational tools based upon it, accessible to the widest possible market. Advantages would include:

- the ease of making modifications or updating material as required;
- minimisation or avoidance of distribution costs;
- the facility of making tailored versions of products accessible to paying customers through a combination of password system and blocking lines in the software;
- the cost of hard copies of products would be borne by the customer;
- a web-site could provide the main method for obtaining feedback on the products; and

- access to the RIVPACS educational package via the World Wide Web means that it would be available to a very wide audience of students, the general public, and professional/academic workers interested in the British freshwater environment.

Aquatic macroinvertebrate BMWP family level key

Using the RIVPACS computer programme to predict which aquatic macroinvertebrate animals should occur at specified locations in unimpacted rivers depends on accurate identification of the animals in the samples. At the simplest level, animals are identified to family or group; at the more advanced level, they are identified to species or species group. Certain commonly occurring families of aquatic macroinvertebrates are known to have greater or lesser tolerance to pollution and, on this basis, the families have been assigned different scores. For example, a mayfly larva of the family Ephemerellidae which is intolerant of pollution has a score of 10, while worms or Oligochaeta which are highly tolerant of pollution have a score of 1. These scores were assigned by the Biological Monitoring Working Party, and the families are consequently referred to as BMWP families. A table, giving the scoring system as used in the 1980 River Quality Survey and later surveys may be found in the 1980 survey report (National Water Council 1981). The ability to identify specimens of the BMWP families of macroinvertebrates is essential when comparing the observed fauna at a site with predictions at BMWP family level using RIVPACS.

Various keys, and in particular the scientific publications of the Freshwater Biological Association exist to help with the task of species level identifications. However, there is also a need for a reliable key to the families of macroinvertebrates (and particularly the BMWP families) found in freshwaters. It is suggested, therefore, that a new kind of interactive on-line key should be developed specifically for the task of helping novices to make correct identifications of the BMWP families of animals because this is necessary for an understanding of freshwater communities of animals and, as previously indicated, is essential for the running of the RIVPACS programme.

LucID is a system for devising the required type of identification key. LucID Professional for Windows is an interactive matrix-based key designed specifically for creating powerful but easy–to-use identification keys (http://www.publish.csiro.au/lucid/). The Windows program consists of the LucID Builder, which allows you to design and build your own identification keys for any material; and the LucID Player, which allows interactive use of those identification keys.

Features of LucID Professional:

- Identification is easy – start with any character.
- The point and click interface is elegant and straightforward.
- Images, videos and sounds can be included.
- States are coded as common or rare, and misinterpretations are allowed for.
- Discrete character data and continuous numeric data are supported.
- ‘Best’ can be asked for the optimum route to identification.
- Related sub-keys can be loaded from the main key.

- Errors can be tolerated and set to your requirements; material within keys can be compared for similarities and differences.
- Remaining possible answers are ranked according to their probability of being correct.
- Keys can be created in languages other than English.

LucID solves several identification key problems. When identifying material, how do you identify something if you do not already know what it is? Generally, you need to use some kind of identification key, a structure built to help you identify an unknown item. Keys can be built to identify members of any group of things. All keys use a common principle: you answer questions about the item until the key can tell you what the item is. Some keys ask questions in turn, others (e.g. LucID keys) present you with a list of questions, and you can choose which you would like to answer first.

Existing keys have certain limitations. Most existing keys are text-based branching keys in which they present you with a first choice from which you make a decision, proceeding to where the answer leads. This works well if you can answer each of the questions in turn, but becomes difficult if you encounter one or more questions that you cannot answer. LucID combats these limitations by being based on a matrix, which means that the key is a list of questions, from which you choose one to answer, depending on the material in your hand. Also LucID is highly graphics-based, enabling complex concepts to be explained simply, with coloured illustrations. Because LucID Professional produces electronic keys that are distributed on CD-ROM, the use of illustrations, video and sound is restricted only by the memory of the CD.

Reference lists to key works such as published (hard copy) identification keys to family and species level of freshwater macroinvertebrates should be included in the package to supplement the LucID BMWP key for higher educational levels and professional use where species identification may be required for use alongside RIVPACS species-level predictions.

Illustrative material would be an essential part of any educational package based on RIVPACS. These would be necessary both to inform and to entertain. They could include colour photographs, line drawings, video footage, and animations. These illustrations could be used to show:

- the types of rivers in different geographical locations;
- rivers in varying states from clean to impacted;
- the equipment used for sampling and identification;
- sampling methodologies with demonstrations by professional biologists;
- macroinvertebrate sample sorting techniques;
- the range of aquatic macroinvertebrates occurring in different types of running waters.
- living animals in natural situations; and
- preserved animals belonging to the full range of BMWP (Biological Monitoring Working Party) groups or families as used in the RIVPACS programme.

Macroinvertebrate reference material

After examining an animal from a sample, and consulting an identification key, professional biologists frequently check their identifications by referring to a collection of preserved reference specimens, for which the identity of the animals has previously been verified. Provision of reference specimens could be considered as part of the educational package based on RIVPACS although there might be practical difficulties associated with the provision of complete sets of BMWP family specimens.

Habitat and life history notes

As mentioned above, different freshwater macroinvertebrates exhibit different tolerances to water quality. Additionally, they have preferences for different habitats. On a broad scale this could be fast or slow flowing water, upland or lowland locations, and chalk or acidic streams. On a smaller scale, their habitat preferences might be associated with certain plant types or riverbed substrates. The life histories and habits of freshwater macroinvertebrates are varied and interesting. The natural history of individual families and species, and information about the communities living in different habitats, provides the background for RIVPACS as a monitoring and assessment tool. This knowledge also fulfils many of the requirements of the National Curriculum regarding such elements as life processes, ecosystems, and biodiversity.

Habitat and life history notes could be made available interactively when on-line identifications are being made, or these notes could be downloaded separately as hard copy.

Downloadable information

Habitat and life history notes are not the only information that could be made available for downloading from the web-site. Teachers need to know which parts of the curriculum can be addressed by which parts of the package. Everything the package contains should be cross-referenced to the National Curriculum and examination specifications. Teachers will more readily use the package if it is organised in such a way that it is easy to apply in the classroom. What teachers might want to find are:- lesson plans and teacher notes; project ideas; instruction sheets for obtaining biological samples and for recording environmental information in the field and from maps; and finally, procedures for sorting samples. Pupils would need work sheets and supplementary information and illustrations. All this information would need to be clearly linked to the RIVPACS programme and to specific items within the National Curriculum.

Kit list

There could be two ways in which the RIVPACS programme is used in an educational package. For most of Key Stages 1 to 4, it is unlikely that pupils would be able to use even a simplified version of the RIVPACS programme to assess the ecological quality of a river as a real-time exercise. The ancillary information, which puts RIVPACS into context, might be more relevant to the curriculum. However, an on-line ‘play’ version of RIVPACS might be feasible (see Riverside Explorer).

At GCSE, AS/A level, and undergraduate level, students would be able to undertake predictions using a simplified version of the RIVPACS programme. However, at all stages there could be an opportunity to carry out fieldwork to collect macroinvertebrate samples and subsequent sorting and identification of specimens.

3.5.2 Likely costs and development times

In his letter of 19 July 2000 Dr R Dines requested 'the best, but easily available guidance, to likely costs (for example, derived from experience with the RHS CD)' for the proposed educational tools based on RIVPACS.

An example of the overall costs involved in the exploitation of an Environment Agency product for its educational potential, is provided by the development of the interactive CD-ROM, *The Riverside Explorer – Investigating rivers and their habitats in England and Wales* Version 1, that was launched in May 2000. This educational tool is based on a database of habitat features recorded during a national survey of rivers (River Habitat Survey), which was conducted jointly by the Environment Agency and the Centre for Ecology and Hydrology. Information on more than 45,000 river sites in England and Wales may be explored and searched by means of an easy to use geographic information system based on Ordnance Survey maps.

The Advisory Unit "Computers in Education" [126 Great North Road, Hatfield, Herts, AL9 5JZ, Tel 01707 266714, Fax 01707 273684, www: http://www.advisory-unit.org.uk] was commissioned to produce the CD-ROM. The assessment of teacher needs, testing in primary and secondary schools, evaluation by an educational and technical panel, and software design were all contracted out to independent specialists. Data and quality assessment were provided by CEH. The CD-ROM was distributed to 28,000 schools for a cost in the region of £300K to which the Ordnance Survey contributed. Further details are available from: Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD, 01454 624400, Fax: 01454 624409,www: http://www.environment-agency.gov.uk.

Further ideas regarding costs and development times might be available from the experiences of other organisations that have already produced educational resources related to the environment, mostly in the form of a CD-ROM or Web site. However, useful information on development costs has not been forthcoming in consultations with other web site producers within CEH.

The Centre for Ecology and Hydrology (CEH) produces *SCHOOLNET,* an Internet teaching resource that is interactive and easy to update [Centre for Ecology and Hydrology, Monks Wood, Abbots Ripton, Huntingdon, Cambs, PE28 2LS, 01487 772534, Fax: 01487 772535, www: http://www.ceh.ac.uk/subsites/ schoolnet]. This is a fairly basic web site, which was researched and established over a six-month period by a sandwich student. Costs were therefore minimal, in this instance, and confined to the cost of student supervision by CEH staff.

CEH also runs *The Environmental Change Network* web site that provides easy access to information resources from the long-term integrated environmental monitoring programme. It allows teachers and students to explore environmental change issues [Centre for Ecology and Hydrology, Environmental Change Network, CEH-Merlewood, Windermere Road, Grange-over-Sands, Cumbria, LA11 6JU, 015395 32264, Fax: 013595 34705, www: www.ecn.ac.uk/]. Although this web site is more complex than SCHOOLNET, and more in line with the proposed RIVPACS web site, development times and costs are not available, as the relevant activities are not distinguished in the financial records from other functions and costs.

The Environment Agency itself seems, therefore, to be best placed to readily assess project costs and development times based on the experience of developing *Riverside Explorer* and the *Greener Futures* Lifestyles Audit.

A crucial first step is to produce a Windows version of RIVPACS with the same functionality as the current DOS version, but also including many of the outputs as Excel files. CEH Dorset staff would need to undertake this initial work, which is estimated to cost in the region of £40K (see section 5.7.2 of this report for a wider discussion of the need for a Windows version of RIVPACS before any further additions are made to the software, for use by the Environment Agency itself).

Once the Windows version is available, decisions on the sequence of developments required for Educational RIVPACS must be made by the Education Section of the Environment Agency. The following list of possible developments includes some items which would need to be undertaken by staff at CEH Dorset whilst others might best be handled by software designers and those with specialist knowledge in the field of education. As yet, it is premature to clarify this area. However, this breakdown of all possible elements of the RIVPACS educational package, for each level of educational or professional use, may assist with the estimation of costs and development times.

FLOW CHART OF POTENTIAL DEVELOPMENTS

TERTIARY	**Professional & Undergraduate**		RIVPACS III+ & manual
		1.	Convert to Windows version
		2.	Add blocking facilities for different levels & customised versions
		3.	Create web site
		4.	Remake sampling training video
		5.	Compile list of published identification keys
		6.	Consider preserved reference specimens
		7.	Interactive BMWP family identification key

SECONDARY	**AS/A level**		RIVPACS blocked to BMWP family level
		8.	Simplified version of the manual
		9.	Shortened version of sampling training video
		10.	Sampling kit list
		11.	Illustrations
		12.	Habitat & life history notes
		13.	Case study materials
		14.	Teachers' notes Lesson plans Worksheets Project ideas
	GCSE -		As for A level
	(Key Stage 4)	15.	Teaching materials at appropriate level.
	Key Stage 4 -	16.	"Play" version of RIVPACS.
	(Non-GCSE)	17.	Instruction sheets for programme operation.
		18.	Instruction sheets for sampling procedures. Other materials as for GCSE.
		19.	Teaching materials at appropriate level.
	Key Stage 3		As for Key Stage 4 non-GCSE
		20.	Teaching materials at appropriate level
PRIMARY	**Key Stage 2**		As for Key Stage 3
		21.	Teaching materials at appropriate level
	Key Stage 1		As for Key Stage 2
		22.	Teaching materials at appropriate level

3.5.3 Potential developers

As with costs, ideas about potential developers or sponsors for educational material based on RIVPACS may best be provided by the Environment Agency itself, drawing on its wide experience of project funding and sponsorship in many fields including education. The Environment Agency would naturally be the main developer but involvement and possibly financial sponsorship might involve various types of organisation. These could include Local Education Authorities, through their Education and Business Partnerships; major businesses or industries with a concern for the environment; computer or software development companies because the RIVPACS educational package would encourage use of information and communication technology; and charitable foundations concerned with wildlife conservation and the environment.

3.6 Objective 4

To review the extent to which potential RIVPACS products link to the educational strategies of the Environment Agency and could be integrated with existing educational material.

3.6.1 Environment Agency policy

There are many ways in which the proposed educational products based on RIVPACS accord with the overall policies of the Environment Agency, in addition to their detailed educational strategies. Before considering the educational strategies, it is worth taking a broader view of the relevance of RIVPACS by way of a recent consultation draft produced by the Agency entitled *Creating an Environmental Vision - Progressing the Environment Agency's contribution to sustainable development by way of a better environment in England and Wales* (Consultation Draft June 2000 http://www.environment-agency.gov.uk**).**

Increased access to information

In the Foreword to their document the Chairman, Sir John Harman, says "We recognise the power of information and we will make data about the environment as widely accessible as we can to effect change and stimulate involvement".

The educational RIVPACS package would make data about the freshwater environment accessible to both students and professionals. It would promote an understanding of the interaction between aquatic macroinvertebrate communities and their physical and chemical environment, and stimulate involvement in the monitoring and assessment of rivers through examination of the animals that live in them.

Education, information and influence

In *Creating an Environmental Vision* (page 11, 2.12) the Environment Agency says "We recognise that we have many roles to play: we regulate, but we can also influence, persuade, educate and inform" and later (page 12, 2.18) "We will develop a strong approach to education, not just of the young but of those we regulate, and of the public itself. We will aim to spend more time on education and influencing than we have done in the past, in order to change understanding and behaviour. We aim to achieve more via this approach than can be achieved by imposing regulations upon those who intend to comply with them; our regulatory effort in the future will be concentrated upon those who do not intend to comply".

The exploitation of the RIVPACS programme for the development of educational tools aligns with the Environment Agency's aim to educate about environmental concerns, in this case the health of British rivers, in order to change perceptions and conduct.

Increased public awareness

In *Creating an Environmental Vision* (page 16), a long-term objective is stated as "People will have peace of mind from knowing that they live in a clean, safe, and diverse environment that they can use, appreciate, and enjoy. And therefore: people will be confident that the environment is well cared for, is not damaged by pollution, and does not provide a health risk because of human activities. The environment will be greatly valued and cared for by all sectors of society, as a source of income, recreation, sport, and wildlife conservation. Public awareness of local environmental matters will be high because of the ready availability of high quality local environmental information".

The educational packaging of RIVPACS through the proposed web site, and ancillary products, will supply knowledge of the environment, including local environmental information, and provide public access to that information. Through improved software with databases, information sheets, identification keys, opportunities for interaction, guidelines for fieldwork activities in local rivers, and analysis of the results, public awareness and understanding of both the local and wider freshwater environment can be increased. One of the ways in which the freshwater environment is cared for, through regular monitoring and assessment of its biological communities, will become more apparent and lead to confidence in the efforts to protect the quality of the aquatic environment.

Use of the Internet

The Environment Agency expresses the view (page 5, 1.5) that "The use of our internet site has played an important role in our strategy by providing national and regional information…"

The Agency therefore recognises that use of the Internet as a means of disseminating information is an efficient system. The suggestion that the Educational RIVPACS package might be best delivered via the World Wide Web is endorsed by this view.

Reliance on biological 'health'

In considering the improvement and protection of inland waters, the Agency (page 28) says "And we will place greater reliance on using information on biology, and the biological 'health' of our aquatic wildlife, to tell us where future improvements need to be made".

RIVPACS is the method used throughout the UK and Northern Ireland for determining the biological 'health' of our rivers. A RIVPACS educational package would be an excellent means of demonstrating to the general public the reasons why the monitoring of aquatic macroinvertebrates is so important to the determination of ecological quality.

3.6.2 Detailed educational strategies

In 1996 the Education Section of the Environment Agency set out its strategy in the *Framework Business Plan 1996-2001* (Version 4 October 1996). Under the heading *Background and Brief* it states that 'Education is accepted amongst informed opinion as being crucial to the delivery of an improved environment for future generations. The Agency has a duty to disseminate information about the environment …; the education strategy will contribute towards that environmental information being used by society at large in support of environmental improvement.'

The **mission** of the education strategy is: 'To initiate, advance and support environmental education, at a local, national and international level in order to develop and influence an environmentally conscious and responsible society.'
The **aims** of the strategy are:

- to promote greater understanding of the environment and environmental issues, through partnership;

- to educate society to protect and enhance the environment; and

- to improve the environmental behaviour and practice of specific stakeholder groups by the provision of relevant and timely information.

The mission and aims will be implemented via six **objectives** which target specific groups.

- To build partnerships through consultation, joint ventures and sponsorship and to enhance and protect the environment for future generations.
  The development of an educational package based on RIVPACS would result from a partnership between the Environment Agency, the Centre for Ecology and Hydrology, educational consultants and software designers. It would be a joint venture, involving sponsorship, that would promote knowledge of the freshwater environment and provide a means of monitoring, and therefore protecting, that environment for the future.

- To educate young people through teaching aids, educational materials and other initiatives to equip them to make informed judgements about future environmental decisions.
  The information, understanding, biological and technical expertise that would be imparted by the educational materials and activities designed around the RIVPACS programme would help to educate and equip young people to make knowledgeable decisions about environmental matters in the future.

- To enhance practitioner understanding of environmental issues, both inside and outside the Agency, through links with tertiary education, work placements/secondments and an awards scheme to achieve alignment with the Agency's aims.
  A simplified and user-friendly Windows version of RIVPACS would be the central feature of the educational package together with a wide range of ancillary products and information. These products could provide an elevated understanding of environmental issues concerning the freshwater environment amongst Environment Agency biologists, professional environmental consultants, research scientists, and prospective freshwater ecologists being trained in universities. Work placements, the Researchers in Residence and Crest Award schemes, jointly sponsored by the Natural Environment Research Council and the Environment Agency could be used as vehicles through which the RIVPACS package could promote the Agency's aims.

- To educate industry through consultation, collaborative activities and targeted campaigns to promote a culture of 'prevention' rather than 'cure'.
  A Windows version of RIVPACS could be made available for purchase by organisations whose own activities may influence river quality.

- To foster public awareness of environmental issues and concerns through publicity, media relations and campaigns, to engender in society a common ownership of the environment and its challenges.
  Not only the direct use of the RIVPACS educational package, but also the promotion of it (for example, through direct advertising, media involvement and conferences) could play a part in raising public awareness of environmental issues and change attitudes from passive to participative.

- To add the international/European dimension to environmental education through the Agency's existing remit and links to the European Environment Agency and by building on established international relationships, to contribute to the common goal of global sustainable development.
  The RIVPACS educational package could potentially provide an international and European dimension to environmental education in order to contribute to the common goal of sustainable development. RIVPACS has formed the basis of other techniques for assessing biological quality in fresh waters such as AUSRIVAS in Australia (Davies, 2000; Simpson & Norris, 2000; Humphrey, Storey and Thurtell, 2000) and BEAST – BEnthic Assessment of SedimenT - in Canada (Reynoldson, Day & Pascoe, 2000; Rosenberg, Reynoldson & Resh, 2000). Additionally, a current initiative is attempting to standardise macroinvertebrate sampling methods used in the European Union, to understand errors associated with each method, and integrate data from samples with other taxonomic groups, in order to provide a unified assessment of the Ecological Status of sites in accordance with the Water Framework Directive. This is attempting to integrate RIVPACS with other methods in Europe.

With particular regard to environmental education, the educational strategy specifies that environmental education should be seen as an ongoing activity concerned not only with passing on information but also with changing attitudes and raising awareness so that people can make value-based decisions on environmental matters. The target audience is not just children but also other identified important groups. Environmental education should involve additional methods to the provision of resource materials.

The proposed RIVPACS educational package could conform in all these areas.

The overall approach would be for every activity to be linked to one or more of the six objectives in the strategy while ongoing discussion with appropriate government departments and other environmental education providers will ensure that due regard is given to existing education strategies and policies. Likewise, curricular considerations will be paramount if the Agency decides to develop resource materials for schools/colleges.

The proposed RIVPACS educational package readily accords with the six objectives in the Environment Agency educational strategy, and it is a fundamental requirement of its development that it should pay heed to national education strategies and policies and curriculum objectives. Thus, the proposed RIVPACS educational package links well to the general and specific educational strategies of the Environment Agency.

3.6.3 Integration with existing Environment Agency educational material

A wide range of materials from leaflets and posters, to activity ideas generated in the different Environment Agency regions has been collated into a central educational resource database which is available to regional Environment Agency educational officers. Resource packs and data are also available through local area offices. A more recent innovation has been the development of the Agency's Education web site: http://www.environment-agency.gov.uk/ education/.

This provides resources for further and higher education, and for schoolteachers. The materials for further and higher education include case studies, simulations and role-play exercises to develop students' personal and interpersonal skills through team working, problem-solving, decision making and presenting in a way that integrates personal development into the normal academic curriculum. They also place academic learning into the work context using real scenarios. Each case study includes both student and tutor notes. Education resources for schoolteachers incorporate worksheets and activities for teachers of key stages 1, 2 and 3 including numeracy and literacy worksheets and follow-up activities; and Ripples and Stepping Stones worksheets which illustrate the activities of the Environment Agency (the information is complemented by suggested questions and activities). The Ripples worksheets for younger pupils cover the topics of the story of a river, droughts and floods, holding back the sea, pollution, conservation, river life. The Stepping Stones worksheets for older pupils cover such subjects as river flooding, coastal flooding, the water cycle, pollution, waste control, uses of the water environment, environmental management (including biological monitoring) and conservation. These resources can be downloaded for use in the classroom. There are also lists and summaries of a range of education resources, together with contact details, available to teachers.

The Activities page of the web site is designed not only to raise awareness of environmental issues but also to encourage students to get involved in practical activities. These activities include details of an aquatic invertebrate sampling kit and basic sampling methodology. Details of partnerships and awards, and interactive games are also provided.

In common with the Agency's education web site, one based on the RIVPACS programme could present related case materials, worksheets and activities all specifically keyed in to the requirements of the National Curriculum and examination specifications. However, it would concentrate on aspects related to the biological monitoring of rivers, and could present information in a wider range of formats, and address the needs of a much wider audience. Clearly, to fulfil all these needs it may be necessary to implement the package in stages.

3.7 Recommendations

This report demonstrates the considerable potential for the development of educational tools based on RIVPACS from primary, through secondary, to tertiary level.

'We recommend that the Environment Agency Education Unit considers the need for a full scoping study into the merits of developing educational tools based on RIVPACS'.

There is also an urgent need to develop a Windows version of RIVPACS, not only for use by the Environment Agency, but as the necessary precursor to the development of a variety of educational tools based on RIVPACS.

'We recommend early consultation between the Environment Agency and CEH Dorset with regard to the funding of a Windows version of RIVPACS and for clarification of future Intellectual Property Rights'.

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4. AN APPRAISAL OF RIVPACS FOR EVALUATING TROPHIC STRUCTURE BY R T CLARKE, J F WRIGHT AND J DAVY-BOWKER

4.1 Introduction

In its present form, RIVPACS offers a classification of running-water sites based on the *structure* of the macroinvertebrate communities at the component reference sites. More importantly, it provides a procedure for predicting the species to be expected at a new site with specified environmental features, if it is of high quality, (i.e. the *structure* of the expected community). This approach to biological surveillance, based on the characterisation of taxonomic richness and composition, represents a sensitive technique for the detection of alterations in aquatic ecosystems (Cairns and Pratt 1993). However, given that benthic invertebrates play an essential role in the food chain, productivity, nutrient cycling and in decomposition processes (Reice and Wohlenberg 1993), new insights may be available by considering the *functioning* of this diverse and complex assemblage of organisms.

The role of macroinvertebrates in stream ecosystem functioning has been considered in a review by Wallace and Webster (1996). They point out that benthic macroinvertebrates are critical to the maintenance of stream functional integrity and that they have evolved a diverse array of morphological and behavioural mechanisms for exploiting foods. Some years ago, a scheme was devised for allocating macroinvertebrates to a series of functional feeding groups (guilds) based on the morpho-behavioural mechanisms they use to acquire foods (Cummins and Klug 1979, Merritt and Cummins 1984). The groups include scrapers, shredders, gatherers, filterers and predators. It is important to recognise that these functional feeding groups refer primarily to modes of feeding or to food-acquisition systems and not to the type of food *per se*, as determined from gut analysis.

The ‘River Continuum Concept’ (Vannote, Minshall, Cummins, Sedell and Cushing, 1980) proposed progressive physico-chemical changes along the length of a river system and concurrent change in species composition along the system such that the local benthic communities are adapted to exploit the particular conditions and food resources available to them. More recently, there have been criticisms of this concept (Statzner and Higler, 1985) and also additional proposals such as the Serial Discontinuity Concept (Ward and Stanford, 1983). Although it is true that there are always discontinuities along river systems, nevertheless, rivers normally present a continuum of water flow from source to mouth. As a consequence many authors have attempted to detect progressive changes in the functional feeding groups along the length of river systems.

The RIVPACS reference sites provide a very substantial dataset on which to examine this idea. If meaningful Functional Feeding Group (FFG) patterns and trends can be detected across the range of high quality sites, this would improve our understanding of benthic communities in UK rivers. Such information would also provide a baseline against which to assess the FFGs reported from impacted sites. This approach would offer an alternative viewpoint from which to interpret the particular form of stress or stresses to which a site is exposed. The potential of RIVPACS to generate expected

FFG information for new sites would then enable indices or other tools based on community functioning to become a practical proposition. It is anticipated that any developments in this area would be based on family-level data, because this is the level at which log abundance data are available.

4.2 Objectives

The overall objective is as follows:

'To produce a scoping report on how RIVPACS could be modified to evaluate trophic structure'

The specific objectives are:

1. To identify the feeding guild of each family. Identify families where individual species or different life stages are likely to belong to different guilds. This will indicate whether the guilds to which taxa are assigned should be absolute or probabilistic, and depend on season or location. If preliminary investigations indicate that further work is necessary to identify the guilds of every species in RIVPACS, this work should be described and costed.

2. To assess the correlation of trophic structure with geology, river type, EQIs and other factors.

3. To evaluate the mechanisms by which information about trophic structure from RIVPACS could be used to evaluate ecological quality.

4. To evaluate the mechanisms by which information about trophic structure from RIVPACS could be used to provide information about the ecological structure of communities to assist with the understanding of invertebrate communities.

5. To identify the mechanisms in specific objectives 3 and 4 which have the greatest practical use as well as those whose integration into RIVPACS would involve the least effort.

6. To evaluate the mechanisms by which information about trophic structure from RIVPACS could be used to provide information for water management in the longer term.

7. To describe the means by which mechanisms identified in specific objective 6 should be incorporated into RIVPACS. Modifications to RIVPACS are to be described in detail and costed.

4.3 Literature Review

4.3.1 Development of the Functional Feeding Group approach

The functional feeding group approach was first proposed in North America by Cummins (1973) and was then developed and modified in later publications (Cummins and Klug 1979, Merritt and Cummins 1984). Cummins and Klug (1979) observed that almost all aquatic insects are omnivorous and therefore a single species can encapsulate different trophic levels such as detritivore, herbivore and carnivore. For example, any moderately sized invertebrate which eats autumn-shed leaves (a shredder) will also ingest associated fungi, bacteria, protozoa and microarthropods plus any algae on the leaf surface and even small macroinvertebrates such as first instar chironomid larvae. Hence, the trophic level approach (Lindeman, 1942) favoured by marine and terrestrial ecologists is less helpful to stream biologists interested in understanding the functioning of the system.

Instead, the functional feeding group approach is based on a limited set of morpho-behavioural feeding mechanisms found in freshwater macroinvertebrates and some basic food resource categories. The latter include (Cummins, 1974):

1.	Detritus	This can be coarse particulate organic matter (CPOM) or fine particulate organic matter (FPOM) and associated microbiota.
2.	Periphyton	Attached algae and associated material.
3.	Live macrophytes	
4.	Prey	

It appears that the mouthparts and associated feeding behaviour of many aquatic insects demonstrate convergent evolution, leading to functionally similar organisms where similar food resource categories are exploited.

The main functional feeding groups proposed by Merritt and Cummins (1984) are:

Shredders – organisms that feed on CPOM - primarily large pieces of decomposing plant tissue, living macrophytes or decomposing wood.

Scrapers (grazers) – animals adapted to graze or scrape periphyton, and associated microbiota from mineral and organic substrates.

Gatherers (collectors) – animals that feed primarily on FPOM deposited in streams.

Filterers (collectors) – animals with specialized anatomical structures or silk-like secretions that act as sieves to remove FPOM from the water column.

Predators – organisms that feed primarily on animal tissue by engulfing their prey.

Piercers –organisms that pierce and suck the body contents of animals or plants.

Note that piercers represent a minor category, not always recognised by other authors. For example, Wallace and Webster (1996) include the animal element of piercers within the predator category.

Merritt and Cummins (1984) argue that the functional feeding group approach provides an assessment, numerically or by standing crop biomass and more significantly by production, of the degree to which the invertebrate biota of a given aquatic system is dependant upon a particular food (nutritional) resource. It also makes more apparent the linkages that exist between food sources and insect morpho-behavioural adaptations.

More recently, Moog (1995) has used the functional feeding group (guild) approach within Europe. He has extended the range of feeding types to ten categories, partly by subdividing some existing groups. Most importantly, he has attempted to categorise the Austrian freshwater fauna into these ten categories on a proportional basis at each of species, genus and family level. Initially, a team of taxonomic specialists and field workers constructed a 'proposed' listing based on the literature, unpublished information, professional judgement and educated assumptions. The draft version was then widely circulated throughout Austria and Germany and criticisms and comments were discussed before the standardised list was agreed upon. However, Moog (1995) correctly emphasises that this procedure is not without its difficulties and that more research is needed to confirm and complete the categorisation process. Nevertheless, this information was regarded as the best currently available and in view of the need for unification of assessment methods and the sparse funding available for species-specific studies, this compromise was the only realistic solution.

4.3.2 Previous use of Functional Feeding Groups

The River Continuum Concept (RCC) developed by Vannote *et al* (1980) predicts changing food availability and utilisation along the longitudinal course of a river and therefore offers a practical test of the value of the Functional Feeding Group approach. Vannote *et al*. (1980) envisage progressive changes from the upper reaches of the system (stream orders 1-3) through the middle reaches (stream orders 4-6) to the lower reaches (stream orders 7 and upwards).

The upper reaches are normally expected to be subject to at least some shading by riparian vegetation including tree cover, resulting in high input of allochthonous material in the form of coarse particulate organic matter (CPOM) and consequently more limited autochthonous production in the form of algae and/or macrophytes. As a result, the shredders are expected to dominate the macroinvertebrate community, thereby generating fine particulate organic matter (FPOM) which is exploited further downstream.

In the middle reaches, as the stream widens, the influence of the riparian zone diminishes and autochthonous production increases. Hence, shredders can be expected to be less abundant, scrapers can exploit the increased algal production and collector gatherers and collector filterers utilise the FPOM generated upstream and within this zone.

Finally, in the lower reaches of large rivers, depositional conditions favour the collector gatherers and collector filterers. Throughout the system, predators can be expected to exploit all the available categories of prey organisms.

During the 1980s, a number of substantial studies took place in the USA and Canada that demonstrated longitudinal changes in FFGs and provided support for the River Continuum Concept. They included studies in Oregon (Hawkins and Sedell, 1981), Idaho (Bruns *et al*. 1982), four different biomes across the USA (Minshall *et al*. 1983), Florida (Scheiring, 1985) and also in Canada (Culp and Davies, 1982). More recently, a comprehensive study involving a first to seventh order river continuum in the southern Appalachian Mountains of the USA using FFGs generally supported the predictions of the RCC when based on production estimates (Grubaugh *et al*. 1997) and also when based on biomass estimates (Grubaugh *et al*. 1996). However, the use of habitat-weighted abundance estimates did not produce similar trends (Grubaugh *et al*. 1996). Within Europe, an investigation of functional feeding groups in Austrian rivers within the range of stream orders 1-4 (Schwingshandl, 1992) provided additional support for the predictions of the RCC.

Nevertheless, some studies have not supported the RCC. For example, Van-der-Velde and Van-den-Brink (1993) made a structural and functional analysis of the macroinvertebrate fauna along the entire length of the River Rhine. The relative contributions of the macroinvertebrate fauna to the various functional feeding groups was remarkably constant, with collectors dominating species composition in all river sections. In New Zealand, Ryder and Scott (1988) studied a series of twelve first to sixth order streams in the South Island to examine the longitudinal distribution of functional feeding groups. They concluded that the predictions of the River Continuum were not confirmed in some cases and that a world-wide evaluation of the RCC was needed because it may only apply to a limited set of rivers.

If reference sites do exhibit predictable patterns in the relative importance of their functional feeding groups along the length of river systems, then there may be potential for using functional feeding groups as indicators of biological quality. In practice, a large number of studies have already found that changes in the absolute or relative importance of FFG categories are useful methods of detecting an impact and that they have added value beyond the structural information present in a species list or statement on richness.

Upstream-downstream changes in FFGs were noted by Poulton *et al*. (1997) after an oil spill and by Camargo (1994) and also by Darschnik and Schumache (1987) as a result of the impact of fish farm effluents. Garcia de Jalon *et al*. (1994) observed changes in FFGs on a river by comparing the fauna prior to and after the construction of a reservoir, whilst Canton *et al*. (1984) also noted changes in FFGs as a result of a drought. Rabeni *et al*. (1985) observed structural and functional aspects of the benthic fauna over a period of seven years when large amounts of money were spent on cleaning up pulp and paper manufacture effluent. They also found that the relative abundances of the FFGs changed and that functional analyses were valuable. Finally, Chung *et al*. (1993) used both control and experimental streams to monitor the initial impact of an insecticide on the macroinvertebrate fauna and the subsequent recovery process, using FFG categories.

However, it would be incorrect to assume that all studies came to a positive conclusion on the value of FFGs. For example, Quinn and Hickey (1993) examined the ecological impact of the discharge of domestic sewage effluent to streams in New Zealand. Benthic invertebrates were compared upstream and downstream of discharges to eight streams. No general relationships were found between relative densities of functional feeding groups and water quality variables. They took the view that early warning of enrichment is more easily seen at the species level than at the functional level.

There have also been some more fundamental criticisms levelled at the use of FFGs. A major concern has been that it may be difficult to assign a single FFG to a macroinvertebrate taxon because diet may change with life stage and/or size of taxon, with season, or due to spatial variation in food availability (King *et al*. 1988). There are ways of taking some account of this criticism (see next section), but when using large datasets with many taxa, it is inevitable that some broad generalisations will be made.

Recently, there has also been further debate on the meaning of FFG results and the extent to which they are genuinely capable of providing information on the 'functioning' of the system. Palmer, O'Keeffe and Palmer (1993) discuss this topic and ask the question: What are the functions in streams which the feeding activities of macroinvertebrates facilitate? They conclude that shredders facilitate organic matter particle size reduction and mobilisation and the enhancement of substrates for microbial colonisation. In contrast, filterers convert fine particulate organic matter to biomass and faeces, thus increasing organic particle size and retaining organic matter. Collectors feed on and excrete fine particles, again leading to retention and enhancement of substrates for microbial activities.

Mihuc (1997) levels more fundamental criticisms. He emphasises that Cummins (1973) originally stated that a functional feeding group denotes a hypothetical particle size range ingested or mode of feeding, and *not a food type or resource assimilated*. The FFG concept is valid in that it allows grouping of a complex benthic community into components based on particle size ingested and mouthpart morphology. Thus FFGs should be useful when describing the mode of feeding or food acquisition and the role of invertebrates in processing of food by particle size. However, Mihuc (1997) points out that some authors have used FFG assignments to infer *assimilation of resources* and have assumed a strong correspondence between FFGs and trophic role. In other words, they have assumed that shredders are essentially detritivores and scrapers are herbivores. Mihuc (1997) also emphasizes the difficulty of grouping taxa into single FFGs and therefore queries whether FFG assignments can accurately describe the process of energy flow and material transfer between trophic levels in stream ecosystems.

In view of these criticisms, it may be argued that the use of the term 'trophic structure' in the title of this chapter and within the stated objectives is overstating what can be achieved through the use of the Functional Feeding Group approach. Nevertheless, as recognised above, the approach is still a useful way of viewing the range of feeding activities utilised by the benthic fauna and the consequences of these activities for the communities further downstream.

4.4 Assignment of RIVPACS Families to Functional Feeding Groups

From the outset, it was clear that practical considerations would dictate that assignment of taxa to functional feeding groups would need to be at family rather than at generic or species level. This was because the RIVPACS sampling protocol is based on timed pond-net collections and not on a quantitative sampling regime. For each site, qualitative listings of taxa are then derived, typically at the species/generic level (Wright *et al*. 1996). In view of the observation that there were often substantial differences in the abundance of given taxa at different sites, log abundance categories were assigned to encapsulate these differences. However, this could only be done at the family level, where taxa were easily distinguished by eye. To attempt the same exercise at species/generic level was always recognised as unrealistic, given the need for microscopic examination of many specimens. When considering the functional role of macroinvertebrates in running waters it is essential to take account of the abundance (or preferably the biomass or production) of taxa and hence the available data dictated that this assessment would have to be at family level.

The assignment of each RIVPACS family to one or more functional feeding groups was an iterative process which utilised existing information held within our research group, together with the major publications of Merritt and Cummins (1984) and Moog (1995) and some recent publications to fill in remaining gaps.

Initially, a series of independent lists were developed. The first was our own research group list of RIVPACS families in which an attempt was made to assign each family to one of five functional feeding group categories (shredders, scrapers, gatherers, filterers, predators). In cases where more than one functional feeding group category was believed to be important this was flagged. Second, we tabulated the Merritt and Cummins (1984) assignments, which only apply to insects. Here, the predators (engulfers) are separated from piercers. In the Merritt and Cummins (1984) system, a given family is sometimes assigned to two or more functional feeding groups.

Next, we listed the Moog (1995) assignments (with some modifications, see below) derived from his classification of functional feeding groups at the family/generic level. As previously indicated, Moog (1995) derived ten separate categories, but we have chosen to reduce these to the original five major groupings for the purposes of this analysis. This is because two categories are easily merged and the remaining four are very minor categories within our dataset. Hence, they do not warrant separate consideration in the current exploratory analyses in which we are looking for general patterns. As a result:

‘Active’ and ‘passive’ filterers have been combined as filterers
Leaf borers, miners - of minor significance in our dataset
Xylophagous taxa (consumers of woody debris) have been reallocated to shredders
Parasites have been reallocated to predators
Other feeding types –not classified by Moog (1995).

Moog (1995) reiterated that few species are obligate feeders on a specific food resource and that diet may change with developmental stage. Hence, he attempted to encapsulate current knowledge at the family/generic level by offering a probabilistic view of the functional feeding groups. If a taxon was a predator and ate nothing else it was assigned a value of 10 in the predator category. However, if it exploited the scraper and gatherer roles in equal measure, it was assigned 5 points in each category.

In attempting to apply the information in Moog (1995) to the RIVPACS families, the generic level values (out of 10) for *the genera present in the UK* were examined and collated in order to generate new values *with the greatest relevance to family-level data within the UK*. This offers the best available source of information at present and, with only minor additions to complete some gaps, has been used in the analyses that follow.

The full listing of all RIVPACS III+ families with their functional feeding groups on a proportional basis is given in Table 4.1. This is subsequently referred to as method 'Prop'. The same table also proposes for each family the 'dominant' functional feeding group (Method 'Dom'). This was derived from the probabilities in Table 4.1 with further consideration of those families with co-dominant functional feeding groups in order to assign a single dominant.

Table 4.1: Assignment of all families within RIVPACS III+ to their functional feeding group. Families are assigned probabilistically (out of 10) to one or more groups. The dominant functional feeding group is also assigned (see text for explanation).

RIVPACS family code	BMWP Score	Functional feeding group probability (x10)					Dominant group	Family name
		1	2	3	4	5		
		Shredders	Scrapers	Gatherers	Filterers	Predators		
02110000	0	0	0	0	10	0	4	Spongillidae
03110000	0	0	0	0	0	10	5	Hydridae
051Z0000	5	0	0	0	0	10	5	Planariidae
05130000	5	0	0	0	0	10	5	Dendrocoelidae
09120000	0	0	0	0	0	10	5	Chordodidae
14000000	0	0	0	0	10	0	4	Ectoprocta
16110000	6	0	10	0	0	0	2	Neritidae
16120000	6	0	7	0	3	0	2	Viviparidae
16130000	3	0	2	6	2	0	3	Valvatidae
161Z0000	3	3	3	4	0	0	3	Hydrobiidae
16210000	3	3	7	0	0	0	2	Physidae
16220000	3	5	5	0	0	0	2	Lymnaeidae
16230000	3	3	7	0	0	0	2	Planorbidae
162Z0000	6	0	10	0	0	0	2	Ancylidae
17110000	0	0	0	0	10	0	4	Margaritiferidae
17120000	6	0	0	0	10	0	4	Unionidae
17130000	3	0	0	0	10	0	4	Sphaeriidae
17140000	0	0	0	0	10	0	4	Dreissenidae
19110000	0	0	0	10	0	0	3	Aeolosomatidae
20110000	1	0	0	10	0	0	3	Lumbriculidae
20210000	1	0	0	10	0	0	3	Haplotaxidae
20310000	1	0	0	10	0	0	3	Enchytraeidae
20330000	1	0	5	5	0	0	2	Naididae
20340000	1	0	0	10	0	0	3	Tubificidae
20420000	1	0	0	10	0	0	3	Lumbricidae
22110000	4	0	0	0	0	10	5	Piscicolidae
22120000	3	0	0	0	0	10	5	Glossiphoniidae
22210000	3	0	0	0	0	10	5	Hirudinidae
22310000	3	0	0	0	0	10	5	Erpobdellidae
24000000	0	0	0	0	0	10	5	Hydracarina
32010000	0	0	0	0	0	10	5	Argulidae
34310000	8	0	0	5	0	5	3	Astacidae
36110000	3	3	3	4	0	0	3	Asellidae
37110000	6	0	0	0	10	0	4	Corophiidae
371Z0000	6	7	1	1	0	1	1	Gammaridae
40110000	10	0	0	10	0	0	3	Siphlonuridae
40120000	4	0	5	5	0	0	2	Baetidae
40130000	10	0	5	5	0	0	2	Heptageniidae
40210000	10	0	0	10	0	0	3	Leptophlebiidae
40310000	10	0	0	9	1	0	3	Potamanthidae
40320000	10	0	0	0	10	0	4	Ephemeridae
40410000	10	0	5	5	0	0	3	Ephemerellidae
40510000	7	0	0	10	0	0	3	Caenidae
41110000	10	1	5	4	0	0	2	Taeniopterygidae
41120000	7	4	3	3	0	0	1	Nemouridae
41130000	10	3	3	4	0	0	3	Leuctridae

Table 4.1: (continued)

Table 4.1: (continued)

RIVPACS family code	BMWP Score	Functional feeding group probability (x10) 1 Shredders	2 Scrapers	3 Gatherers	4 Filterers	5 Predators	Dominant group	Family name
41140000	10	6	2	2	0	0	1	Capniidae
41210000	10	0	2	0	0	8	5	Perlodidae
41220000	10	0	1	0	0	9	5	Perlidae
41230000	10	1	1	2	0	6	5	Chloroperlidae
42110000	6	0	0	0	0	10	5	Platycnemididae
42120000	6	0	0	0	0	10	5	Coenagriidae
42130000	8	0	0	0	0	10	5	Lestidae
42140000	8	0	0	0	0	10	5	Calopterygidae
42210000	8	0	0	0	0	10	5	Gomphidae
42220000	8	0	0	0	0	10	5	Cordulegasteridae
42230000	8	0	0	0	0	10	5	Aeshnidae
42240000	8	0	0	0	0	10	5	Corduliidae
42250000	8	0	0	0	0	10	5	Libellulidae
43110000	5	0	0	0	0	10	5	Mesovelidae
43210000	5	0	0	0	0	10	5	Hydrometridae
43220000	0	0	0	0	0	10	5	Veliidae
43230000	5	0	0	0	0	10	5	Gerridae
43310000	5	0	0	0	0	10	5	Nepidae
43410000	5	0	0	0	0	10	5	Naucoridae
43420000	10	0	0	0	0	10	5	Aphelocheiridae
43510000	5	0	0	0	0	10	5	Notonectidae
43520000	5	0	0	0	0	10	5	Pleidae
43610000	5	0	4	4	0	2	3	Corixidae
45110000	5	0	6	2	0	2	2	Haliplidae
45120000	5	0	0	0	0	10	5	Hygrobiidae
451Z0000	5	0	0	0	0	10	5	Dytiscidae
45150000	5	0	0	0	0	10	5	Gyrinidae
453Z0000	5	2	4	3	0	1	2	Hydrophilidae
45510000	5	0	0	10	0	0	3	Scirtidae
45620000	5	0	5	5	0	0	2	Dryopidae
45630000	5	0	10	0	0	0	2	Elmidae
46110000	4	0	0	0	0	10	5	Sialidae
47110000	0	0	0	0	0	10	5	Osmylidae
47120000	0	0	0	0	0	10	5	Sisyridae
481Z0000	7	0	4	1	0	5	5	Rhyacophilidae
48130000	6	0	10	0	0	0	2	Hydroptilidae
48210000	8	0	0	0	10	0	4	Philopotamidae
482Z0000	8	0	8	1	1	0	2	Psychomyiidae
48240000	7	0	0	0	1	9	5	Polycentropodidae
48250000	5	0	2	0	5	3	4	Hydropsychidae
48310000	10	2	1	1	0	6	5	Phyrganeidae
48320000	10	0	2	0	5	3	4	Brachycentridae
48330000	10	5	5	0	0	0	1	Lepidostomatidae
48340000	7	5	2	1	0	2	1	Limnephilidae
48350000	10	0	9	1	0	0	2	Goeridae
48360000	10	0	10	0	0	0	2	Beraeidae
48370000	10	10	0	0	0	0	1	Sericostomatidae
48380000	10	3	3	4	0	0	3	Odontoceridae
48390000	10	0	0	3	0	7	5	Molannidae
48410000	10	5	2	1	0	2	1	Leptoceridae
49110000	0	5	5	0	0	0	1	Pyralidae

RIVPACS family code	BMWP Score	Functional feeding group probability (x10)					Dominant group	Family name
		1	2	3	4	5		
		Shredders	Scrapers	Gatherers	Filterers	Predators		
50100000	5	2	0	4	0	4	5	Tipulidae
50210000	0	0	5	5	0	0	3	Psychodidae
50220000	0	5	0	5	0	0	3	Ptychopteridae
50310000	0	0	0	3	7	0	4	Dixidae
50320000	0	0	0	0	0	10	5	Chaoboridae
50330000	0	0	10	0	0	0	2	Culicidae
50340000	0	0	10	0	0	0	2	Thaumaleidae
50350000	0	0	0	0	0	10	5	Ceratopogonidae
50360000	5	0	0	0	10	0	4	Simuliidae
50420000	2	0	0	1	0	9	5	Tanypodinae
50440000	2	0	8	1	0	1	2	Diamesinae
50450000	2	0	0	8	2	0	3	Prodiamesinae
50460000	2	0	5	5	0	0	3	Orthocladiinae
50470000	2	0	2	5	2	1	3	Chironomini
50490000	2	0	2	4	4	0	3	Tanytarsini
50610000	0	3	3	3	1	0	3	Stratiomyidae
50620000	0	0	0	0	0	10	5	Rhagionidae
50630000	0	0	0	0	0	10	5	Tabanidae
50710000	0	0	0	5	0	5	5	Empididae
50720000	0	0	0	0	0	10	5	Dolichopodidae
50810000	0	0	0	10	0	0	3	Syrphidae
50820000	0	0	0	0	0	10	5	Sciomyzidae
50830000	0	2	4	2	0	2	2	Ephydridae
50850000	0	0	0	0	0	10	5	Muscidae
20000000	1	0	1	9	0	0	3	Oligochaeta
50400000	2	0	3	5	1	1	3	Chironomidae

4.5 Calculating the Observed and Expected Relative Abundance of Functional Feeding Groups

4.5.1 Use of log abundance categories

All previous RIVPACS analyses involving the use of taxon abundances have been based on the RIVPACS log abundance categories, (i.e. 0 = absent, 1=1-9 individuals, 2=10-99, 3=100-999, 4=1000-9999, 5=10000+) rather than back-transformed estimates of the raw abundances or, where available, the recorded raw abundances (Clarke *et al.* 1997, Clarke and Wright 2000). This was done for several reasons. In most cases the raw abundances were not readily available and there is considerable subjectivity in estimating the abundances from the RIVPACS integer log categories. More importantly, it was felt that the relative or proportional abundance of all taxa in a sample should not be dominated by the abundance of any one very common family. This is a frequent approach in scientific ecological studies. The influence of the most common taxa is down-weighted by transforming the abundances and working with the square roots or the logarithms of the raw abundances or abundance densities. In studies of marine fauna community composition using multivariate clustering and ordination techniques, the double square root ($\sqrt{\sqrt{x}}$) transformation of all abundance or biomass data is recommended and often used (Clarke and Green 1988, Clarke, 1993). Clarke and Warwick (1994) from the Plymouth Marine Laboratory comment that this double square root transformation gives very similar results to using logarithms and that both transformations focus attention on the whole community structure, mixing contributions from both common and rare species. We have continued with this general approach and assessments of the relative abundance of the various functional feeding groups have been based on summing the log abundance categories. This prevents a few very numerous taxa, such as Chironomidae and Oligochaeta, from dominating the assessment.

4.5.2 Methods of calculating observed and expected abundance of each group

The observed total log abundance of a functional feeding group (FFG) at a site was calculated as follows:

For method Dom: sum the observed log abundance categories of all families for which the FFG in question is the dominant group; and

For method Prop: for each family multiply its observed log abundance category by its probability of belonging to the FFG and sum the products across all families.

RIVPACS calculates the expected log abundance value for a particular family at a test site as a weighted average of the observed log abundance categories for that family at all environmentally similar RIVPACS reference sites (with site weightings proportional to the environmental similarity to the test site). Unlike the observed log abundance categories, the expected log abundance values are not generally integer numbers. The expected total log abundance of a FFG at a site was calculated as follows:

For method Dom: sum the expected log abundance value of all families for which the FFG in question is the dominant group; and

For method Prop: for each family multiply its expected log abundance category by its probability of belonging to the FFG and sum the products across all families.

This calculation is most naturally performed using all macroinvertebrate families, because all families contribute to the functioning of the system. However, it is common to only record the presence and abundance of BMWP scoring families (Table 4.1). There are therefore four possible methods for calculating the relative abundance of each functional feeding group: using the dominant (Dom) or proportional (Prop) assignment of families to groups and using all or just the BMWP scoring families. Figure 4.1 and Table 4.2 assess the effect of using the four different methods by plotting the values and calculating the correlations between the estimates of the relative abundance of a functional feeding group for any two methods for the 614 RIVPACS reference sites.

Table 4.2: Correlations between the four different methods of calculating the percentage of the sum of the observed log abundances in each functional feeding group for the 614 RIVPACS Reference sites. The four methods are denoted by a combination of F/M defined as: F= Families used (i.e. All families or just BMWP families); M= Method of assigning families to feeding group (i.e. Proportional or using Dominant group)

Methods correlated		Shredders	Scrapers	Gatherers	Filterers	Predators
F/M	F/M					
All/Prop	All/Dom	0.83	0.84	0.58	0.88	0.89
All/Prop	BMWP/Prop	0.97	0.92	0.84	0.97	0.95
All/Prop	BMWP/Dom	0.80	0.78	0.45	0.90	0.81
All/Dom	BMWP/Prop	0.80	0.76	0.43	0.92	0.84
All/Dom	BMWP/Dom	0.99	0.92	0.86	0.98	0.94
BMWP/Prop	BMWP/Dom	0.81	0.83	0.54	0.94	0.88

It appears to make very little difference whether all families or just the BMWP scoring families are used as the two sets of estimates are very highly correlated for each functional feeding group, irrespective of the method (Proportional or Dominant) of assigning families to FFGs. The lowest correlations and hence the greatest discrepancies between the four methods occurs for gatherers (Table 4.2). The reasons were not initially obvious, but appear to be due to the fact that of the large number of families which are at least partly classified as gatherers, a high percentage are assigned as 0.4-0.5 gatherers, but are not necessarily treated as being dominated by gatherers (Table 4.3). Table 4.4 gives a real example illustrating the potentially large discrepancy between using Proportional and Dominant assignment to FFGs. In contrast to gatherers, of the 64 families which were classed as at least partly predators, 50 were classed as being dominated by predators. This explains why using the Dom and Prop methods give similar relative abundances for the predators FFG and their correlations are all high (Table 4.2, Figure 4.1(e)).

This is not a criticism of the particular choice of assigning families to FFGs, but merely shows the potential for differences between the Dom and Prop methods. Moreover, the weight of published literature suggests that it is more realistic and robust to proportionally assign each family to the FFGs rather than commit a family to be in just one FFG when it is known that its component species and/or their life stages belong to different FFGs.

The remainder of our analyses will therefore be based on using the proportional (Prop) method of assigning families to FFGs as specified in Table 4.1.

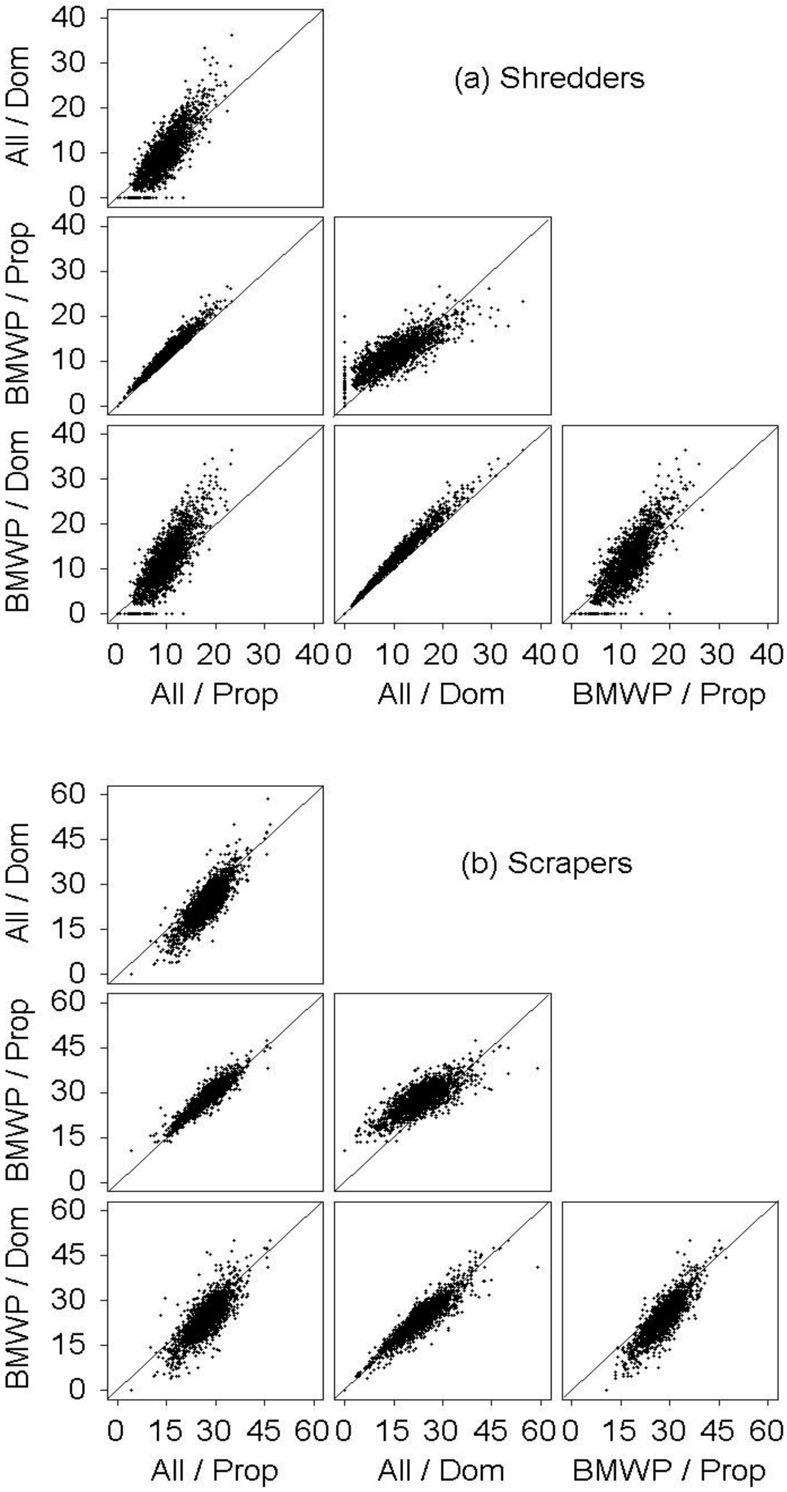
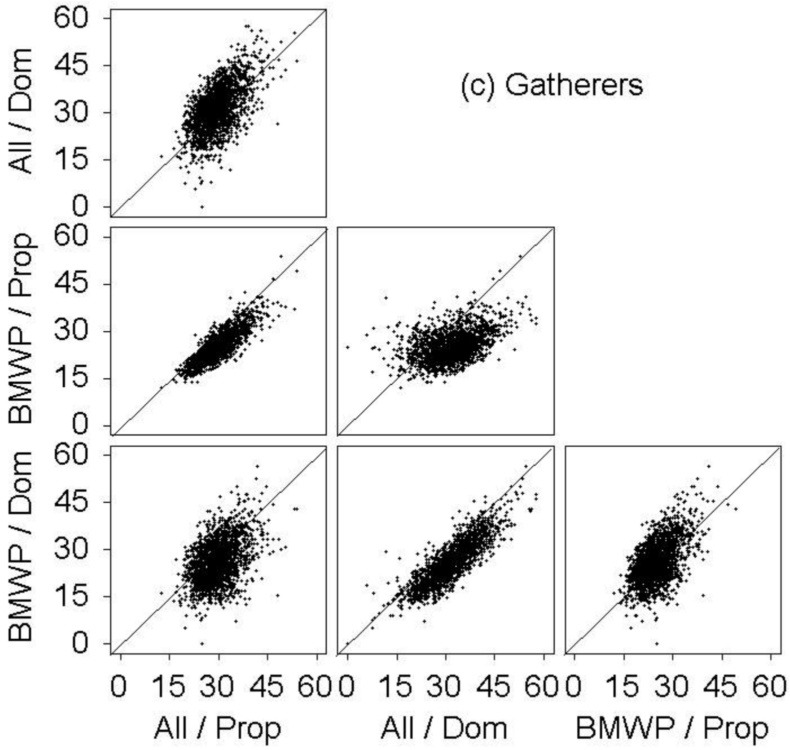


Figure 4.1: Comparison of the four different methods of calculating the percentage of the sum of the observed log abundances in each functional feeding groups for the 614 RIVPACS Reference sites. The four methods are denoted by a combination of F/M defined as: F= Families used (i.e. <u>All</u> families or just <u>BMWP</u> families); M= Method of assigning families to feeding group (i.e. <u>Prop</u>ortional or using <u>Dom</u>inant group)



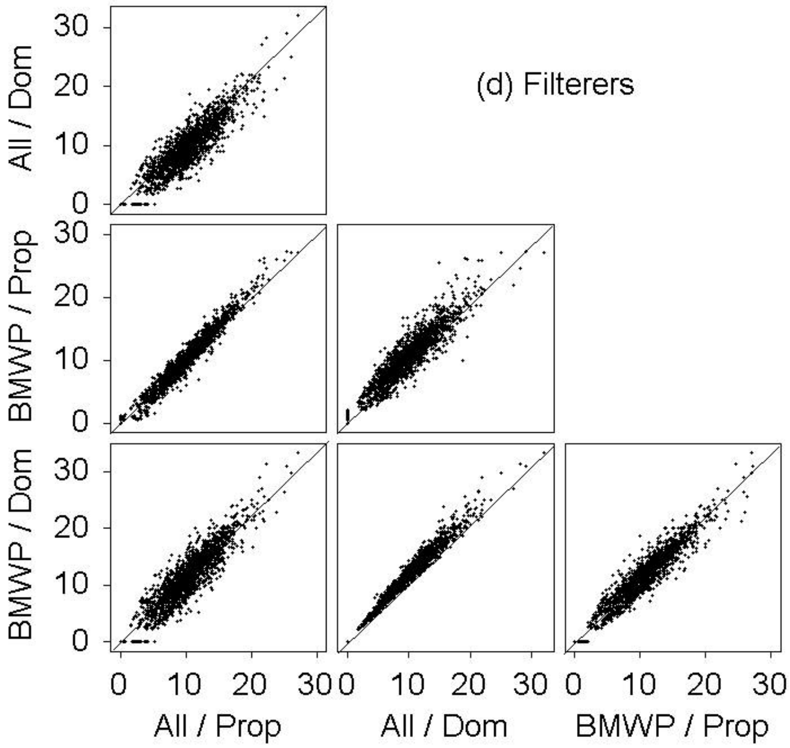


Figure 4.1: (continued)

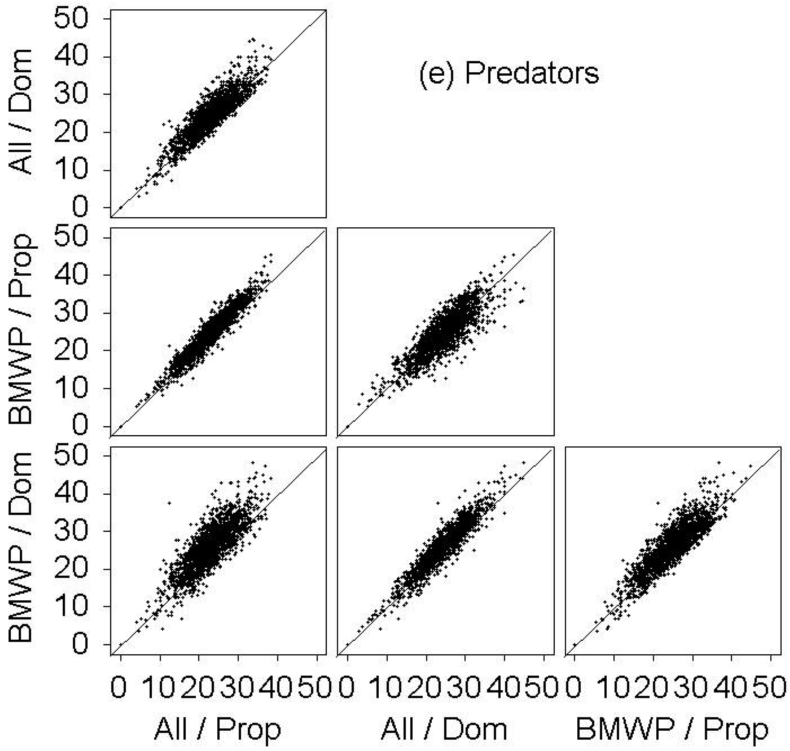


Figure 4.1: (continued)

Table 4.3: Comparison of the effects of assigning families to functional feeding groups as either the single most dominant group or probabilistically.

	Functional Feeding Group (FFG)				
	Shredders	Scrapers	Gatherers	Filterers	Predators
Number of families for which FFG was dominant	8	22	29	13	51
Sum of probabilities of belonging to FFG	8.8	23.7	26.6	13.5	50.4
Number of families with non-zero assignment to FFG	23	50	53	23	64
Percentage of families with non-zero assignment to FFG with proportional assignment of 0.4-0.5	30%	30%	38%	13%	6%

Table 4.4: Comparison of estimated percentage abundance of each functional feeding group (FFG) using either Dominant (Dom) or Proportional (Prop) method of assigning families to groups using an autumn sample from a RIVPACS reference site.

Family		Log Abudance Category	Dominant FFG	Functional Feeding Group Probability (x10)				
				1	2	3	4	5
Code	Name			Shredders	Scrapers	Gatherers	Filterers	Predators
4012	Baetidae	1	2	0	5	5	0	0
4013	Heptageniidae	2	2	0	5	5	0	0
4112	Nemouridae	1	1	4	3	3	0	0
4121	Perlodidae	1	5	0	2	0	0	8
4122	Perlidae	1	5	0	1	0	0	9
4123	Chloroperlidae	1	5	1	1	2	0	6
4563	Elmidae	1	2	0	10	0	0	0
481Z	Rhyacophilidae	1	5	0	4	1	0	5
5010	Tipulidae	1	5	2	0	4	0	4
Percentage abundance of each FFG			Dom	10%	40%	0%	0%	50%
estimated using method:			Prop	7%	36%	25%	0%	32%

4.6 Abundance of Each Functional Feeding Group for the RIVPACS Reference Sites in Relation to Site Characteristics

The initial analyses were based on the 614 RIVPACS III reference sites for Great Britain and were conducted on each of the data-sets for spring, summer and autumn.

4.6.1 Relationships with TWINSPAN group, distance from source and alkalinity

The total log abundances summed over all families showed large and statistically significant ($p<0.001$) differences between the 35 RIVPACS biological site groups (Figure 4.2). The 35 TWINSPAN groups were subdivided into four major TWINSPAN subgroups to assess differences in FFG patterns between the main types of biological community and site type. Total abundances tended to be lowest in small and/or upland streams and highest in large and/or lowland rivers (Table 4.5). It was therefore not particularly surprising that the total log abundances of each FFG also showed the same general pattern, being highest in large lowland sites (Table 4.5). The patterns in terms of average total log abundances were similar in all three seasons. However, summer samples had the highest total log abundance summed over all families and the highest total log abundances for each FFG except for shredders. Shredders were marginally more abundant overall in autumn samples, probably because sampling followed leaf fall in some of the sites (Table 4.5).

The changing importance of the FFGs downstream was examined by grouping the reference sites into a series of distance downstream categories. These categories were defined using the same approach as that used in previous analyses of environmental patterns of the biological condition of the 1995 GQA sites (Clarke *et al*. 1999; Davy-Bowker *et al*. 2000). The distance categories were chosen so that roughly 20% of all sites fell into each category but with the most downstream category being subdivided to separate off the 3% of sites which were furthest from source (Table 4.6). Sites within 5km of their source had about 20% fewer individuals in total than sites further

downstream. Moreover, all the FFGs except shredders had, on average, fewer individuals in sites near their source (Table 4.6). Shredders were least abundant in the sites over 84 km from their source.
In-stream alkalinity is measured or estimated for every RIVPACS site and can used as a surrogate to represent some aspects of differences in upstream catchment geology. Sites with very low alkalinity (<23 mg l^{-1} $CaCO_3$) had fewer individuals of each of the five FFGs than sites with any other class of alkalinity; this was a clear pattern in each season (Table 4.7).

The above analyses based on summing the log abundances for each FFG suggest that the total number of macroinvertebrates is less in headwater streams, highest in lowland rivers and varies with stream type. The aim of this section is to assess whether and how the "trophic structure" of the macroinvertebrate community varies with river type. In other words, does the relative abundance of the FFGs vary with stream type. Therefore, all subsequent analyses were based on the relative abundance of each FFG. In particular, the relative abundance of, for example, shredders is defined as the sum of the log abundance categories attributable to shredders as a percentage of the sum of log abundance categories of all families.

The mean relative abundances of the FFGs (as defined above), averaged over all the types of RIVPACS reference site were 10% shredders, 27% scrapers, 30% gatherers, 10% filterers and 23% predators; these average percentages were approximately the same regardless of season (Table 4.8).

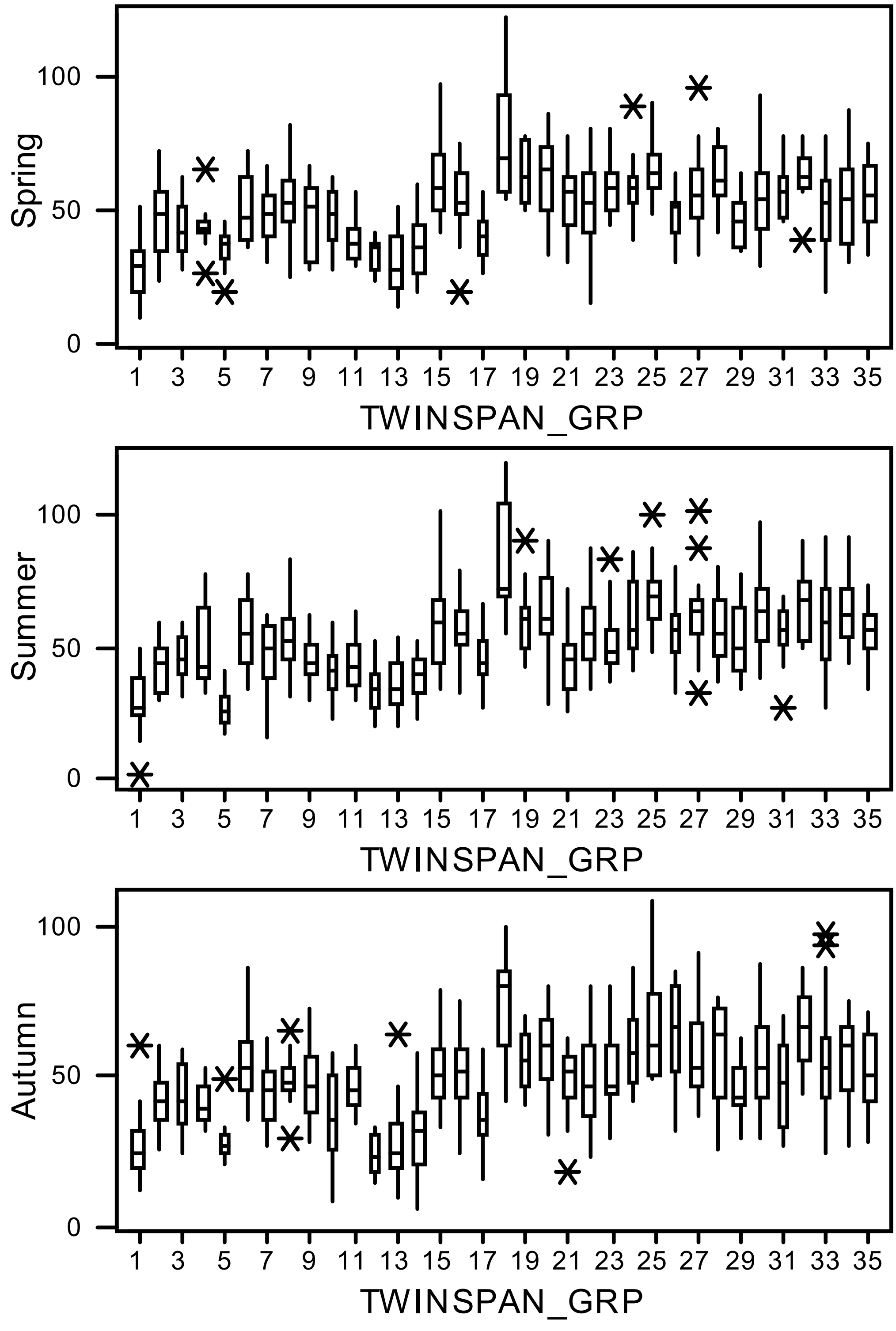


Figure 4.2: **Boxplot of the sum of the log abundances of all families for the 614 RIVPACS references sites, classified according to their TWINSPAN site group (1-35). Results are given separately for each season. [Boxplot interpretation: box denotes range of middle half of data values (25-75 percentile values); middle line denotes median (i.e. 50 percentile); outer lines denote range of values except for outliers which are marked individually by a *].**

Table 4.5: Average sum of the observed log abundances of (a) all families (b) shredders (c) scrapers (d) gatherers (e) filterers and (f) predators for the 614 RIVPACS reference sites, classified by TWINSPAN site group. Results are given separately for each season and also averaged across seasons. Site groups: 1-9 = "small streams"; 10-17 = "upland streams"; 18-24 = "intermediate streams and rivers"; 25-35 = "lowland streams and rivers".

	TWINSPAN site groups				Overall
	1-9	10-17	18-24	25-35	
(a) all families					
Spring	41.8	42.5	59.1	55.4	49.8
Summer	42.4	44.3	58.1	60.1	51.5
Autumn	40.2	37.9	54.9	56.5	47.6
Overall	41.5	41.6	57.4	57.3	49.6
(b) shredders					
Spring	4.9	4.0	5.6	5.4	5.0
Summer	4.4	3.5	5.4	5.8	4.8
Autumn	4.9	3.9	5.7	5.7	5.1
Overall	4.7	3.8	5.6	5.6	5.0
(c) scrapers					
Spring	10.7	12.3	15.7	14.1	13.2
Summer	10.7	12.8	15.9	16.0	13.9
Autumn	10.1	11.2	15.0	14.5	12.8
Overall	10.5	12.1	15.5	14.9	13.3
(d) gatherers					
Spring	12.7	13.3	18.2	15.7	14.9
Summer	13.3	13.9	16.9	16.3	15.1
Autumn	12.3	11.6	15.5	14.8	13.5
Overall	12.8	12.9	16.9	15.6	14.5
(e) filterers					
Spring	4.1	3.6	6.0	6.5	5.1
Summer	4.9	4.2	6.7	6.9	5.7
Autumn	4.2	3.0	6.1	6.8	5.1
Overall	4.4	3.6	6.2	6.7	5.3
(f) predators					
Spring	9.3	9.4	13.6	13.7	11.6
Summer	9.1	9.8	13.2	15.2	12.0
Autumn	8.7	8.2	12.7	14.6	11.2
Overall	9.1	9.1	13.1	14.5	11.6

There were highly statistically significant differences between TWINSPAN groups (all $p<0.001$) in the percentage abundance of each of the five FFGs (Figure 4.3). This shows that the relative abundance of the FFGs definitely changes with the environmental characteristics of river sites. Classifying the sites into their four major TWINSPAN groups, re-enforced the conclusion that large lowland rivers have a slightly lower proportion of shredders and a higher proportion of filterers and predators (Table 4.8, Figure 4.4).

Table 4.6: Average sum of the observed log abundances of (a) all families, (b) shredders, (c) scrapers, (d) gatherers, (e) filterers and (f) predators for the 614 RIVPACS reference sites, classified by their distance from source (km). Results are given separately for each season and averaged across seasons.

	Distance from Source (km)						
	<5	5-11.9	12-22.9	23-40.9	41-84	85-203	Overall
n =	108	132	129	121	102	22	614
(a) all families							
Spring	42.8	50.0	53.3	51.8	51.1	44.4	49.8
Summer	43.3	51.3	55.8	51.7	54.6	52.4	51.5
Autumn	40.2	46.9	50.0	49.8	50.0	50.7	47.6
Overall	42.1	49.4	53.0	51.1	51.9	49.2	49.6
(b) shredders							
Spring	5.1	5.4	5.3	4.8	4.5	3.2	5.0
Summer	4.6	4.9	5.2	4.6	4.8	4.2	4.8
Autumn	5.0	5.1	5.2	5.1	4.9	4.5	5.1
Overall	4.9	5.1	5.2	4.8	4.7	4.0	4.9
(c) scrapers							
Spring	10.7	13.3	14.4	14.0	13.7	11.4	13.2
Summer	10.9	13.7	15.2	14.3	15.3	14.2	13.9
Autumn	9.9	12.5	13.6	13.7	13.8	13.4	12.8
Overall	10.5	13.1	14.4	14.0	14.3	13.0	13.3
(d) gatherers							
Spring	12.7	14.9	16.1	15.9	15.1	13.7	15.0
Summer	13.2	15.2	16.3	15.0	15.8	14.8	15.1
Autumn	11.8	13.6	14.3	13.9	13.7	13.8	13.5
Overall	12.6	14.6	15.6	14.9	14.9	14.1	14.5
(e) filterers							
Spring	4.3	5.1	5.3	5.2	5.4	6.0	5.1
Summer	5.0	5.6	6.1	5.7	5.8	7.2	5.7
Autumn	4.5	4.9	5.3	5.2	5.3	6.6	5.1
Overall	4.6	5.2	5.5	5.4	5.5	6.6	5.3
(f) predators							
Spring	10.0	11.3	12.3	12.0	12.4	10.2	11.6
Summer	9.6	11.8	13.1	12.0	13.0	12.0	11.9
Autumn	9.0	10.8	11.5	11.8	12.3	12.4	11.2
Overall	9.5	11.3	12.3	11.9	12.6	11.5	11.6

The basic patterns to emerge in relation to distance downstream, based on the mean relative abundance of the five different categories were as anticipated from the River Continuum Concept (Table 4.9, Figure 4.5). In each season, shredders had their highest relative abundance in headwater streams (i.e. <5 km from their source) and formed the lowest percentage of the total abundance in the sites furthest from source (i.e. >84 km). The relative abundance of scrapers, although not varying much with distance downstream, did peak at intermediate distances, as predicted by the RCC. Filterers were relatively most abundant in the sites furthest from source, which would tend to be large lowland rivers (Table 4.9). The relative abundance of gatherers showed no consistent trend with distance from source. Predators formed a slightly lower percentage of total log abundance in headwaters streams (Figure 4.5).

Table 4.7: Average sum of the observed log abundances of (a) all families (b) shredders (c) scrapers (d) gatherers (e) filterers and (f) predators for the 614 RIVPACS reference sites, classified by their alkalinity (mg l^{-1} $CaCO_3$). Results are given separately for each season and also averaged across seasons.

	Alkalinity (mg l^{-1} $CaCO_3$)					
	<23	23-62	63-127	128-206	206-365	Overall
n =	120	125	122	122	124	614
(a) all families						
Spring	42.5	48.2	50.3	53.6	54.2	49.8
Summer	42.7	49.9	51.8	55.5	57.4	51.5
Autumn	38.0	46.1	46.5	54.5	52.7	47.6
Overall	41.0	48.1	49.5	54.5	54.8	49.6
(b) shredders						
Spring	4.3	4.6	4.9	5.5	5.5	5.0
Summer	3.6	4.5	4.7	5.5	5.7	4.8
Autumn	4.1	5.0	4.8	5.7	5.6	5.1
Overall	4.0	4.7	4.8	5.6	5.6	4.9
(c) scrapers						
Spring	11.4	13.0	13.4	14.3	13.9	13.2
Summer	11.7	13.7	14.2	15.0	14.9	13.9
Autumn	10.6	12.7	12.6	14.3	13.5	12.8
Overall	11.2	13.2	13.4	14.5	14.1	13.3
(d) gatherers						
Spring	13.1	14.9	15.7	15.6	15.5	15.0
Summer	13.2	15.0	15.7	15.8	15.8	15.1
Autumn	11.6	13.4	13.8	15.1	13.9	13.5
Overall	12.6	14.4	15.1	15.5	15.1	14.5
(e) filterers						
Spring	3.8	4.4	5.1	5.8	6.2	5.1
Summer	4.5	5.1	5.7	6.5	6.7	5.7
Autumn	3.4	4.4	4.8	6.6	6.3	5.1
Overall	3.9	4.6	5.2	6.3	6.4	5.3
(f) predators						
Spring	9.8	11.2	11.3	12.3	13.1	11.6
Summer	9.6	11.6	11.5	12.6	14.3	11.9
Autumn	8.4	10.6	10.5	12.9	13.4	11.2
Overall	9.3	11.1	11.1	12.6	13.6	11.6

Although the relative abundance of the FFGs did not show major differences in relation to site alkalinity, scrapers were slightly less relatively abundant at high alkalinity sites whilst filterers and predators were slightly more abundant (Table 4.10, Figure 4.6).

In summary, the above analyses have shown that although there is considerable variation between the reference sites in the absolute and relative abundance of the various functional feeding groups, there are definite trends in abundance of the FFGs in relation to site type, distance from source and in-stream alkalinity. Amongst high quality sites, large lowland river sites a long way from source have relatively more filterers and predators and less shredders than small upland headwater streams (Table 4.6).

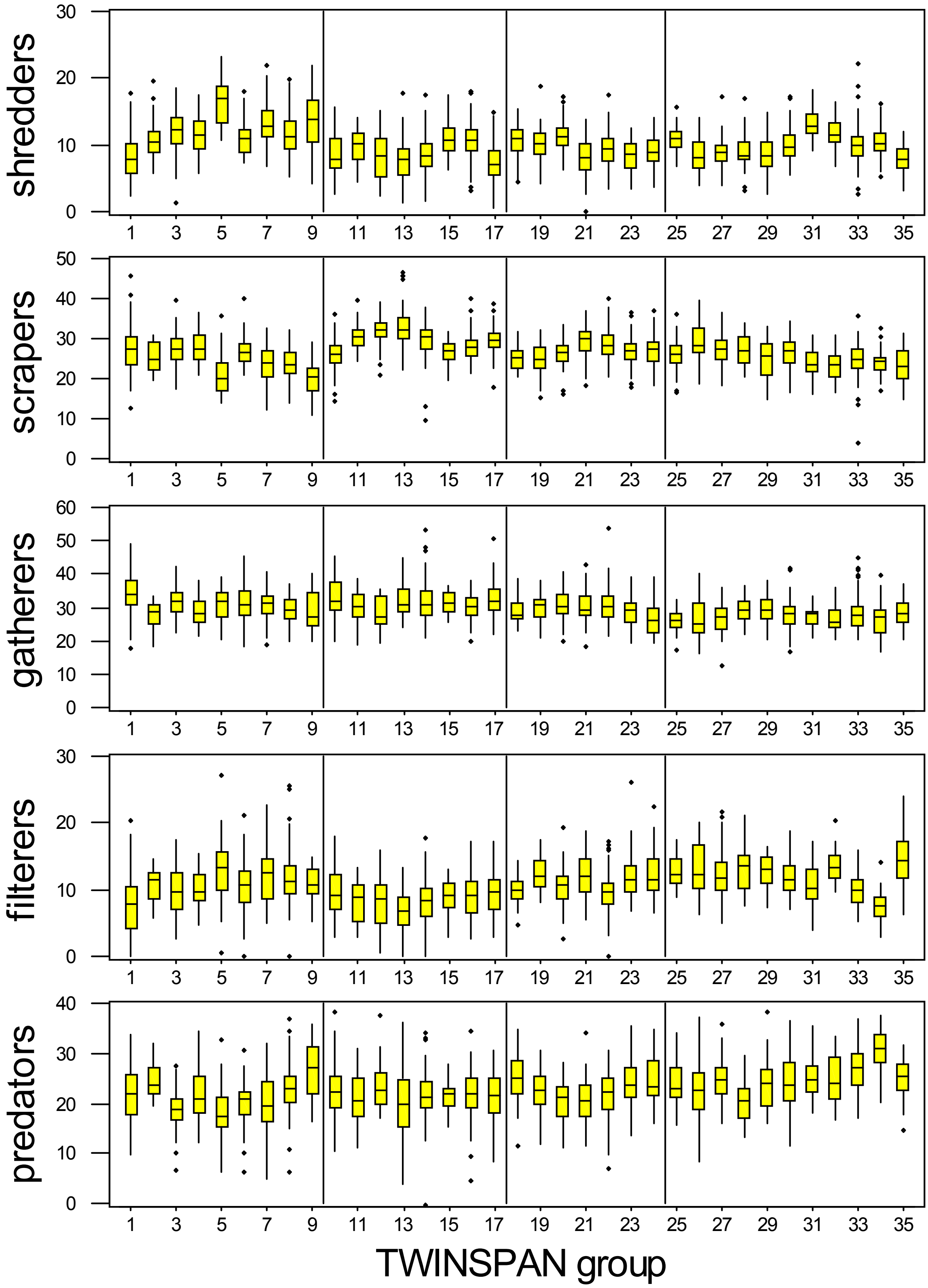
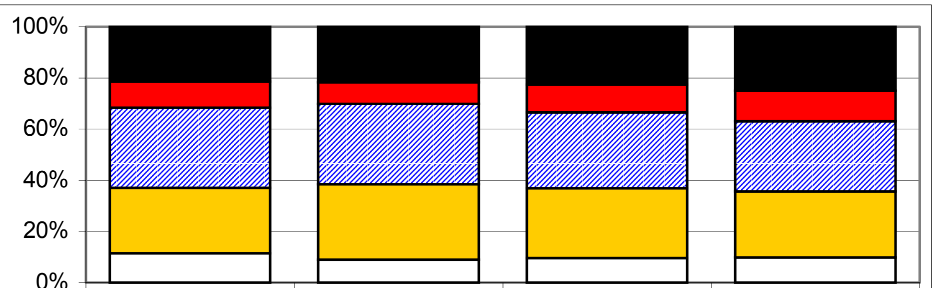


Figure 4.3: **Boxplot of the relative abundances of each functional feeding group for the 614 RIVPACS reference sites, classified by TWINSPAN site group (1-35). See Figure 4.2 for explanation of boxplot. Vertical lines differentiate the four major site groups: 1-9 = "small streams"; 10-17 = "upland streams"; 18-24 = "intermediate streams and rivers"; 25-35 = "lowland streams and rivers".**

Table 4.8: **Average percentage of sum of the observed log abundances which are (a) shredders, (b) scrapers, (c) gatherers, (d) filterers and (e) predators for the 614 RIVPACS sites, classified by TWINSPAN site group; Results are given separately for each season and also averaged across seasons. Site groups: 1-9 = "small streams"; 10-17 = "upland streams"; 18-24 = "intermediate streams and rivers"; 25-35 = "lowland streams and rivers".**

	TWINSPAN site groups				
	1-9	10-17	18-24	25-35	Overall
(a) shredders					
Spring	11.7	9.1	9.2	9.8	9.9
Summer	10.5	7.6	9.2	9.6	9.2
Autumn	12.3	10.0	10.3	10.2	10.7
(b) scrapers					
Spring	25.9	29.3	26.8	25.3	26.8
Summer	25.4	29.4	27.7	26.5	27.2
Autumn	25.4	29.8	27.5	25.6	27.0
(c) gatherers					
Spring	30.8	31.4	31.2	28.7	30.4
Summer	31.9	31.6	29.2	27.3	29.9
Autumn	31.0	31.4	28.4	26.3	29.2
(d) filterers					
Spring	9.4	8.3	10.1	11.8	10.0
Summer	11.4	9.5	11.6	11.6	11.0
Autumn	10.1	7.6	11.0	12.1	10.3
(e) predators					
Spring	22.3	21.9	22.6	24.4	22.9
Summer	20.9	21.9	22.2	25.0	22.6
Autumn	21.1	21.2	22.9	25.7	22.9

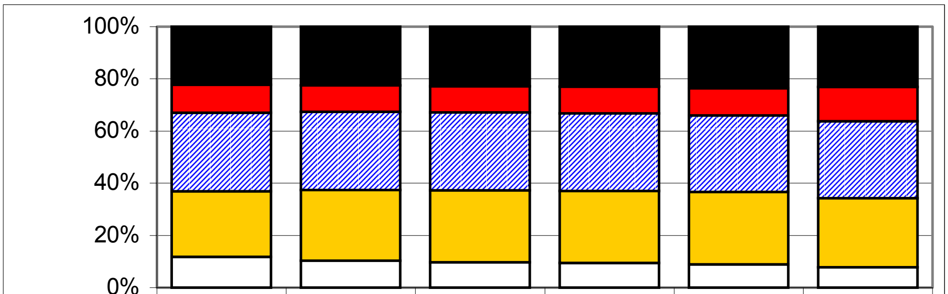


	Groups 1-9	10-17	18-24	25-35
predators	21.4	21.7	22.6	25.1
filterers	10.3	8.4	10.9	11.8
gatherers	31.2	31.5	29.6	27.5
scrapers	25.5	29.5	27.3	25.8
shredders	11.5	8.9	9.6	9.9

Figure 4.4: **Average percentage of the sum of the observed log abundances in each of five functional feeding groups for the 614 RIVPACS sites classified by major TWINSPAN site group.**

Table 4.9: Average percentage of sum of the observed log abundances which are (a) shredders, (b) scrapers, (c) gatherers, (d) filterers and (e) predators for the 614 RIVPACS sites, classified by their distance from source (km). Results are given separately for each season and also averaged across seasons.

	Distance from Source (km)						
	<5	5-11.9	12-22.9	23-40.9	41-84	85-203	Overall
n =	108	132	129	121	102	22	614
(a) shredders							
Spring	12.0	10.7	9.8	9.1	8.6	7.1	9.9
Summer	10.8	9.5	8.9	8.7	8.5	7.7	9.2
Autumn	12.8	10.7	10.6	10.3	9.5	8.6	10.7
(b) scrapers							
Spring	25.3	27.1	27.2	27.1	27.2	25.9	26.8
Summer	25.2	27.2	27.6	27.8	28.4	27.1	27.2
Autumn	24.7	27.0	27.7	27.7	27.9	26.6	27.0
(c) gatherers							
Spring	29.9	30.3	30.6	31.1	30.2	31.7	30.5
Summer	31.0	30.1	29.7	29.6	29.3	28.8	29.9
Autumn	29.6	29.9	29.2	28.8	28.5	27.7	29.2
(d) filterers							
Spring	9.7	9.7	9.6	9.9	10.5	13.2	10.0
Summer	11.6	10.8	10.8	11.0	10.5	13.7	11.0
Autumn	11.0	9.7	9.9	10.1	10.2	12.7	10.3
(e) predators							
Spring	23.2	22.3	22.9	22.8	23.6	22.1	22.9
Summer	21.4	22.5	23.0	22.8	23.3	22.8	22.6
Autumn	21.9	22.6	22.6	23.1	23.9	24.3	22.9

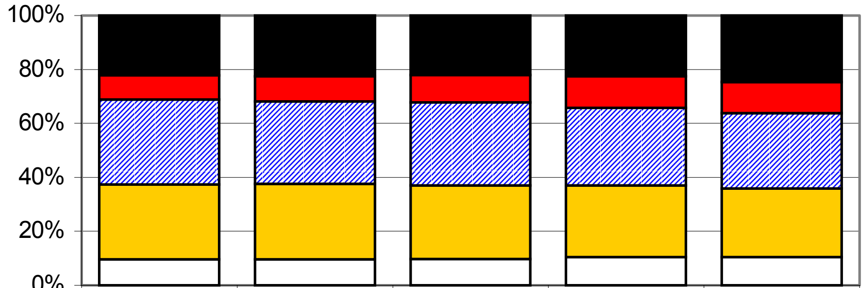


	<5 km	5-11.9	12-22.9	23-40.9	41-84	85-203
predators	22.2	22.5	22.8	22.9	23.6	23.1
filterers	10.8	10.1	10.1	10.3	10.4	13.2
gatherers	30.2	30.1	29.8	29.8	29.3	29.4
scrapers	25.1	27.1	27.5	27.6	27.8	26.5
shredders	11.8	10.3	9.7	9.4	8.9	7.8

Figure 4.5: Average percentage of the sum of the observed log abundances in each of five functional feeding groups for the 614 RIVPACS sites classified by distance from source (km).

Table 4.10: Average percentage of sum of the observed log abundances which are (a) shredders, (b) scrapers, (c) gatherers, (d) filterers and (e) predators for the 614 RIVPACS sites, classified by alkalinity (mg l^{-1} $CaCO_3$). Results are given separately for each season and also averaged across seasons.

	Alkalinity (mg l^{-1} $CaCO_3$)					
	<23	23-62	63-127	128-206	206-365	Overall
n =	120	125	122	122	124	614
(a) shredders						
Spring	10.0	9.3	9.7	10.4	10.2	9.9
Summer	8.0	8.7	9.0	10.2	10.0	9.2
Autumn	10.9	10.6	10.3	10.7	10.9	10.7
(b) scrapers						
Spring	27.2	27.7	26.9	26.7	25.4	26.8
Summer	28.1	27.9	27.6	27.0	25.6	27.2
Autumn	27.9	28.2	27.4	26.1	25.4	27.0
(c) gatherers						
Spring	31.4	31.4	31.4	29.3	28.9	30.5
Summer	31.6	30.6	30.6	28.8	27.9	29.9
Autumn	31.5	29.7	30.2	28.0	26.5	29.2
(d) filterers						
Spring	8.7	8.9	9.9	10.9	11.4	10.0
Summer	10.3	10.1	11.0	11.9	11.8	11.0
Autumn	8.1	9.0	10.1	12.1	12.0	10.3
(e) predators						
Spring	22.7	22.8	22.1	22.7	24.0	22.9
Summer	22.0	22.6	21.8	22.0	24.5	22.6
Autumn	21.6	22.5	21.9	23.1	25.2	22.9



	<23 mg/l	23-62	63-127	128-206	206-365
predators	22.1	22.6	22.0	22.6	24.6
filterers	9.0	9.3	10.3	11.7	11.7
gatherers	31.5	30.5	30.7	28.7	27.8
scrapers	27.7	28.0	27.3	26.6	25.5
shredders	9.6	9.6	9.7	10.4	10.4

Figure 4.6: Average percentage of the sum of the observed log abundances in each of five functional feeding groups for the 614 RIVPACS sites classified by alkalinity (mg l^{-1} $CaCO_3$).

4.6.2 Effectiveness of RIVPACS predictions of expected relative abundances of each Functional Feeding Group

The differences between TWINSPAN site groups 1-35 in the observed relative abundance of each FFG were statistically highly significant. However, the average percentage of total variance in the relative abundance of each FFG amongst the 614 sites explained by site group type for any single season samples was only 31% (shredders), 27% (scrapers), 16% (gatherers), 29% (filterers) and 18% (predators). This compares with equivalent figures of 45% and 68% for number of BMWP taxa and ASPT respectively. Thus the relative abundance of the five FFGs varies in a less consistent manner with the environmental characteristics of sites than do the BMWP indices, especially ASPT. This means that RIVPACS is less effective at predicting the expected relative abundance of FFGs than the expected values of BMWP indices.

Because the relative abundances of the FFGs do not vary greatly between the TWINSPAN site groups, the expected values predicted by RIVPACS, which are weighted averages of the site group means, do not vary much across all types of site (Table 4.11). The consequence of the expected (E) values having a low coefficient of variation (CV = standard deviation divided by mean) is that the observed to expected ratios (O/E) of the relative abundance of the FFGs will be very highly correlated with the observed (O) relative abundances and hence the pattern of values for the O and O/E values across a wide range of sites will be similar and they will lead to similar conclusions. This is discussed further in the next section which assesses the way in which the relative abundance of the FFGs varies with the site quality.

Table 4.11: Range of expected values predicted by RIVPACS for the percentage abundance of each functional feeding group based on the 614 RIVPACS reference sites for all three single season expected values.

	Mean	%CV	Min	Max	Range
shredders	9.9	18%	6.1	17.3	11.2
scrapers	26.8	8%	18.9	32.9	14.0
gatherers	29.5	7%	24.9	34.2	9.3
filterers	10.5	17%	6.1	15.8	9.7
predators	23.3	10%	16.7	31.8	15.1

4.7 Functional Feeding Groups and Site Quality

In the previous section, patterns in the relative abundance of the five functional feeding groups (FFGs) were examined across the full range of high quality RIVPACS reference sites. This provided the basis from which to assess the "natural" variation in FFGs without the confounding effects caused by environmental stress and pollution in poorer quality sites. The current section assesses whether there are discernible trends in the relative abundance of FFGs in relation to the quality of sites. Where necessary, the observed trends will be assessed in relation to the "natural" patterns expected from the sites' characteristics through the use of RIVPACS observed to expected (O/E) ratios of the abundances of the various FFGs.

4.7.1 Assessments based on the BAMS sites

Initially, assessments were carried out using the sites available in the Biological Assessment Methods Study (BAMS) of Furse *et al.* (1995). The BAMS sites were selected from the NRA's 1990 River Quality Survey (RQS) using a stratified random scheme to cover a wide range of types and quality of site. Four sites were selected from each of the four major types (from the then latest RIVPACS, version II) and within each type one site was selected from each of the four 1990 River Quality Survey (RQS) bands A, B, C and D (Table 4.12). In each of the three RIVPACS seasons at each of the 16 BAMS sites, three replicate samples were taken, two by an IFE biologist (person A) and one by a local NRA biologist (person B). This provided a total of 144 samples although they are not independent. However, having replicate samples from the same site in any one season enabled an assessment to be made of the variability in the relative abundance of the FFGs due to sampling variation. This was important because if sampling variability is very high, it is difficult to detect differences and trends between sites and types of site.

For each of the 144 samples, we calculated the observed (O), expected (E) and ratio O/E of relative abundance of each FFG together with the standard RIVPACS O/E ratios for number of BMWP taxa and for ASPT, referred to as Ecological Quality Indices (EQI) in the Environment Agency's national General Quality Assessment (GQA) surveys, and denoted here as EQI_{TAXA} and EQI_{ASPT}. The EQI values for a sample are used here to represent the estimated biological quality or condition of a sample or site.

Figure 4.7 plots the observed sum of log abundances of each FFG in a BAMS sample in relation to the value of EQI_{TAXA} and EQI_{ASPT} for the sample. The observed abundances of each FFG all tend to decline with site quality with correlations in the range 0.62-0.87 (Table 4.13). Figure x.8 plots the observed to expected ratio (O/E) of the sum of log abundances of each FFG in a BAMS sample in relation to the value of EQI_{TAXA} and EQI_{ASPT} for the sample. Figures 4.7 and 4.8 show very similar patterns. Because the range of expected values for the sum of log abundances of a FFG is relatively small, the correlation of observed sum of log abundances and O/E of sum of log abundances with the EQIs are very similar and standardising by RIVPACS expected values does not improve relationships between the observed abundances of each FFG and site quality. The general decrease in the abundance of all FFGs with declining site quality is a similar result to that of Clarke *et al*. (1999), who found that a trial index, Q19, equal to the observed to expected ratio of the sum of abundances of all families, also declined linearly with site quality with correlations of 0.94 and 0.82 with EQI_{TAXA} and EQI_{ASPT} respectively for the BAMS sites.

Table 4.12: Characteristics of the stratified random selection of the 16 BAMS study sites in terms of (a) their quality bands as defined by range of O/E BMWP quality index values; (b) RIVPACS II environmental group type and (c) the full list of the 16 sites selected for replicate sampling.

(a) quality band: Range of O/E values based on:	band A "best" condition	B	C	D "worst" condition
BMWP score	0.91 - 1.09	0.52 - 0.62	0.29 - 0.39	< 0.18
Number of BMWP taxa	0.94 - 1.06	0.64 - 0.72	0.41 - 0.53	< 0.30
ASPT	0.97 - 1.03	0.80 - 0.85	0.68 - 0.74	< 0.60
(b) RIVPACS	Site type group			
mean value of environmental variable	group 3a	5b	8a	9b
distance from source (km)	15.3	8.2	11.3	33.0
width (m)	7.5	4.8	4.8	13.1
depth (cm)	19.8	21.7	32.5	77.5
altitude (m)	74	40	40	5
alkalinity (mg l^{-1} $CaCO_3$)	81	153	229	170
predominant substratum	cobbles/pebbles	gravel	gravel/sand	silt
Regions of England and Wales	SW, NE, Wales	central south + midlands	east Wales to East Anglia + southern chalk streams	SE + East Anglia

(c) Site group	Quality band	River name	Site name	National grid ref.	NRA Region
3a	A	River Okement	South Dornaford	SS 600 000	South Western
3a	B	River Darracott	Tantons Plain	SS 494 198	South Western
3a	C	River Croxdale	Croxdale House	NZ 272 379	Northumbria& Yorkshire
3a	D	Twyzell Burn	B6313 Bridge	NZ 257 517	Northumbria & Yorkshire
5b	A	Petworth Brook	Haslingbourne Bridge	SU 982 204	Southern
5b	B	Sheppey River	Woodford	ST 537 441	South Western
5b	C	Sheppey River	Bowlish	ST 613 440	South Western
5b	D	Moss Brook	PTC Bedford Brook	SJ 676 983	North West
8a	A	Summerham Brook	Seend Bridge	ST 945 595	South Western
8a	B	Cuttle Brook	Swarkestone	SK 375 288	Severn Trent
8a	C	Poulshot Stream	Jenny Mill	ST 979 592	South Western
8a	D	Spen Beck	Dewsbury	SE 225 208	Northumbria & Yorkshire
9b	A	Old River Ancholme	Brigg	TA 001 065	Anglian
9b	B	Broad Rife	Ferry Sluice	SZ 854 963	Southern
9b	C	Skellingthorpe Drain	U/S Skellingthorpe	SK 937 727	Anglian
9b	D	Keyingham Drain	Cherry Cob	TA 219 224	Northumbria & Yorkshire

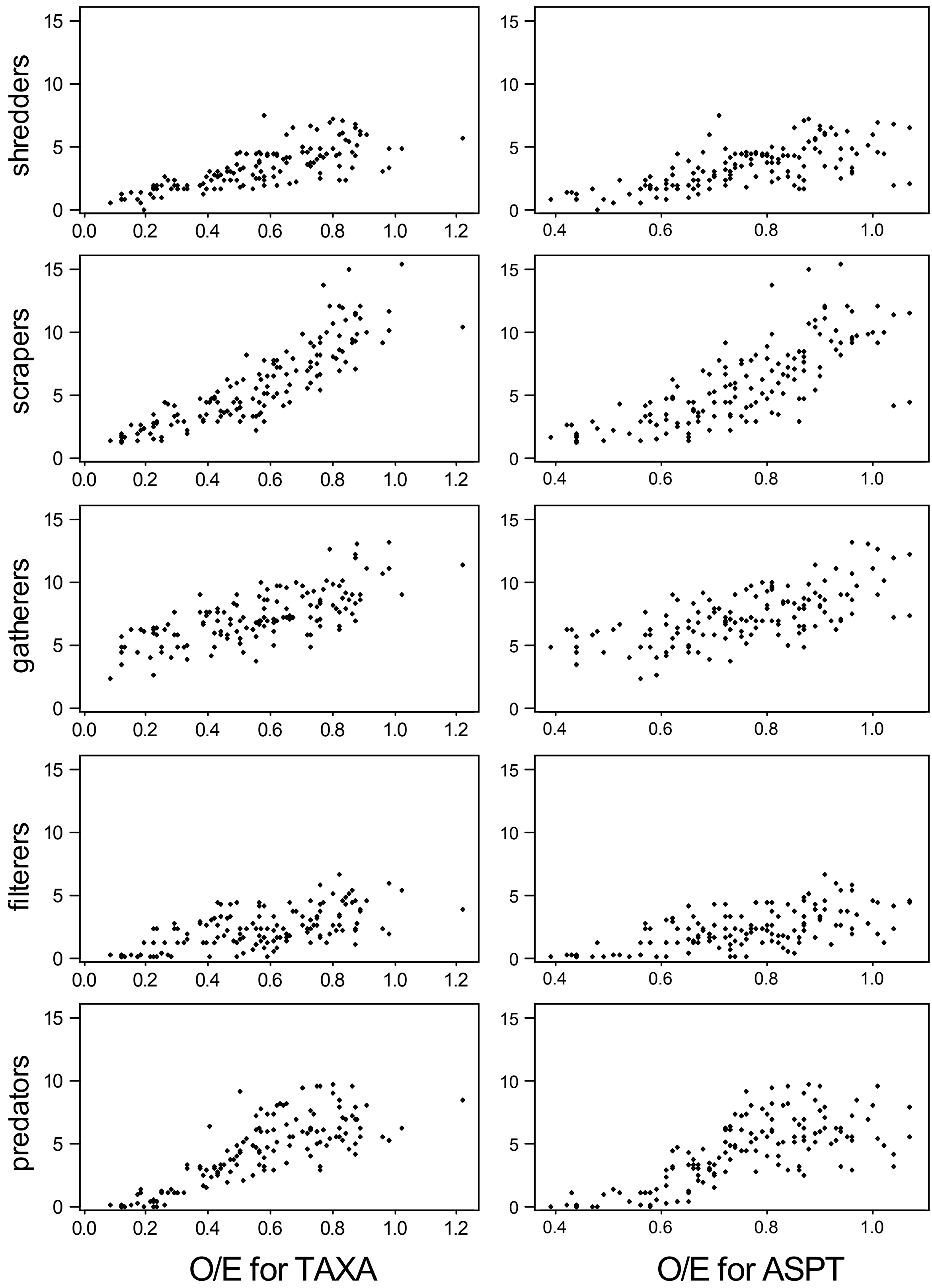


Figure 4.7: Sum of log abundances of each functional feeding group for all replicate samples from the BAMS sites plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS). *n* = 16 sites x 3 seasons x 3 samples = 144.

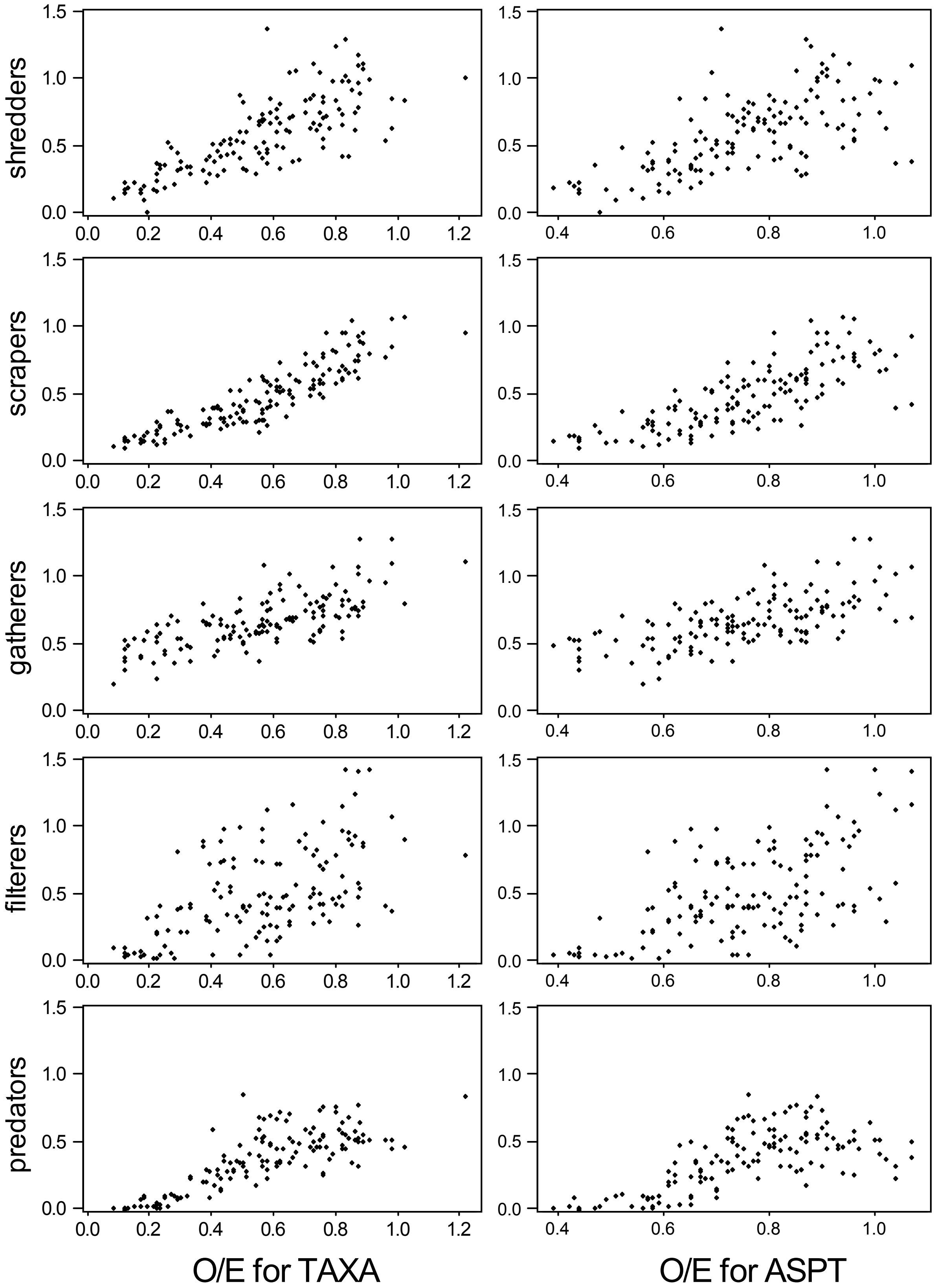


Figure 4.8: Ratio O/E of observed to expected sum of log abundances of each functional feeding group for all replicate samples from the BAMS sites plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS).

Table 4.13: Correlations of the observed or observed to expected ratio (O/E) of either the abundance (i.e. sum of log abundances) or relative abundance of the functional feeding groups with EQI_{TAXA} and EQI_{ASPT} for the BAMS sites (*n* = 16 sites x seasons x 3 replicates).

	Correlations between EQI_{TAXA} and			
	Observed abundance	O/E for abundance	Observed relative abundance	O/E for relative abundance
shredders	0.78	0.79	0.18	0.14
scrapers	0.87	0.90	0.42	0.34
gatherers	0.72	0.72	-0.80	-0.81
filterers	0.63	0.60	0.24	0.20
predators	0.81	0.81	0.56	0.57

	Correlations between EQI_{ASPT} and			
	Observed abundance	O/E for abundance	Observed relative abundance	O/E for relative abundance
shredders	0.68	0.66	0.11	0.06
scrapers	0.76	0.78	0.32	0.29
gatherers	0.66	0.65	-0.76	-0.75
filterers	0.62	0.61	0.31	0.31
predators	0.75	0.69	0.56	0.51

Figure 4.9 shows plots of the observed relative abundance of each FFG in a BAMS sample in relation to the value of EQI_{TAXA} and EQI_{ASPT} for the sample. The relative abundance of shredders shows no relationship with either EQI. Figure 4.10 shows plots of the observed to expected ratio (O/E) of the relative abundance of each FFG in a BAMS sample in relation to the value of EQI_{TAXA} and EQI_{ASPT} for the sample. Once again, because of the small range in RIVPACS predictions of the expected relative abundance of each FFG, the correlation of observed relative abundances and O/E of relative abundances with the EQIs are very similar. Thus, standardising by RIVPACS expected values does not improve relationships between the observed relative abundances of each FFG and site quality (Table 4.13). For the BAMS samples, the relative abundance of gatherers shows the strongest relationship with site quality, forming 50-60% of total log abundances for very poor quality sites, but only 20-30% for good quality sites (Figure 4.9). The relative abundance of shredders does not change with site quality, while the relative abundance of each of scrapers and filterers tends to increase with site quality. The relative abundance of predators is least for very poor quality sites (averaging 10% for sites with values of EQI_{TAXA} of around 0.3), increases with site quality, but appears to peak at an average of 25% relative abundance at intermediate quality sites with EQI_{TAXA} values of 0.5-0.8 (Figure 4.9).

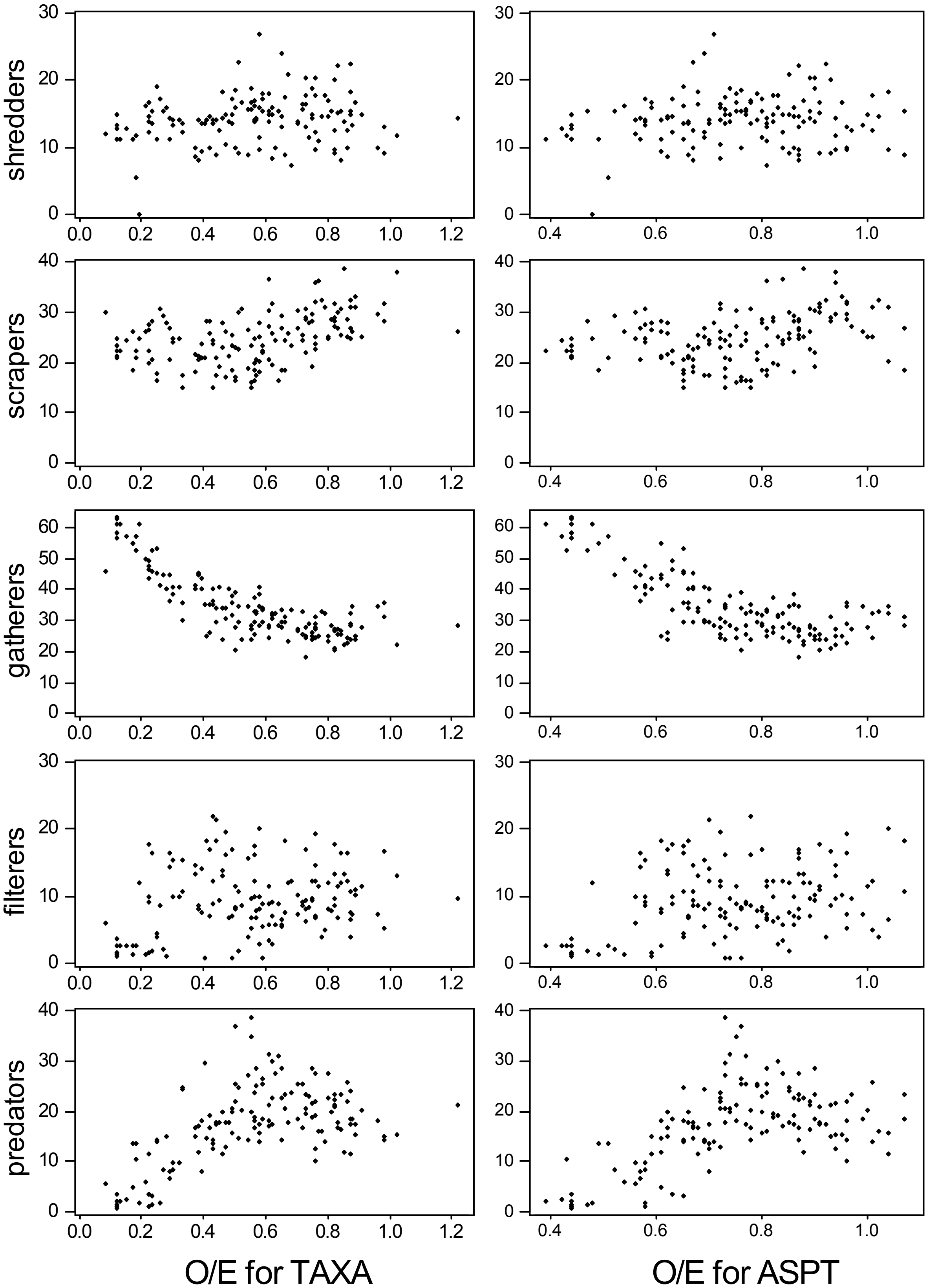


Figure 4.9: Relative abundance of each functional feeding group for all replicate samples from the BAMS sites plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS). *n* = 16 sites x 3 seasons x 3 samples = 144.

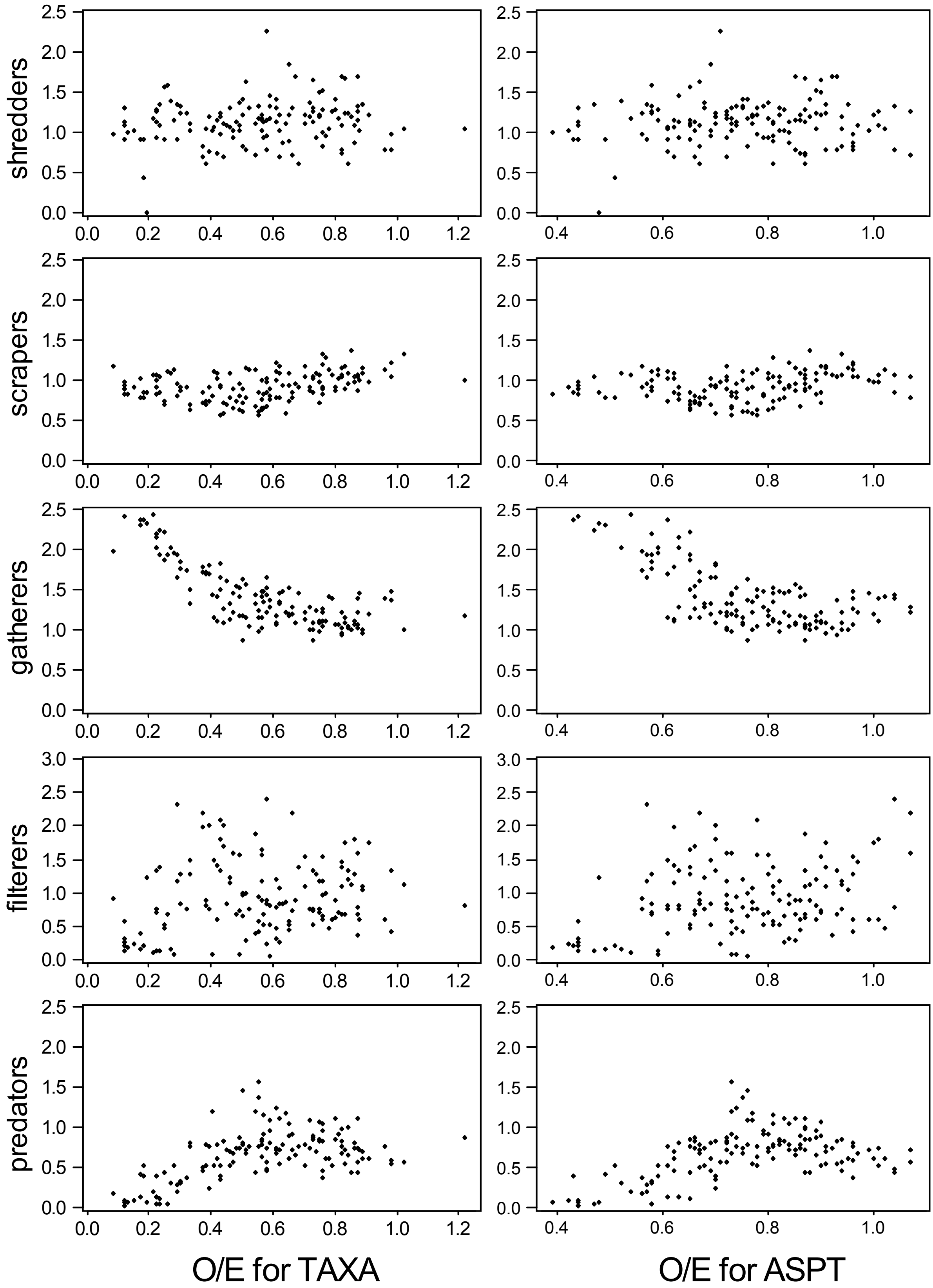


Figure 4.10: Ratio O/E of observed to expected relative abundance of each functional feeding group for all replicate samples from the BAMS sites plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS).

4.7.2 Assessments based on the 1995 GQA sites

The analyses based on the BAMS samples involved only 16 sites, albeit with three replicate samples in each of three seasons, giving a total of 144 samples. Thus the estimated correlations and relationships between the relative abundance of each FFG and site quality must be rather tentative as the plots in Figures 4.9 and 4.10 contain, in a sense “pseudo-replication”.

Therefore, it was considered important to check these relationships using a much larger dataset of GQA sites from the 1995 GQA survey. Specifically, these were the 6106 validated GQA sites available to CEH for which both spring and autumn samples were available, as used by Clarke and Wright (2000) and Davy-Bowker *et al*. (2000) in their analyses of the GQA survey data. To do this, it was necessary to run these GQA sites through RIVPACS III+ to obtain spring and autumn single season values for EQI_{TAXA} and EQI_{ASPT}. (All previous analyses of these sites had been for the best available season combination, namely the spring and autumn combined season samples). In separate analyses of the abundance data for these GQA sites, we then calculated the observed total abundance, observed relative abundance and their O/E ratio equivalents for each functional feeding group.

As with the BAMS samples, the observed total abundance (and its O/E ratio) for each of the FFGs declines with site quality (Table 4.14, Figures 4.11 and 4.12). Therefore, we need to assess whether and how the relative abundance of the FFGs changes with site quality, as this will provide more independent information on the effects of reduction in the quality of river sites.

Table 4.14: Correlations of the observed or observed to expected ratio (O/E) of either the abundance (i.e. sum of log abundances) or relative abundance of the functional feeding groups with EQI_{TAXA} and EQI_{ASPT} for 6016 GQA sites sampled in autumn 1995.

	Correlations between EQI_{TAXA} and			
	Observed abundance	O/E for abundance	Observed relative abundance	O/E for relative abundance
shredders	0.78	0.78	0.05	0.05
scrapers	0.83	0.83	024	024
gatherers	0.74	0.74	-0.48	-0.48
filterers	0.65	0.65	0.09	0.09
predators	0.80	0.80	0.14	0.14

	Correlations between EQI_{ASPT} and			
	Observed abundance	O/E for abundance	Observed relative abundance	O/E for relative abundance
shredders	0.62	0.62	0.14	0.14
scrapers	0.64	0.64	0.24	0.24
gatherers	0.56	0.65	-0.40	-0.40
filterers	0.48	0.48	0.08	0.08
predators	0.53	0.53	0.03	0.03

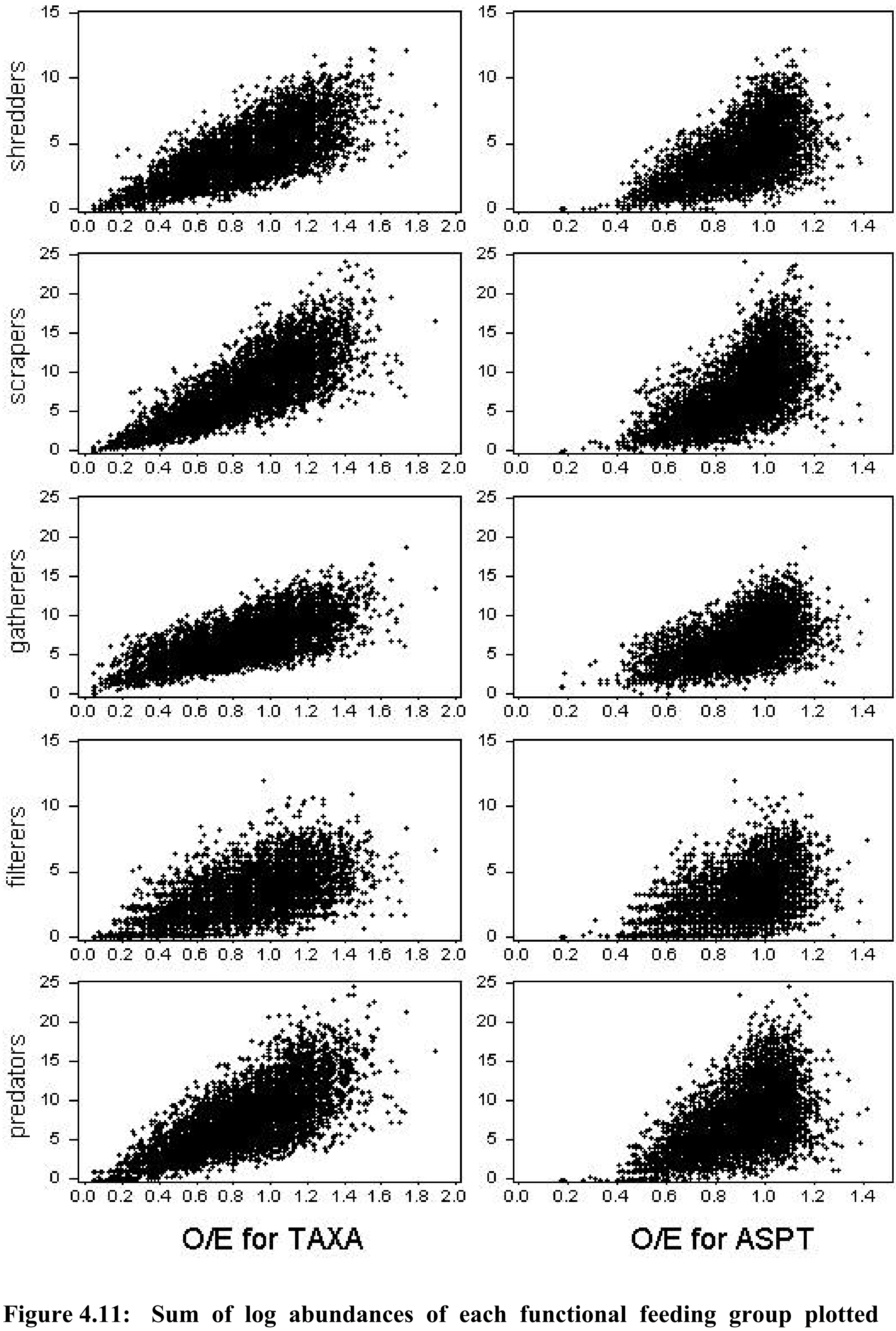


Figure 4.11: Sum of log abundances of each functional feeding group plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS) for 6016 GQA sites sampled in autumn 1995.

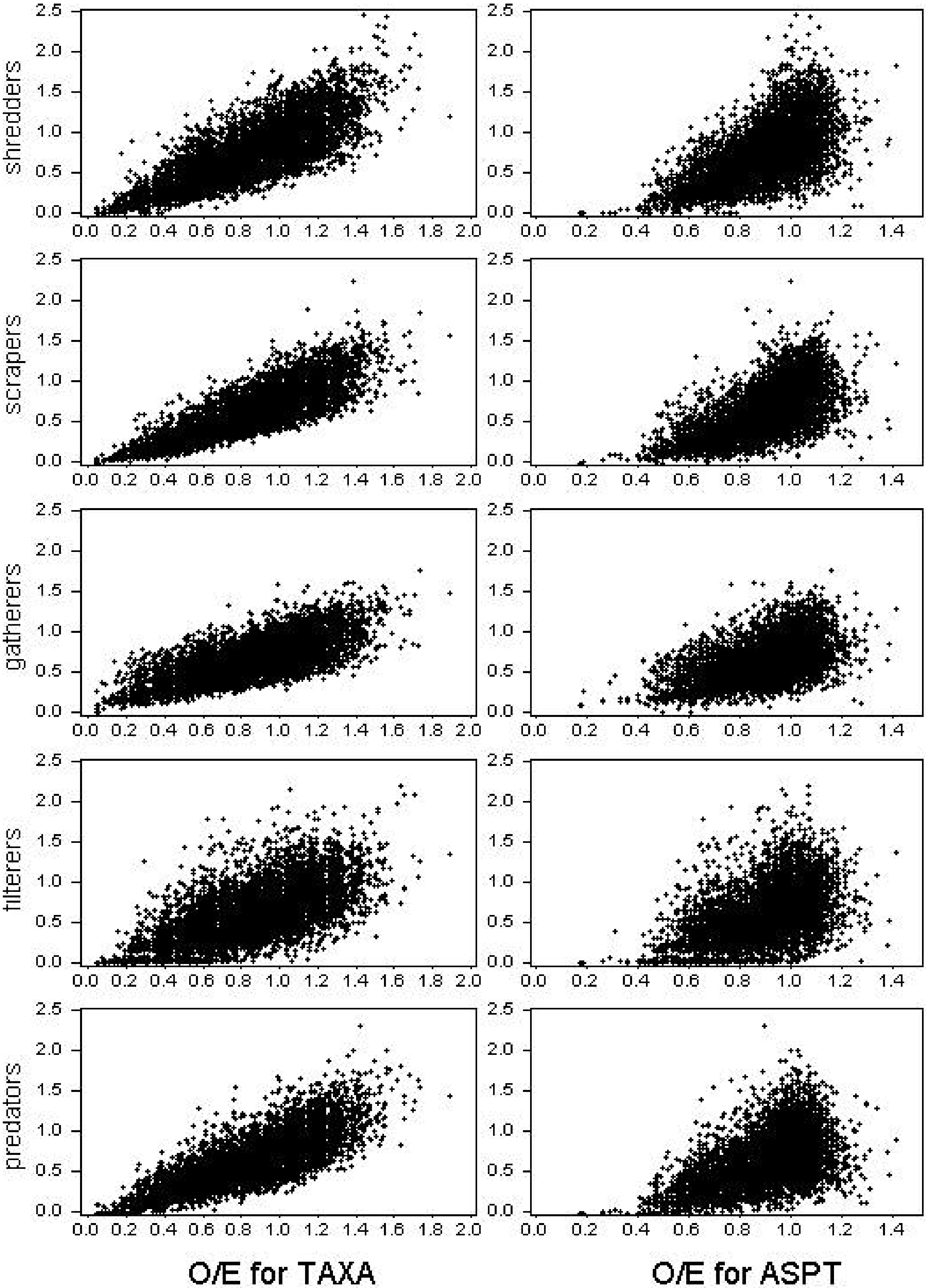


Figure 4.12: Ratio O/E of observed to expected sum of log abundances of each functional feeding group plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS) for 6016 GQA sites sampled in autumn 1995.

The correlations between the relative abundance of each FFG and EQI_{TAXA} or EQI_{ASPT} are weaker when based on all the GQA sites (Table 4.14) than when derived for the replicate samples from the BAMS sites (Table 4.13). There are now only weak positive correlations between percentage scrapers or percentage predators and EQI_{TAXA} and between percentage scrapers or shredders and EQI_{ASPT}. The relative abundance of gatherers still shows the strongest relationship with site quality, being much higher for very poor quality sites (Figures 4.13 and 4.14).

Although there is considerable variation in relative abundance of any one FFG amongst sites of a given EQI value (Figure 4.13), there are still trends with site quality as highlighted in Table 4.15 which gives the average relative abundance of each FFG for sites in classes of EQI values. Poor quality sites have relatively more gatherers and consequently relatively fewer filterers and predators and to a lesser extent relatively fewer scrapers and shredders. A similar pattern emerges when the relative abundances are standardised by the expected values as O/E ratios (Table 4.16, Figure 4.14). For very poor quality sites, the average O/E ratio for the relative abundance of gatherers is considerably greater than 1.0, while for all other FFGs it is less than 1.0.

In summary, once averaged across a very wide range of types of site, the relative abundance of the various functional feeding groups varies only weakly with the environmental characteristics of sites and only changes dramatically for very poor quality sites.

Table 4.15: Average observed relative abundance of the functional feeding groups for 6016 GQA sites sampled in autumn 1995 in relation to their values of EQI_{TAXA} and EQI_{ASPT}. Number of site per EQI class given in brackets.

	EQI_{TAXA}							
	<0.2	0.21-0.4	0.41-0.6	0.61-0.8	0.81-1.0	1.01-1.2	1.21-1.4	>1.4
	(71)	(380)	(895)	(1273)	(1431)	(1326)	(527)	(113)
shredders	11.5	13.7	14.4	14.2	14.0	14.0	14.1	14.4
scrapers	22.0	22.8	23.8	25.6	27.1	27.5	27.7	28.1
gatherers	47.1	31.7	26.0	23.4	22.5	21.8	21.2	21.0
filterers	3.7	8.9	11.1	10.9	10.5	10.5	10.3	9.8
predators	15.6	22.9	24.7	26.0	25.9	26.1	26.7	26.6

	EQI_{ASPT}				
	<0.6	0.61-0.8	0.81-1.0	1.01-1.2	>1.2
	(314)	(1219)	(2674	1752	(57)
shredders	12.7	14.1	14.2	14.2	14.1
scrapers	23.9	23.8	26.3	27.8	27.0
gatherers	34.5	25.5	22.8	22.1	23.4
filterers	8.8	11.0	10.2	10.6	12.7
predators	20.0	25.6	26.4	25.3	22.8

Table 4.16: Average observed to expected ratio (O/E) of the relative abundance of the functional feeding groups for 6016 GQA sites sampled in autumn 1995 in relation to their values of EQI_{TAXA} and EQI_{ASPT}. Number of site per EQI class given in brackets.

	EQI_{TAXA}							
	<0.2	0.21-0.4	0.41-0.6	0.61-0.8	0.81-1.0	1.01-1.2	1.21-1.4	>1.4
	(71)	(380)	(895)	(1273)	(1431)	(1326)	(527)	(113)
shredders	0.95	1.08	1.15	1.14	1.14	1.15	1.16	1.19
scrapers	0.84	0.86	0.90	0.96	1.00	1.00	1.01	1.01
gatherers	2.09	1.39	1.13	1.02	0.98	0.95	0.92	0.90
filterers	0.30	0.72	0.93	0.93	0.92	0.92	0.90	0.93
predators	0.62	0.90	0.96	1.00	0.99	1.01	1.04	1.05

	EQI_{ASPT}				
	<0.6	0.61-0.8	0.81-1.0	1.01-1.2	>1.2
	(314)	(1219)	(2674	1752	(57)
shredders	0.99	1.10	1.16	1.17	1.25
scrapers	0.90	0.90	0.97	1.02	1.02
gatherers	1.50	1.11	0.99	0.97	1.03
filterers	0.73	0.92	0.90	0.92	1.01
predators	0.81	1.01	1.01	0.97	0.85

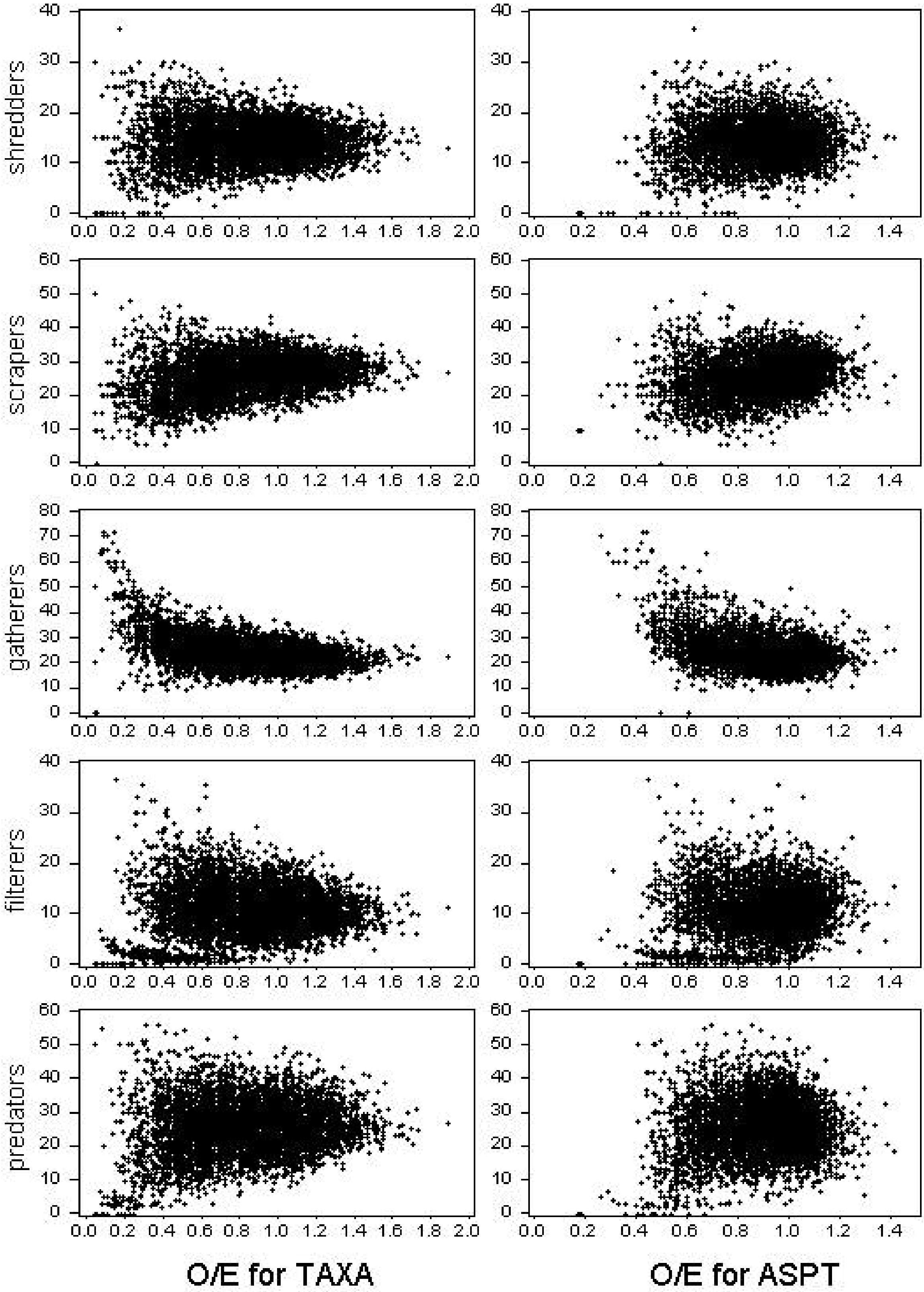


Figure 4.13: Relative abundances of each functional feeding group plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS) for 6016 GQA sites sampled in autumn 1995.

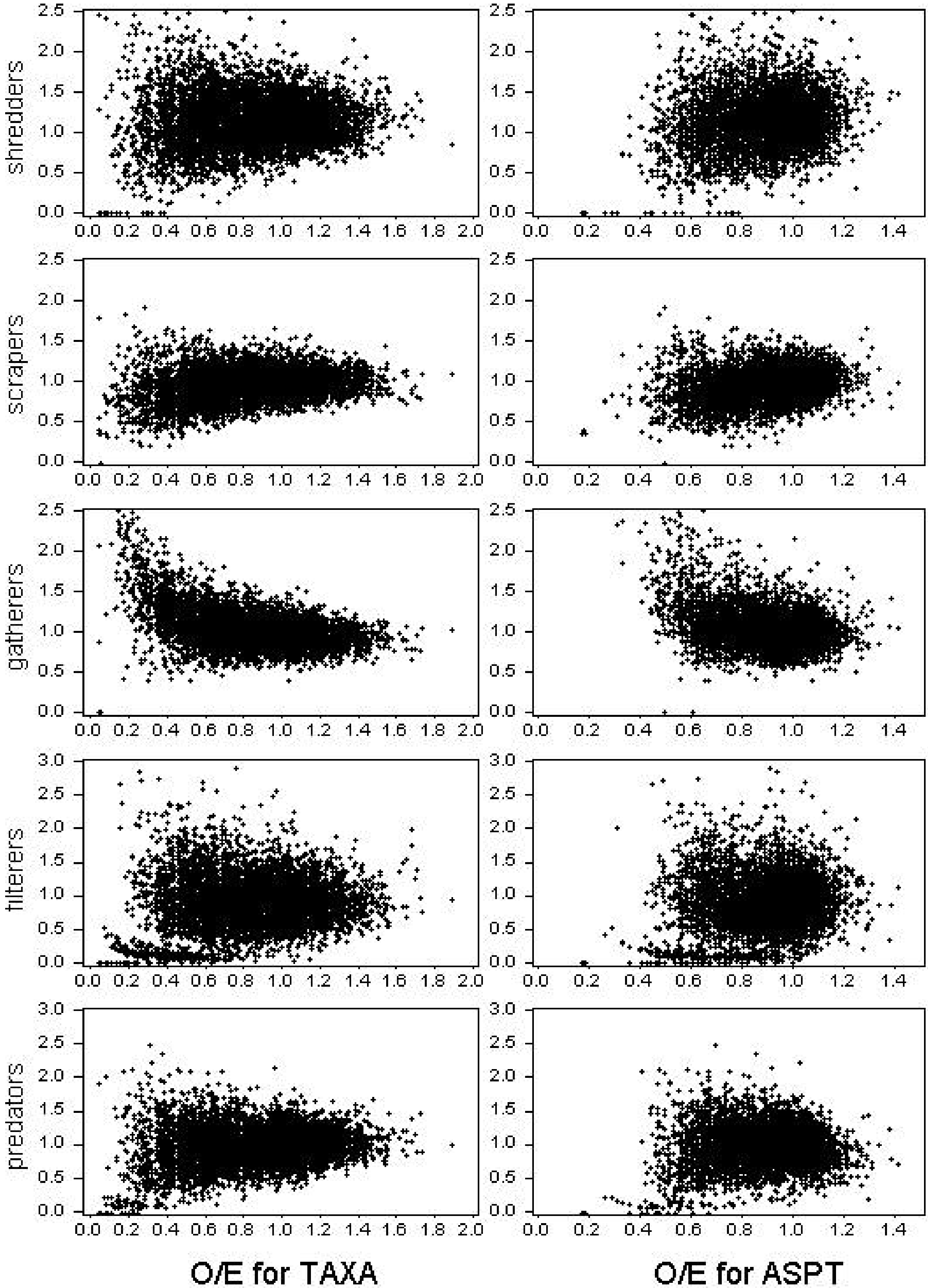
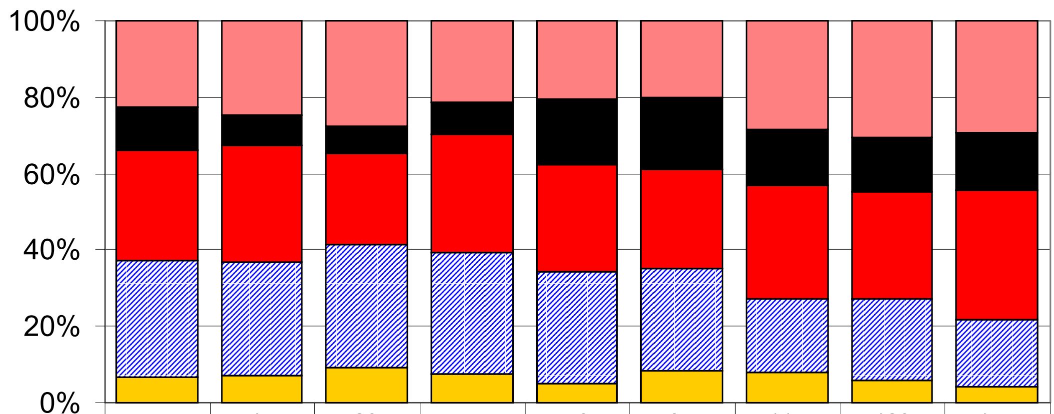


Figure 4.14: Ratio O/E of observed to expected relative abundances of each functional feeding group plotted against sample O/E for number of taxa (LHS) and O/E for ASPT (RHS) for 6016 GQA sites sampled in autumn 1995.

4.8 Trends in Functional Feeding Group Abundance Along Individual Rivers

The River Continuum Concept (RCC) proposes that local benthic communities are adapted to exploit changing food resources along the length of a river system. Using this concept, it is reasonable to anticipate that the relative abundance of the functional feeding groups may change in a systematic pattern with progression downstream. The analyses above do show up the expected RCC patterns with distance from source when averaged across all the RIVPACS reference sites but the trends are not dramatic. This may be because rivers with different environmental attributes may exhibit differences with respect to the FFGs for a given distance from source. Therefore we also assessed whether the RCC was supported by the changes in FFG abundance with distance downstream along some individual rivers for which we had a series of high quality reference sites (Figure 4.15 to 4.17).

The longest river chosen for this analysis was the Swale-Ure-Ouse system in northern England (Figure 4.15) with nine sites over a 144 km length of river incorporating both upland and lowland sections. Sites 1-6 were on the River Swale and whereas sites 1-4 were above 100 m in altitude with a relatively steep (gradient ca. 10-4 m per km), sites 5 and 6 were at an altitude of 27 and 18 m with slope of 0.3 m per km. Nevertheless, all six sites were shallow (< 0.4 m) with a coarse substratum. By site 7 the Swale had joined the River Ure and sites 8 and 9 were on the River Ouse, as a result of the entry of further tributaries. All three of sites 7-9 on the Ure/Ouse system were much deeper (1.6-2.0 m) and with a finer substratum than the Swale.



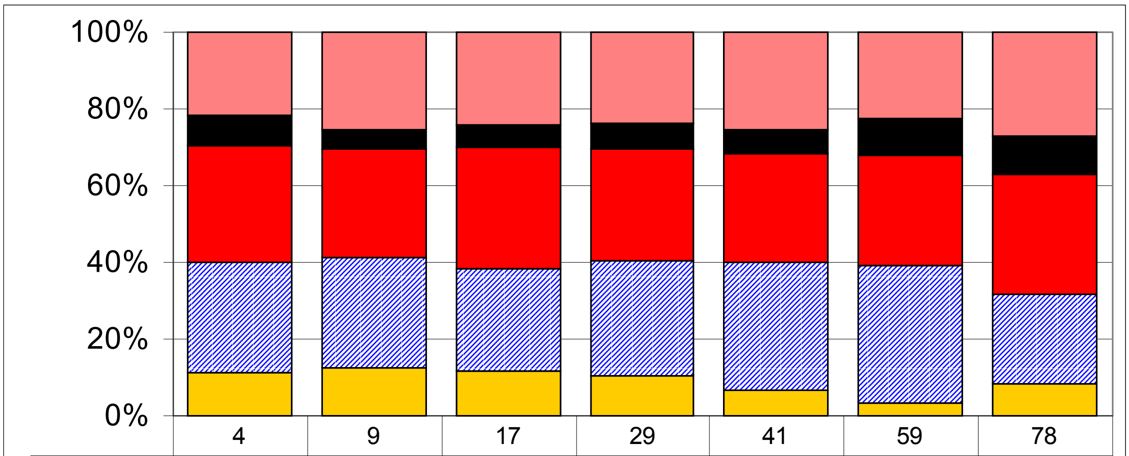
	7	14	29	44	70	94	114	129	144
predators	22.5	24.7	27.8	21.2	20.6	20.0	28.4	30.7	29.3
filterers	11.3	8.1	6.9	8.5	17.1	18.8	14.8	13.9	14.9
gatherers	29.2	30.3	24.1	30.9	28.1	26.1	29.8	28.0	33.9
scrapers	30.4	29.7	32.2	31.8	29.0	26.9	19.1	21.5	17.8
shredders	6.7	7.2	9.1	7.6	5.2	8.2	8.0	5.9	4.1

Figure 4.15: Percentage abundance of each functional feeding group in relation to distance from source (7, 14, 29, 44, 70, 94, 114, 129 and 144 km) of sites down the Swale-Ure-Ouse river.

Given the length of this river system and the substantial differences in the physical characteristics of the system downstream, was there evidence of a pattern in the percentage abundance of each functional feeding group downstream?

In the case of shredders, which were generally under-represented in this system (compared to 10% in the 614 RIVPACS reference sites) there is no evidence of a clear pattern of change downstream. This also applies in the case of the gatherers, which tend to be the dominant FFG group at most sites. However, the scrapers do show more of a consistent pattern with highest values at sites 1-4, somewhat lower values at 5 and 6 and a further decrease at sites 7-9. In contrast, filterers exhibit a consistently lower percentage abundance at sites 1-4 than at all sites further downstream, as expected in the RCC. Finally, predators show substantial changes between sites, but with their greatest representation at sites 7-9. In conclusion, although some features of the scrapers and filterers follow the expectations of the RCC, this is not the case in the remaining three functional feeding groups.

The River Exe in south-west England, with 7 sites over a distance of 78 km, shows a more even progression in physical change downstream whilst retaining a coarse substratum throughout. The most downstream site is substantially wider and deeper than all upstream sites. Shredders have a higher percentage abundance at sites 1-4 than at sites 5-7, as anticipated by the RCC. Scrapers achieve highest percentage abundance at sites 5 and 6 before decreasing substantially at site 7. Gatherers exhibit a relatively even pattern of abundance throughout, although there are undoubted changes in taxonomic composition downstream. Filterers have their highest percentage abundance at downstream sites 6 and 7, whilst there is no clear pattern for predators, although the highest percentage occurrence is at site 7. Thus, shredders, scrapers and filterers all show some conformity with the predictions of the RCC on this river system.

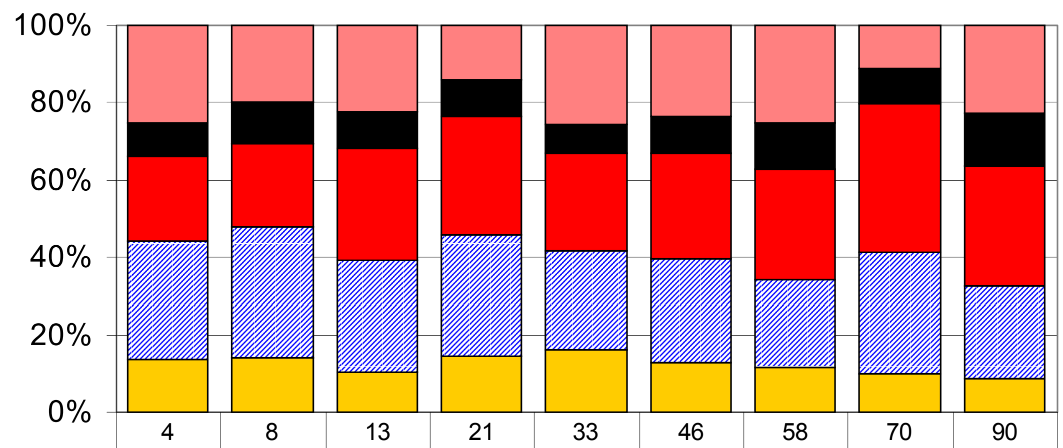


	4	9	17	29	41	59	78
predators	21.6	25.6	24.4	23.6	25.5	22.7	27.0
filterers	7.9	4.9	5.6	6.9	6.3	9.5	10.2
gatherers	30.5	28.4	31.8	29.1	28.4	28.5	31.3
scrapers	28.9	28.7	26.4	29.9	33.3	35.9	23.2
shredders	11.1	12.5	11.8	10.6	6.5	3.4	8.3

Figure 4.16: Percentage abundance of each functional feeding group in relation to distance from source (4, 9, 17, 29, 41, 59 and 78 km) of sites down the River Exe.

Finally, nine sites were available for analysis on the River Usk in south Wales. Like the River Exe, the Usk showed some progressive changes in its physical features downstream, whilst retaining a coarse substratum. However, Usk reservoir was present between sites 1 and 2. Shredders were normally present in higher percentage abundance at upstream sites (1-5) than at downstream sites, but site 4 was an exception. In this river scrapers were better represented at the most upstream sites 1-4 than further downstream, although site 8 also had high representation of scrapers. Gatherers showed substantial between site differences, in contrast to the River Exe and whereas percentage representation at sites 1 and 2 was low, it was unusually high at site 8. Filterers assumed greatest percentage abundance at downstream sites 7 and 9. Predators exhibited a considerable degree of between-site variation in percentage abundance with unusually low representation at sites 4 and 8. Thus, on the Usk, only shredders and to a certain degree the scrapers and filterers conformed to expectation with respect to the RCC.

In summary, although each of shredders, scrapers and filterers did on some rivers, and in particular on the River Exe, provide some evidence of progressive change downstream in the manner expected by the RCC, there were frequent exceptions and little in the way of pattern in the case of the gatherers and predators. We can therefore conclude that, based on numerical data (as opposed to biomass or production data) obtained from RIVPACS samples identified to family level with attached abundance categories, three rivers in different locations within England gave differing results and only weak evidence in support of the RCC.



	4	8	13	21	33	46	58	70	90
predators	25.1	20.0	22.1	14.1	25.7	23.5	25.3	11.3	22.8
filterers	8.7	10.5	9.6	9.6	7.4	9.7	11.8	9.0	13.8
gatherers	21.9	21.6	28.8	30.4	25.2	27.1	28.5	38.3	30.7
scrapers	30.6	33.7	29.0	31.4	25.7	26.8	22.6	31.3	24.3
shredders	13.8	14.2	10.4	14.5	15.9	12.9	11.8	10.0	8.5

Figure 4.17: Percentage abundance of each functional feeding group in relation to distance from source (4, 8, 13, 21, 33, 46, 58, 70 and 90 km) of sites down the River Usk.

4.9 Summary and Conclusions

In this package, an attempt has been made to provide a new viewpoint on the macroinvertebrate community data collected for RIVPACS through the application of the functional feeding group (FFG) approach, in order to shed light on the functioning of the system.

Use of information on abundance is critical to studies designed to provide insights into the functioning of running-water systems and therefore, in using information acquired for RIVPACS, it was necessary to utilise the family-level log category data. The lack of abundance data relating to individual species within the RIVPACS dataset meant that species-level analyses could not be attempted.

Five functional feeding groups were defined for this study, namely shredders, scrapers, gatherers, filterers and predators. Each family recorded in the RIVPACS III dataset was assigned to the FFG system using two separate methods. These were a) the proportional method and b) the use of the dominant FFG. The former method was used for all the main analyses because it is more realistic and robust.

RIVPACS samples are timed pond-net samples designed to include all available habitats in proportion to their occurrence. They may be viewed as a short cut/crude attempt to encapsulate at least some of the basic features of community structure, but cannot take the place of a replicated quantitative sampling programme which takes account of each habitat at a site. In addition, the direct use of logarithmic category abundance data, which ignores the fact that the various families differ in the body size of individuals, is not ideal. The use of biomass or even production data would be more appropriate, but is unrealistic in the present assessment.

The River Continuum Concept (RCC) of Vannote *et al*. (1980) predicts changes in relative dominance (as biomass) of functional feeding groups along the length of (pristine) running-water systems. Shredders, in utilizing coarse particulate organic matter such as leaf litter, are predicted to be co-dominant with collectors in headwaters. Scrapers are expected to follow shifts in primary production and therefore become relatively more important in midsized rivers. As river size increases, there will be a general reduction in detrital particle size, enabling collectors (both collector gatherers and filterers) to dominate the macroinvertebrate assemblages of large rivers. The predator component of the fauna is expected to change very little with stream order.

Of the many published studies around the world which have examined this concept, a majority have provided qualified support, but others have not. The 614 reference sites in the Great Britain module of RIVPACS III were examined from several viewpoints, including a series of distance downstream categories. This was considered to be more appropriate than the use of stream order because drainage pattern, which has a major influence on stream order, depends upon underlying geology and Great Britain is notable for the diversity of its geology.

When the mean relative abundance of the five functional feeding groups was examined in relation to distance downstream across the 614 RIVPACS sites, it was found that the basic pattern to emerge was in broad agreement with the predictions of the RCC (Table 4.9 and Figure 4.5). That is, shredders had their highest relative abundance in headwaters (< 5 km from source) and decreased downstream. The relative abundance of scrapers increased very slightly downstream, peaking in the 41-84 km downstream category. Collector gatherers and filterers together maintained a dominant role throughout the dataset. This broad gatherer category remained very stable downstream, apart from in the 85-203 km distance category, where there was a slight overall increase caused by the gatherer filterer component. The predator category was also very stable downstream, with only a very slight rise with increasing distance downstream.

It is worth bearing in mind that the relatively small landmass of Britain means that it only has small river systems compared to continental catchments. Therefore, the FFG patterns expected in high-order river systems, including an overwhelming dominance of the collector group, are unlikely to emerge in their final form.

Overall, the mean relative abundances derived from the 614 RIVPACS reference sites were 10% shredders, 27% scrapers, 30% collector gatherers, 10% collector filterers and 23% predators. These average percentages were approximately the same, regardless of season (i.e. the spring, summer and autumn RIVPACS sampling seasons).

Examination of the relative abundance of each FFG on three river systems in different geographical locations in England and Wales provided some evidence of pattern, as predicted by the RCC. However, there was also some unexplained between-site variation. This may have been the result of discontinuities along the river system impacting on available food resources (and hence FFGs), but could also be a demonstration that the RIVPACS sampling technique is incapable of documenting changes in FFGs with sufficient accuracy. The real reason is unclear.

When differences between the observed relative abundances of each FFG were analysed in relation to TWINSPAN groups 1-35, they were shown to be statistically highly significant. Nevertheless, the relative abundances of the five FFGs varied in a less consistent manner with the environmental characteristics of sites than did the various BMWP indices, and especially ASPT. Thus, RIVPACS will be less effective at predicting the expected relative abundance of FFGs than the expected values of BMWP indices.

Because the relative abundances of the FFGs vary little between TWINSPAN groups, the expected (E) values predicted by RIVPACS are fairly similar across the full range of sites. As a result, O/E ratios of the relative abundance of the FFGs will be very highly correlated with observed (O) relative abundances and hence the pattern of values for the O and O/E values across a wide range of sites will be similar and lead to similar conclusions.

Following on from this appraisal of the behaviour of the five FFGs across the full range of high quality RIVPACS reference sites, the next step was to assess whether there were trends in the relative abundance of FFGs in relation to site quality. The BAMS study sites (Furse *et al*. 1995), which included sites of differing quality in different river types were of particular value because they included replicated samples in each of three seasons. Replication enables an assessment to be made of the variability in the relative abundance of FFGs *due to sampling variation*. Clearly, if sampling variability is high, it will be difficult to detect differences between sites due to site quality and/or site type.

The observed relative abundance of each FFG from each of the 144 BAMS replicates was plotted against EQI_{TAXA} and also against $EQI_{ASPT.}$ Only two FFGs demonstrated a strong relationship with site quality. Whereas gatherers formed 20-30% of total log abundance at good quality sites, their relative importance increased as site quality decreased such that they contributed 50-60% of total log abundance at very poor quality sites (Figure 4.9). In contrast, the relative abundance of predators was least at very poor quality sites (ca. 10% for sites with values of EQI_{TAXA} of 0.3) and peaked at ca 25% relative abundance at sites with intermediate site quality (EQI_{TAXA} of 0.5 - 0.8).

As anticipated, the small range of expected relative abundances predicted by RIVPACS meant that the correlation of observed relative abundances and O/E relative abundances with the EQIs were very similar. In other words, standardising by the RIVPACS expected values did not improve relationships between the observed relative abundances of each FFG and site quality. In view of the limited number of BAMS sites (16) and the amount of scatter in the relative abundance of each FFG at any given river quality, it was considered important to examine these relationships using the much larger 1995 GQA dataset.

Correlations between the relative abundance of each FFG and EQI_{TAXA} and also EQI_{ASPT} were found to be weaker for the available 6106 GQA sites than for the more limited BAMS dataset. (See Tables 4.14 and 4.13). It was also apparent that there was considerable variation in the relative abundance of any given FFG amongst sites of a given EQI value. Despite this, there were still trends in the relative abundance of each FFG with respect to site quality (Table 4.15). Thus, poor quality sites had relatively more gatherers and consequently relatively fewer filterers and predators, and to a lesser extent relatively fewer scrapers and shredders. Once again, as anticipated, a similar pattern of results was obtained when the relative abundances were standardised by the expected values as O/E ratios.

In conclusion, it was apparent that the relative abundance of the various FFGs varied only weakly with the environmental characteristics of a wide range of high quality reference sites and substantial differences in FFGs only occurred at very poor quality sites.

These findings increase our knowledge and understanding of macroinvertebrate assemblages in British rivers. However, several factors indicate that there would be little to be gained at present by incorporating the facility to generate expected FFGs in the next version of RIVPACS. These factors include the marginal differences in FFGs across reference sites, the high level of variation in FFGs for a given quality of site, and the fact that extreme response in FFG behaviour is limited to poor quality sites only. These sites can be recognised very effectively using the existing EQI_{TAXA} and EQI_{ASPT} approach.

4.10 Recommendations

1. In view of the limited practical application of FFGs based on RIVPACS samples, it is recommended that no attempt is made to incorporate procedures for calculating the expected relative abundances of each FFG for any given site with stated environmental features into the next version of RIVPACS.

2. However, the possibility that this approach might have some practical application at a future date should be kept under periodic review. Thus, the possibility of calculating the estimated biomass of each FFG or understanding the factors contributing to variability in relative abundances of FFGs at poor quality sites (different forms of stress?) may repay future investigation.

3. The family-level designation of FFGs for Great Britain, although relatively crude and subject to future improvement may, nevertheless, be of value in other studies undertaken by the Environment Agency or their contractors. In particular, the probability-based system for designating FFGs is more realistic and robust than the simpler version which designates one dominant FFG for each family.

4. The use of FFGs has greater credibility where quantitative sampling procedures are being used by the Agency or their contractors. For example, numerical (or biomass) data could be used to investigate spatial change along a river system or temporal change at a site subject to periodic stress. In each case, changes in the relative abundance of FFGs might provide understanding of changes in available food resources.

5. Within Europe, attempts have already been made to designate FFGs at species level (Moog 1995). Issues related to conservation and biodiversity are now receiving a higher profile within the Agency, and there is an argument for generating FFGs at the species level in order to acquire more comprehensive knowledge of the British macroinvertebrate fauna. In the future, there will be an increasing need for this and other forms of information on the biological attributes of individual species to be easily accessible from a database for application to a wide range of conservation and management issues.

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5. EVALUATION OF THE USE OF RIVPACS IN THE CONTEXT OF BIODIVERSITY AND SUSTAINABILITY BY J F WRIGHT

5.1 Introduction

In 1990, the government published a White Paper entitled '*This common inheritance, Britain's environmental strategy'*. In this document sustainable development was described as follows:

Living on the earth's income rather than eroding its capital. Keeping the consumption of renewable natural resources within the limits of their replenishment. Handing down to successive generations not only man-made wealth, but also natural wealth, such as clean and adequate water supplies, good arable land, a wealth of wildlife, and ample forests.

In 1992, at the Earth Summit held at Rio de Janeiro, a total of 157 governments signed the Convention on Biological Diversity and in so doing, agreed to take positive action to halt and reverse the alarming loss of habitats and also animal and plant species around the world.

The Convention required the development of national plans for the conservation and sustainable use of biological diversity, and in 1994, the UK Government launched '*Biodiversity: the UK Action Plan*' (Department of the Environment, 1994). The objective was to conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all appropriate mechanisms. The responsibility for overseeing implementation of this objective was addressed by a steering group whose 1995 report (Department of the Environment, 1995) included the principles for delivering the plan and a number of costed actions plans for species and habitats considered to be under greatest threat.

The Environment Agency has a more holistic role than the organisations from which it was formed. Its principal aim, as set out in the Environment Act 1995, is 'to protect or enhance the environment, taken as a whole, in order to play its part in attaining the objective of sustainable development, as guided from time to time by Ministers'.

Statutory guidance has now been issued by Ministers with respect to the Agency's overall objectives and its contribution to sustainable development. Amongst the requirements included in this guidance is the need to conserve and enhance biodiversity. In response to this guidance, the Agency reassessed its environmental monitoring and assessment programme. In January 1997, the Agency issued a consultation document entitled '*Viewpoints on the Environment: developing a national environmental monitoring and assessment framework*'. The proposed framework includes six complimentary 'viewpoints' of which one – the status of biological communities and populations, and of biodiversity – is of particular relevance to this package.

The Agency continues to play a very important role in the issues of biodiversity and sustainability. Two recent examples include the following. First, the publication in April 2000 of '*Focus on Biodiversity: The Environment Agency's contribution to* *wildlife conservation*', which provides an excellent summary of the contribution made by the Agency to the UK Biodiversity Action Plan. Second, the production in June 2000 of a consultation draft entitled '*Creating an Environmental Vision*' which progresses the Environment Agency's contribution to sustainable development by way of a better environment in England and Wales. Recently, the final version of this document has appeared under the title *'An Environmental Vision: The Environment Agency's contribution to Sustainable Development'.*

The purpose of the current package is to assess the current role of RIVPACS in the wider context of biodiversity and sustainability and determine whether its value may be enhanced.

5.2 Objectives

The overall objective is as follows:

'To produce a scoping report on how RIVPACS may be modified or used to address the needs of the Agency for monitoring and assessing sustainability and contributing to the maintenance of biodiversity and to identify small modifications to the output of the existing RIVPACS which could be implemented at the next revision of the software'.

The specific objectives (modified from the original specification with the agreement of the nominated officer) are as follows:

1. To identify, in broad terms, how the current version of RIVPACS could contribute to the UK's responsibilities under the Convention on Biological Diversity.

2. To describe outputs which could be generated from RIVPACS that would be of use in assessing biodiversity, species rarity and threat status, and also habitat rarity. This may include flagging the Red Data Book status and other conservation status of taxa, and providing information on the commonness of taxa in the RIVPACS reference data-set.

3. To identify any species in RIVPACS that are in any of the biodiversity lists drawn-up by the UK Biodiversity Steering Group. If there are any, indicate how much data is included in RIVPACS, and how reliable RIVPACS predictions may be for them.

4. To identify modifications to RIVPACS which may assist with the UK's responsibilities under the Convention on Biological Diversity. To recommend which of these should be implemented and describe the modifications required to RIVPACS.

5.3 Sustainability/Sustainable Development

5.3.1 Background

A definition of 'sustainable development ' was provided at the beginning of this chapter, taken from the Government White paper published in 1990 and entitled '*This common inheritance, Britain's environmental strategy'*. Since then, a considerable amount of thought has gone into this subject at national and international level, but also at regional and local levels within this country. The UK Government strategy for sustainable development, entitled '*A better Quality of Life'* has four main aims. These are:

- Social progress which recognises the needs of everyone
- Effective protection of the environment
- Prudent use of natural resources
- Maintenance of high and stable levels of economic growth and employment

The Environment Agency, in responding to the Government's strategy for sustainable development, has now set out a thematic approach in their document entitled *'An Environmental Vision: The Environment Agency's contribution to Sustainable Development'.* This represents a new attempt to define long-term objectives within the broader social context which is essential to sustainable development. In all, there are nine themes as follows:

1. a better quality of life
2. an enhanced environment for wildlife
3. cleaner air for everyone
4. improved and protected inland and coastal waters
5. restored, protected land with healthier soils
6. a 'greener' business world
7. wiser, sustainable use of natural resources
8. limiting and adapting to climate change
9. reducing flood risks

This is a very wide-ranging subject and one in which the current version of RIVPACS, and future developments based on the system and its supporting dataset, do have a role. Given that this package is essentially concerned with exploring new ideas, it is appropriate to start with a broad canvas before starting to focus in on the particular areas where RIVPACS and associated data can make a genuine contribution.

Within *'An environmental vision'* each of the above nine themes is explored and through this document it is possible to flag areas where RIVPACS currently plays a role and where there is potential for enhancement of that role in the future. In order not to restrict this process from the outset, a majority of the above nine themes will be considered briefly. However, four of them, including 3 (cleaner air for everyone), 5 (restored, protected land with healthier soils), 6 (a 'greener' business world) and 9 (reducing flood risks) will be excluded because their potential for impacting on river systems is already covered by other themes.

'An environmental vision' provides a long-term objective for each theme, together with some consequences which follow on as result of pursuing that goal. Both the stated Environment Agency long-term objective and *selected* consequences for the remaining six themes are listed below. These are followed by some very brief comments, in bracketed italics, giving instances where RIVPACS is currently relevant or may be relevant in the future.

5.3.2 A better quality of life

Long-term objective: People will have peace of mind from knowing that they live in a healthier environment, richer in wildlife and natural diversity - an environment that they care for and can use, appreciate and enjoy.

Therefore:

- People will be confident that the environment is well cared for, is not damaged by pollution, and does not provide a health risk because of human activities.
  (RIVPACS currently provides a mechanism for determining whether a running-water site is of high biological quality)

- The environment will be greatly valued and cared for by all sectors of society, as a source of food, water, materials, income, recreation, sport and wildlife conservation.
  (There is the potential for further information on the freshwater fauna to be made more widely available, first to the Environment Agency and later to the public at large on the occurrence of both common and rare species of running-water macroinvertebrates and on locations where taxon richness is high).

- Information and processes will be readily available to enable citizens, communities, businesses and government and its agencies to agree quality of life and environmental targets and the plans that will realise them.
  (RIVPACS currently offers to the Environment Agency a clear demonstration of the biological quality of a given site and whether quality has changed over time. There is potential for this information to be made more widely available).

5.3.3 An enhanced environment for wildlife

Long-term objective: Wildlife will thrive in urban and rural areas. Habitats will improve in their extent and quality to sustainable levels for the benefit of all species. Everyone will understand the importance of safeguarding biodiversity.

Therefore:

- Degraded habitats, especially rivers, estuaries, and wetlands, will have been restored.
  (The process of restoration, in terms of the return of the expected fauna, can be documented using RIVPACS. Questions related to the local availability of lost taxa may also be addressed using the RIVPACS dataset)

- Wildlife corridors and their associated habitats will be of high quality, with no artificial barriers to wildlife movement.
  (Sites of high biological quality, as determined using RIVPACS, require both high quality habitat and the absence of major instream stresses such as water pollution)

- The UK's Biodiversity Action Plan will have been successfully delivered and priority species will no longer be under threat.
  (Over the past 20 years, sampling at RIVPACS reference sites has increased our knowledge of some BAP species. The current extensive network of Biological GQA sites operated by the Environment Agency may have some potential for documenting the future spread of BAP species)

- There will be a broad consensus on how biodiversity should be managed against a background of climate change.
  (The RIVPACS dataset provides a unique historical record of the geographical distribution of 642 taxa throughout the UK in the last 20 years of the 20th Century)

- Threats to the genetic integrity of our native wildlife will be greatly reduced.
  (The occurrence and spread of alien species is of continuing concern. Sampling at RIVPACS reference sites and also the more extensive quinquennial sampling at the Environment Agency Biological GQA sites may help to document the rate of spread of alien species and their future impact on the native fauna)

5.3.4 Improved and protected inland and coastal waters

Long-term objective: Our rivers, lakes and coastal waters will be far cleaner. They will sustain diverse and healthy ecosystems, water sports and recreation such as boating and fishing, and those uses needed by a thriving and healthy community.

Therefore:

- Abstractions and discharges will neither damage the environment, nor threaten human health.

- Damaging pollution incidents will have been prevented at source.

- The causes of water pollution, eutrophication, and acidification will have been fully controlled.
  (Again, for abstractions and pollution as listed in the three bullet points above, the use of RIVPACS O/E ratios can establish whether damage has occurred and documentt improvement over time).

- Surface waters will sustain a diverse variety of habitats and wildlife.
  (Because RIVPACS offers site-specific predictions of the macroinvertebrate fauna to be expected at a given site, it provides relevant information on both the species composition and the site richness to be expected at a site with given environmental features).

5.3.5 Wiser, sustainable use of natural resources

Long-term objective: Business, public agencies, other organisations and individuals will minimise the waste they produce. They will reuse and recycle materials far more intensively, and make more efficient use of energy and materials.

Therefore:

- People will be aware of their natural resource consumption and take responsibility for its environmental impact.
  (RIVPACS O/E ratios provide an important method for measuring environmental impact and subsequent improvement over time).

- Water will be acknowledged as a valuable resource and will be used wisely by all sectors of society. The justifiable demands for water use will be understood and the means of meeting them in place.
  (RIVPACS may provide one means of early warning to ensure that excessive groundwater and surface water abstraction, with undesirable consequences for the macroinvertebrate fauna as a result of man-induced low flows, is avoided).

5.3.6 Limiting and adapting to climate change

Long-term objective: Drastic cuts will have been made in the emission of 'greenhouse gases' such as carbon dioxide and society as a whole will have taken account of, and be prepared for, the probable changes to our climate. Therefore:

- Environmental monitoring programmes will provide accurate information on the direct effects of climate change.
  (As previously indicated, the RIVPACS dataset is a unique historical record of the geographical distribution of 642 taxa throughout the UK over the last 20 years. As such, it has some potential value as a yardstick against which to measure any future changes in the fauna resulting from the long-term effects of temperature changes and the impact of more floods and droughts. Similarly, RIVPACS outputs may help to assess some of these changes).

5.4 Biodiversity

5.4.1 Definition of Biodiversity

The word 'biodiversity' is a contraction of the term 'biological diversity'. The latter has a long history of use in a variety of contexts but its current usage dates from the 1980s. Norse *et al*. (1986) were the first to refer unequivocally to biological diversity at three different levels, namely genetic (within species), species (species numbers) and ecological (community) diversity. The contracted form 'biodiversity' was coined by an American, W. R. Rosen, in 1985 prior to a key meeting, the National Forum on Biodiversity, convened in Washington D.C. in September 1986.

'Biodiversity' can be considered as synonymous with 'biological diversity' and this is reinforced by the official definition in Article 2 of the 'Convention on Biological

Diversity' signed by 156 nations and the European Community at the United Nations Conference on the Environment and Development, 'The Earth Summit' in 1992. Thus:

'Biological diversity' means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Clearly, when using the term biological diversity or biodiversity in a scientific context, it is important to convey whether you are using the term in its general sense to embrace all three levels, or whether one specific level is intended. Some clarification of each of these three levels is provided below.

Genetic Diversity

This is the heritable variation within and between populations of organisms. Ultimately, it is represented in the sequence of the four base-pairs which, as components of nucleic acids, constitute the genetic code. The genetic variation present within an interbreeding population is acted upon by selection and the consequent differential survival results in changes in gene frequencies, which are equivalent to population evolution. Thus, genetic variation enables natural evolutionary change to occur.

Within the scientific community there is an increasing awareness and concern over loss of genetic diversity. The Environment Agency share this concern and are pledged to ensure that the genetic integrity of aquatic life, and in particular the genetic integrity of freshwater fish is conserved. Threats can come from several directions including pollution, habitat loss and also the introduction of alien species. In reality, resources are likely to be focussed on a small number of high profile species. The genetic variation within and between populations of macroinvertebrates is largely unknown and current actions to limit pollution, habitat loss and the spread of alien species are probably the most realistic approaches for the conservation of genetic diversity. The importance of maintaining genetic diversity becomes ever more relevant as the Agency considers the consequences of climate change.

Species diversity

Biodiversity is often used as a synonym of species diversity, and in particular of species richness, which is simply the number of species in a site or habitat. Consideration of richness for a given taxonomic group in, for example, a river system, a country or globally is also most naturally done at species level. It is, after all, at the species level that evolutionary mechanisms act, and the origin and extinction of species are the principal agents in governing biological diversity.

However, it is not always possible to recognise and enumerate taxa at the species level, and for this reason some scientists prefer to use the term 'organismal diversity' in order to embrace taxonomic categories above species rank. Because of the common problem of identifying all the species present at a site, scientists have also been investigating the question of whether the number of higher taxa, such as phyla, orders and families provide a more appropriate (and more easily acquired) measure of biodiversity.

A further consideration is whether all species at a site, within and across the systematic groups represented at that site, contribute equally to biodiversity. It is generally accepted that a site with many different higher taxa has more 'taxonomic diversity' than a site with fewer higher taxa but more species. Ideally, a measure of the biodiversity of a site should therefore indicate how different the organisms are from each other. For example, marine habitats frequently have more different phyla but fewer species than terrestrial habitats, that is, they have higher taxonomic diversity but lower species diversity. Measures are currently under development to try to encapsulate these features.

Ecosystem Diversity

It is questionable whether the term 'ecosystem diversity' should be used, and some have preferred the term 'community diversity' or even 'ecological diversity'. The word 'ecosystem' was first use by Tansley (1935) to refer to a community of organisms in relation to their physical environment. Given that the physical environment does not have biodiversity, the term ecosystem diversity does not seem appropriate.

In practice, assessment of diversity at ecosystem, community or habitat level is fraught with problems because there are no global systems of classification through which to compare diversity. Hence ecosystem/community diversity is frequently assessed on a regional or local basis using well-studied life forms. It may be evaluated using an assessment of the relative abundance of different species as well as a consideration of the types of species present. Community A would be regarded as more diverse than community B when the total number of individuals present in A was shared more equitably between the component species than in B, where a few species accounted for most of the individuals. With regard to types of species, a community might be regarded as more diverse when it included different size classes of organisms, several different trophic levels or different taxonomic groups. The problem with such schemes is that different weightings can be given to different factors and, without agreed standards, it becomes difficult to rank different areas.

In conclusion, many basic and difficult questions remain on the practicalities of measuring biodiversity at the genetic, species and community level. Undoubtedly, the major focus for the Environment Agency at present is on species diversity. The recent Environment Agency publication entitled 'Focus on Biodiversity' provides a clear and simple answer to the question 'What is biodiversity?' It is repeated below.

'Biological diversity, or biodiversity, is the living component of the natural world and embraces all plant and animal species and communities associated with terrestrial, aquatic and marine habitats. It also includes genetic variation within species. Wildlife conservation generally aims to maintain or enhance natural biodiversity'.

5.4.2 Wildlife conservation and the UK Biodiversity Action Plan

Recording and conservation of the freshwater fauna in the UK

Although the primary function of the Environment Agency is not wildlife conservation, it does make a major contribution to the conservation of wetland and riverine habitats and their biota through its functions in pollution control and water management. In addition, there are many specific ways in which the Agency contributes to wildlife conservation. A number of these are outlined in 'Focus on Biodiversity'.

Before providing brief details on the UK Biodiversity Action Plan, it is worth making a few introductory remarks on some aspects of research and survey in river ecology which have laid the groundwork on which the present actions can proceed. First, it is critical to be able to identify organisms accurately and the UK is particularly fortunate in having access to reliable keys to most major groups of freshwater macroinvertebrates as a result of the efforts of past and present generations of taxonomists. The number of species known to occur in fresh water in the British Isles has increased since the initial coded checklist published by Maitland (1977). An up-to-date version of the present Maitland/Furse coded checklist is available on the CEH website (www.ceh.ac.uk/subsites/eic/ddc/furselist/index.htm).

Second, the long-term efforts of both amateur and professional collectors have provided detailed knowledge of the geographical distribution of selected groups of freshwater macroinvertebrates. The Biological Records Centre co-ordinates a number of Biological Recording Schemes for freshwater invertebrates and again, further information on these can be accessed on the CEH website (www.ceh.ac.uk/subsites/eic/brc/index.htm).

However, there are a number of groups of freshwater macroinvertebrates for which there are no recording schemes. The RIVPACS database, which includes a total of 642 taxa recorded at the 614 sites in Great Britain plus the 70 reference sites in Northern Ireland, represents a unique historical record of the macroinvertebrate fauna at these sites, because they were all subjected to the same level of identification. A full listing of the 637 taxa recorded at the 614 sites in Great Britain, together with their frequency of occurrence may be found in Wright *et al*. (1996). An equivalent listing for the 313 taxa recorded at the 70 sites in Northern Ireland may be found in Wright *et al*. (2000).

For some time the statutory nature conservation organisations have developed procedures for recognising threatened species in order to take action when this was considered necessary. Species with Red Data Book status are regarded as threatened. There are two Red Data Books for invertebrates: one for invertebrates other than insects (Bratton, 1991) and a second for insects (Shirt, 1987). These books, which include terrestrial and freshwater species, use a series of progressive threat categories, which define the extent of the perceived threat. The threat categories used in these books include RDB 1 (Endangered), RDB 2 (Vulnerable) and RDB 3 (Rare). Although it is important to recognise that the species are categorized according to degree of threat and not rarity, taxa in RDB categories 1-3 are unlikely to occur in more than 15 10 x 10 km squares of the National Grid.

Rare species may be accorded 'Nationally Scarce' status (previously referred to as 'Nationally Notable'), in which case they should be known from 100 or fewer 10 x 10 km squares. A further division into Nationally Scarce A (30 or fewer 10 x 10 squares) and Nationally Scarce B (31-100 squares) has also been used for some groups.

All Red Data Book and Nationally Scarce species, as defined above, which occurred at any of the 614 reference sites in the RIVPACS data-set for Great Britain have been flagged in Wright *et al.*(1996).

However, in 1994 the World Conservation Union (IUCN) adopted a revised list of Red List categories and criteria (IUCN, 1994). The new system of threat assessment relies heavily on quantitative criteria and has been designated for use at the global scale. It is also being recommended for use at regional and national levels. This system is more rigorous than the previous version, and results in fewer species being assigned to the Red Lists (now defined as Critically Endangered, Endangered and Vulnerable). Further categories including Data Deficient (not Red List, but may be when more data available) and Near Threatened (not Red List, but present in 15 or fewer 10 x 10 km squares in GB) are also available. In addition, the IUCN has accepted that individual countries are entitled to create their own categories. Hence, the British system of designating Nationally Scarce species will continue.

As yet, the new system has not been widely applied to freshwater macroinvertebrates and the old system is still in use, with the exception of one major group, the Coleoptera. The Joint Nature Conservation Committee plan to publish a review of the scarce and threatened Coleoptera of Great Britain (Foster, in press) which will give listings of both the present IUCN categories and also the previous RDB and Nationally Scarce categories.

Protection of freshwater species within Great Britain is through the Wildlife and Countryside Act 1981, together with subsequent quinquennial reviews. Schedule 5 of the Act has a select list of freshwater invertebrates, most of which are Red Data Book species, where legal protection is considered likely to bring tangible conservation benefits. It also includes a few additional species which are giving cause for concern, including the white-clawed crayfish (*Austropotamobius pallipes*) and the freshwater pearl mussel (*Margaritifera margaritifera*).

The UK Biodiversity Action Plan

The Earth Summit in Rio de Janeiro in 1992 resulted in an International Agreement on sustainable development which included amongst its major initiatives, the Convention on Biological Diversity. This is essentially a commitment to conserving and sustaining the variety of life on earth. Each of the 157 governments which signed the agreement accepted the need to develop national strategies, plans and programmes for the conservation and sustainable use of biological diversity, and to share resources to help implement such programmes.

The UK Government response to the Biodiversity Convention appeared in 1994 under the title *Biodiversity: The UK Action Plan.* This sets out the broad strategy for conserving and enhancing wild species and wildlife habitats in the UK for the next 20 years. The overall goal of the plan is *'to conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all* *appropriate mechanisms'*. The objectives for conserving biodiversity which underpin this goal are to conserve and, where practicable, to enhance:

- the overall populations and natural ranges of native species and the quality and range of wildlife habitats and ecosystems;

- internationally important and threatened species, habitats and ecosystems;

- species, habitats and natural and managed ecosystems that are characteristic of local areas; and

- the biodiversity of natural and semi-natural habitats where this has been diminished over recent decades.

A UK Biodiversity Steering Group was set up with the task of preparing a detailed programme of action in order to achieve the above objectives. *Biodiversity: The UK Steering Group Report* was published in December 1995 and included the following key components:

- Developing costed targets for our most threatened and declining species and habitats.

- Establishing an effective system for handling the necessary biological data at both local and national level.

- Promoting increased public awareness of the importance of biodiversity, and broadening public involvement.

- Promoting Local Biodiversity Action Plans as a means of implementing the national plan.

The selection of what are now called 'priority' species and habitats is an ongoing process and is based on a detailed appraisal of the current status of critical species and habitats in the UK, together with the threats to their survival. Since the publication of the first group of costed action plans in 1995, which provided a way ahead for 116 priority species and 14 habitats under the greatest threat, there have been six further volumes of action plans, covering a total of 391 species and 45 habitats. Note, however, that only a small fraction of these relate to freshwater invertebrates found in flowing waters or to lotic habitats. For each priority species and habitat, quantifiable targets are being set, defining clear objectives for their conservation. Some examples related to freshwater species may be found in *Focus on Biodiversity*. By monitoring future progress in achieving stated objectives, it will be possible to measure the success achieved for individual species and habitats.

The UK Steering Group recognised early on the need for and benefits to be gained by involving a broader range of organisations in the process. In fact, over the last few years, there has been a remarkable awakening of interest and concern over the future of the flora and fauna of the UK, and the Steering Group were able to build on the enthusiasm of a number of non-governmental organisations to participate in the process.

As a result, individual action plans to safeguard species and habitats have frequently involved not only the participation of the statutory nature conservation agencies (English Nature, Countryside Council for Wales, Scottish Natural Heritage), together with the Environment Agency, but also organisations such as the Royal Society for the Protection of Birds and the Wildlife Trusts partnership.

5.5 Current Outputs from RIVPACS Relevant to Biodiversity and/or Sustainability

5.5.1 Background

From the previous sections, it is apparent that RIVPACS is relevant to the field of sustainability, and more specifically to the topic of biodiversity. Hence, in this section we will identify, in broad terms, how the current version of RIVPACS can contribute to the UK's responsibilities under the Convention on Biological Diversity (specific objective 1).

Essentially, RIVPACS contributes to two separate, but interconnected, topics:

- the appraisal of site (or habitat) quality; and
- the appraisal of the component taxa (at species, family or BMWP family level).

From the broad perspective of sustainability the first topic (site quality) is relevant to three headings included in the publication entitled *'An Environmental Vision: The Environment Agency's contribution to Sustainable Development'*. They are *A better quality of life*, *Wiser, sustainable use of natural resources* and *Improved and protected inland and coastal waters*. The second topic (appraisal of taxa) is relevant to *An enhanced environment for wildlife* and *Limiting and adapting to climate change*.

The first objective of the UK Action Plan is 'to conserve and where practicable, to enhance the overall populations and natural ranges of native species and the quality and range of wildlife habitats and ecosystems'. Although the focus is on species, there is a clear understanding of the need to maintain high quality habitat for long-term survival of the biota.

Further, in the consultation document produced by the Environment Agency in 1997 entitled '*Viewpoints on the Environment: developing a national environmental monitoring and assessment framework*', two of the six 'viewpoints' in the proposed framework for use in appraising the state of the environment are:

- the quality of the environment as determined by assessing compliance with existing standards and targets; and
- the status of key biological communities and populations, and of biodiversity.

Thus, the current version of RIVPACS has a role to play in both of these areas of interest.

5.5.2 Appraisal of site quality

It has been said that biological surveillance of communities, with special emphasis on characterising taxonomic richness and composition, is perhaps the most sensitive tool now available for quickly and accurately detecting alterations in aquatic ecosystems (Cairns and Pratt, 1993). Different sites along the course of a single river and different types of rivers all have their own characteristic macroinvertebrate assemblages and hence this must be taken into account when considering the fauna to be expected at a previously unsampled site. RIVPACS has been developed to provide site-specific predictions of both the expected taxon richness and composition for a site with stated environmental features for comparison with the observed taxon composition and richness at that site (Wright, Sutcliffe and Furse 2000). The assessment can be undertaken for single seasons (spring, summer or autumn), paired seasons or three seasons combined. Within the Environment Agency, routine assessments are normally undertaken at BMWP family level, but family and species level are also available as options.

Appraisal of the biological quality of a site involves a comparison of the observed fauna in relation to the expected fauna. This observed/expected ratio may be in the form of the observed/expected number of taxa at the site, but in the case of BMWP family level, can also be expressed in the form of biological indices, such as O/E N-TAXA (number of BMWP taxa), O/E ASPT (Average Score Per Taxon) and O/E BMWP Score (Biological Monitoring Working Party Score).

O/E ratios (sometimes referred to as Ecological Quality Indices or EQIs) were first used on a large scale by the National Rivers Authority (NRA) in the 1990 National Biological Survey. Later research by Clarke *et al*. (1994) recommended that O/E ratios for N-TAXA and ASPT provided the most meaningful information. Following on from this, regional biologists within the NRA met to consider how best to integrate the O/E ratios for these two indices and to define a series of quality grades for use in the 1995 National biological General Quality Assessment (GQA) survey (Hemsley-Flint, 2000). Their final decision was to adopt six biological quality grades (a-f) ranging from very good (a) to bad (f).

By the end of 1995 the IFE delivered the new RIVPACS III software and this formed the basic framework for reporting the results of the 1995 National Biological survey. Then followed RIVPACS III+ (Clarke, 2000) which provided new procedures for detecting statistically significant temporal and spatial changes. These new procedures were applied to the data obtained during the 1995 and the previous 1990 survey in order to make between-year comparisons. An ability to make such detailed comparisons over time is critical if we are to detect a loss of biological quality due to pollutants/habitat change or, alternatively, a gain in quality as a result of pollution control or habitat restoration.

5.5.3 Appraisal of the taxa at species, family or BMWP family level

The term biodiversity is intended to include all the taxa within a community and is not restricted to rare and threatened species. RIVPACS offers a prediction for each site of

the expected taxon richness at the site and also the taxonomic composition at the level of identification requested.
Considering first taxonomic richness, the prediction can be made at species level (in which case it will draw on the 637 standardized taxa in the 614 site Great Britain reference dataset) but more frequently the Environment Agency uses BMWP family level data (based on the 82 BMWP families). The O/E N-TAXA ratio at BMWP family level provides information on whether macroinvertebrate biodiversity reaches expectation for the site whose environmental features were used in the prediction. O/E N-TAXA ratios below unity may indicate loss of quality due to pollution or poor habitat quality, but ratios in excess of unity are also possible and indicate that site richness exceeds expectation. The reasons for this would need to be assessed for each individual case but might, for example, indicate the presence of a high quality site with diverse habitats and/or extra features (e.g. a tributary stream) which was capable of supporting additional taxa.

In a recent study, Wright *et al*. (1998) used the 614 reference sites of the RIVPACS III dataset for Great Britain to compare macroinvertebrate site richness at three taxonomic levels (standardised species level, family level and BMWP family level). The study demonstrated very highly significant correlation coefficients between the number of species and families ($r = 0.890$) and between the number of species and BMWP families ($r = 0.854$) based on this comprehensive dataset. This result is not unexpected, but it has practical application in so far as BMWP family level data are available for a very wide range of sites in England and Wales as a result of the quinquennial GQA surveys undertaken by the Environment Agency. Sites shown to have high O/E N-TAXA at BMWP family level can be expected to be taxon rich at species level and hence the GQA survey results have broader relevance to the statutory conservation agencies in England and Wales with responsibilities for appraising the conservation value of river reaches.

RIVPACS also predicts taxonomic composition by providing a listing of taxa at the chosen taxonomic level, with expected probabilities of occurrence for each taxon, based on the standard sampling protocol. In other words, for any site with specified environmental features, the user is given the likelihood of capturing particular taxa after a standard sampling effort, based on the assumption that the site of interest is not subject to some form of stress. The taxa will include common, infrequent, and occasionally rare and also threatened species within the UK, although the last two categories will, inevitably, be listed very infrequently.

When considering the component taxa as opposed to site richness, species level predictions are more likely to be the focus of attention rather than family or BMWP family predictions. Whereas species predictions are offered with an attached probability of occurrence, the actual faunal listing for the site based on the standardized sampling period will record taxa as either present or absent. At a high quality site the expectation is that almost all taxa with a very high probability of capture will be present, that roughly half the taxa listed with a probability of capture around 50% will be present and that taxon occurrence will progressively tail off as predicted probability decreases further.

If one particular species is of interest then its absence at a site, despite a high predicted probability of occurrence, may imply that the site conditions are, or have recently been, unsuitable for that species. It is also possible to amalgamate the predicted probabilities of a number of taxa within one or more major taxonomic groups (e.g. Ephemeroptera, Plecoptera, Trichoptera etc.) and then compare the number of observed and expected taxa within each group (see Wright 1995). Knowledge of the susceptibilities of a particular taxonomic group or groups to particular forms of stress may help to explain the reason for under representation of one or more taxonomic groups at a site. As yet, little attention has been paid to interpretation of the significance of the absence of particular species at stressed sites. Instead, the concurrent use of O/E N-TAXA and O/E ASPT based on BMWP level data has been used to document the impact of stress on richness and composition.

5.6 Opportunities for Developments Within or Alongside RIVPACS

5.6.1 Introduction

RIVPACS has already progressed through three major versions and the last of these has been subject to some important additional features. These developments will continue into the future and are likely to include a user-friendly Windows version of the system and further developments currently being explored in other packages of this contract. In future, the benefits of having RIVPACS accessible on the World Wide Web, with access operated via a password system, may also become compelling. This approach has been adopted for AUSRIVAS, the Australian river assessment system (Simpson and Norris, 2000) which is based on the RIVPACS approach. This allows the Australian research group with responsibility for developing AUSRIVAS models for the different States and Territories in Australia to provide the latest updates and improvements with the minimum of delay.

In view of the probability of so many new developments in the next few years, it is sensible to consider which potential developments in the area of biodiversity are best placed within a future version of RIVPACS and which developments are best made alongside RIVPACS with easy access as and when required. Hence, Section 5.6.2 deals with specific objective 2 while section 5.6.3 extends the scope of this objective. Once these aspects have been explored, specific objective 3, which relates to the separate question of BAP species within the RIVPACS III standardised species list, is considered in section 5.6.4.

5.6.2 Potential developments within RIVPACS

Site richness

At present, a high proportion of the predictions undertaken using RIVPACS are at BMWP family level. This is in line with the use of RIVPACS as a rapid and effective method of assessing the biological quality of large numbers of sites, as undertaken in the quinquennial GQA surveys. As a consequence, all the procedures for calculating O/E ratios and for the subsequent grading of sites are centred around the use of BMWP family level data.

In future, as the need for information on the occurrence of individual species and site richness increases as a consequence of the higher profile of biodiversity and related issues, there may be growing pressure within the Agency for identification at family or species level at selected sites. As a consequence there will be a future need to:

- ***automate the calculation of O/E ratios at both family and standardized species level, in line with procedures currently available at BMWP family level***

Site Composition

RIVPACS predictions offer a listing of the taxa expected at a given site with defined environmental features in the absence of major environmental stress. The sequence of the listing is from the taxon with the highest expected probability of occurrence to the lowest expected probability. Where biological data for the site and season(s) are also available, the printout can indicate (with an asterisk) which of the taxa on the probability listing are actually present at the site.

Additional information could be added to the printout in order to increase the information content for individual taxa. In the context of biodiversity, the logical taxonomic level to use is the standardized species level. First, there is an opportunity to provide a broad indication of whether individual taxa are common, frequent or rare in running waters within Great Britain as follows:

- ***append to the probability listing the frequency of occurrence of each species derived from the 637 species in the 614 site Great Britain reference dataset***

In theory, frequency of occurrence data could also be provided at family and BMWP family level. However, this is less relevant to the issue of biodiversity and most Environment Agency biologists will be familiar with the status of each family in running waters.

Another topic relevant to biodiversity is provision of information to identify threatened species with Red Data Book (RDB) status and those relatively rare species with 'Nationally Scarce (NS) status'. (See section 5.4.1. for further details). It is apparent from Table 5.1 that although RDB and NS designations have been applied to a majority of the major taxonomic groups to be found in freshwaters, the listings are by no means complete. For taxa with no RDB and/or NS designations, frequency of occurrence data for the 614 RIVPACS III sites is the only source relating to rarity.

It would be useful to add the RDB/NS designations to species level predictions in order to alert biologists to the status of these species in the printout. If species in either of these categories were recorded at the site, this would provide a clear signal regarding the conservation interest of the freshwater assemblage. Hence:

- **identify within the probability listing any species with Red Data Book status; and**

- **identify within the probability listing any species with Nationally Scarce status**

As noted in an earlier section, all Red Data Book and Nationally Scarce species which occurred at any of the 614 reference sites in the RIVPACS data-set for Great Britain have been flagged in Wright *et al*.(1996). A first attempt at a listing of all freshwater macroinvertebrates in the British Isles with Red Data Book status or Nationally Scarce status is offered in Appendix 1. It is important to recognise that the status of species will change over time as new information is collated, and therefore this listing should not be seen as definitive. Note also that the original RDB system applies throughout this Appendix. Refer to Foster (in press) to obtain the revised IUCN Red List categories for aquatic Coleoptera.

Table 5.1: Contribution of each major taxonomic group to the 637 standardized taxa within the 614 GB reference sites in RIVPACS III. Groups for which Red Data Book (RDB) and Nationally Scarce (NS) designations have been made are shown, together with the supporting reference. A 'YES' in parentheses indicates that species have been designated in that taxonomic group but none is represented in the RIVPACS III data-set.

Major Group	No. taxa in 614 site dataset	RDB species designated?	Reference	NS species designated?	Reference
Tricladida	9	NO	-	NO	-
Gastropoda	29	YES	Bratton 1991	YES	Ball 1986
Bivalvia	22	YES	Bratton 1991	YES	Ball 1986
Oligochaeta	51	NO	-	NO	-
Hirudinea	14	(YES)	Bratton 1991	NO	-
Crustacea	11	(YES)	Bratton 1991	(YES)	Ball 1986
Ephemeroptera	37	YES	Bratton 1990	YES	Bratton 1990
Plecoptera	27	(YES)	Bratton 1990	YES	Bratton 1990
Odonata	13	(YES)	NCC 1989	YES	NCC 1989
Hemiptera	28	(YES)	Kirby 1992	(YES)	Kirby 1992
Coleoptera	104	YES	Foster 1992*	YES	Foster 1992
Megaloptera	3	NO	Kirby 1991	YES	Kirby 1991
Neuroptera	2	NO	Kirby 1991	(YES)	Kirby 1991
Trichoptera	98	YES	Wallace 1991	YES	Wallace 1991
Diptera	182	SOME	Falk 1991	SOME	Falk 1991

A further seven taxonomic groups were recorded, but not identified to species: Spongillidae; Hydridae; Chordodidae; Ectoprocta; Aeolosomatidae; Hydracarina; Lepidoptera

*A new publication (Foster, in press) which gives the revised IUCN Red List categories for the aquatic Coleoptera will soon be available.

5.6.3 Potential developments alongside RIVPACS

In theory, information relevant to biodiversity for the 637 running-water taxa present at the 614 reference sites in RIVPACS III could be made available as hardcopy, on a CD-ROM or via the World Wide Web. If a future version of RIVPACS were to be made available on the World Wide Web, then links to this ancillary information source would become even simpler. The two major sources of information are:

- ***dot maps to indicate the geographical distribution of standardized taxa present at the 614 RIVPACS sites*; and***

- ***information on the environmental ranges of the above species.***

* Information on taxa recorded at few sites may only warrant a descriptive statement.

Detailed information on the distribution and environmental ranges of the British fauna is valuable as a source of reference for current and future use by Environment Agency biologists. It provides a baseline against which to assess new and unexpected information. Over the last 25 years our knowledge in this field has increased considerably and some changes in the geographical distribution of both native and invading non-native species have been observed (Wright and Armitage, 2001). There are good reasons to anticipate further changes in the future (e.g. climate change) and a reliable source of information which can be built upon with new data is essential for future documentation and understanding of the processes at work.

The format for presentation of these datasets would be a matter for discussion, but there would be merit in keeping the distribution and environmental range data for a given species together. In hard copy format, this might mean presenting the two datasets on adjacent sides of a page. All RDB and Nationally Scarce species could be flagged as such and brief notes provided on additional points of interest. Suitable keys for identification could also be listed.

There would also be potential for adding further distributional records acquired through other projects and currently held on the CEH National Invertebrate Database.

There are, of course, a number of National Biological Recording schemes for freshwater invertebrates supported by the Biological Records Centre (list given in Table 13.1 of Wright and Armitage, 2001). These include taxa present in both still and running waters. The focus of attention for these schemes is the acquisition of comprehensive data on species distribution and in a number of cases, distribution maps are already available. Some excellent recent examples include an *Atlas of Land and Freshwater Molluscs of Britain and Ireland* (Kerney, 1999), which represents almost 40 years of recording and an *Atlas of the Dragonflies of Britain and Ireland* (Merritt *et al*. 1996), also representing an enormous amount of effort by many volunteers with an interest in this popular group of insects. The distributional data available from the RIVPACS reference sites cannot match these examples, but does provide distributional data for many groups and species not covered by BRC schemes, together with some environmental data.

5.6.4 Information on Biodiversity Action Plan species within the RIVPACS III dataset

After the 1992 Earth Summit in Rio de Janeiro, the government published the UK Biodiversity Action Plan (DOE, 1994) followed by the UK Steering Group Report (DOE, 1995) which outlined a major programme for the conservation of biodiversity. The Steering Group Report included 'short' and 'middle' lists representing species which are either globally threatened or are rapidly declining in the UK. At that time, action plans had already been developed for the short list species and the intention was to generate action plans for the middle list species in later years. The short list included action plans for 11 freshwater invertebrates, representing both still and running-water species. Since then, a 'priority' listing has been drawn up (Table 5.2) which includes the short list species plus another 14 additional freshwater invertebrates largely, but not exclusively, drawn from the original middle list. More recently, further freshwater species have been added, including a freshwater bryozoan, beetles and true flies, all of which are detailed in Focus on Biodiversity (Environment Agency, 2000). However, of all the freshwater species with current action plans, only three have been confirmed in the RIVPACS III dataset. They are the bivalve molluscs *Margaritifera margaritifera* (1 site) and *Pisidium tenuilineatum* (2 sites) and the stonefly *Brachyptera putata* (10 sites).

Table 5.2: Freshwater Invertebrates on the 'priority' listing for Species Action Plans. Species in bold were recorded in the 614 site RIVPACS III GB dataset. The frequency of occurrence of these species, as recorded in Wright *et al*. (1996), is also given.

Major group	Species	Major Group	Species
Nemertea	Prostoma jenningsi	Plecoptera	**Brachyptera putata (10)**
Hirudinea	Hirudo medicinalis*	Odonata	Coenagrion mercuriale*
Gastropoda	Anisus vorticulus*	Hemiptera	Hydrometra gracilenta
	Catinella arenaria*	Coleoptera	Agabus brunneus
	Myxas glutinosa*		Bidessus minutissimus
	Segmentina nitida* (1)#		Bidessus unistriatus
	Vertigo moulinsiana*		Helophorus laticollis
Bivalvia	**Margaritifera margaritifera*(1)**		Hydrochara caraboides
	Pseudanodonta complanata*		Hydroprus cantabricus
	Pisidium tenuilineatum* (2)		Hydroporus rufifrons
Crustacea	Austropotamobius pallipes*		Laccophilus poecilus
	Triops cancriformis		Graphoderus zonatus
			Paracymus aeneus

* Species on the 'short' list with Action Plans in the UK Steering Group Report (1995)

\# More recent examination of this single specimen, which is now in poor condition, has failed to provide conclusive corroboration of the earlier identification and this must therefore be rejected.

Given the very restricted data available in RIVPACS for the two molluscs, it is apparent that RIVPACS can offer very little information. *Margaritifera margaritifera,* the freshwater pearl mussel, is a species of global conservation concern and the subject of a substantial body of detailed research into its biology and ecological requirements. The Environment Agency and Scottish Natural Heritage are lead partners in the BAP. *Pisidium tenuilineatum*, the fine-lined pea mussel, is a small, little-known species, but recent surveys sponsored by the Environment Agency are providing some encouraging information on its distribution and status (John Murray-Bligh, pers. comm).

The stonefly, *Brachyptera putata*, is endemic to the British mainland and is also a Nationally Scarce species. Scottish Natural Heritage has prepared a dossier on this species which indicates that within Scotland it occurs in just 13 Hectads. In England and Wales it is only known from the R. Wye in Herefordshire and the R. Usk in Gwent. All RIVPACS records refer to sites in Scotland and provide the bulk of the recent records. Hence, they form a very important source of information on this species. The Environment Agency, whilst neither the contact point nor lead partner, does have actions within the BAP.

5.7 Recommendations for Future Developments

A number of modifications to RIVPACS which may assist with the UK's responsibilities under the Convention on Biological Diversity (part of specific objective 4) have been flagged in a previous section (5.6.2). In this concluding section, we are asked to recommend which of these should be implemented in a future version of RIVPACS and how this may be achieved.

5.7.1 Some specific recommendations

In section 5.6.2, four items were flagged as potential developments within RIVPACS. The first related to site richness and was to:

- automate the calculation of O/E ratios at both family and standardized species level, in line with procedures currently available at BMWP family level.

When calculating O/E ratios at BMWP family level, all BMWP families are included in the calculation, even if the requested printout of family probabilities stops at 50%.

This practice should continue at family level. However, at standardized species level, where a full printout would be excessively long, there would be merit in having the option of both printing and calculating O/E ratios down to, for example, the 50% and 25% probability levels.

Current practice within the Environment Agency suggests a heavy reliance on BMWP family level predictions, and the corresponding O/E ratios. It appears that the family level, standardized species and customised level options are still largely unused by Agency staff. Therefore, a perceived need for O/E ratios at these taxonomic levels is required within the Agency before this development can be regarded as important.

Recommendation 1 Automation of O/E ratios at family and standardised species level is a relatively low priority at present, but should be borne in mind as a future option if biodiversity issues related to site richness assume a higher profile

The remaining three items relate to site composition and involve the frequency of occurrence, threat status and rarity of the individual species:

- Append to the probability listing the frequency of occurrence of each species derived from the 637 species in the 614 site Great Britain dataset

- Identify within the probability listing any species with Red Data Book status

- Identify within the probability listing any species with Nationally Scarce status

These three items are best viewed as a single unit which may be requested (or not) when a standardised species level prediction is undertaken. The simplest form of presentation in a single line across the page would be:

probability of occurrence of the species, followed by
name of species, then
frequency of occurrence in the 614 site dataset, and finally
Red Data Book/Nationally Scarce status (if relevant)
The frequency could be expressed as a percentage only or as a fraction and a percentage, as in the case of the oligochaete, *Vejdovskyella comata* 7 / 614 = 1.1%. This second option has the advantage, particularly for the less frequent and rare lotic species for which there are no RDB or Nationally Scarce designations, of providing more direct information on the number of times the species has been recorded in the RIVPACS dataset.

It would be important to ensure, through adequate explanation within the manual, or even by comment at the head of the printout, that no confusion was possible between the percentage before the species name, representing the probability of occurrence of the species, and the percentage offered after the species name, representing the frequency of occurrence in the RIVPACS dataset. Some examples, as they might appear in a printout are given below.

91.2%*Baetis rhodani*	550 / 614 =	89.6%	
51.3%*Isoperla grammatica*	391 / 614 =	63.7%	
3.7%*Heptagenia fuscogrisea*	6 / 614 =	1.0%	N
1.1%*Pisidium tenuilineatum*	2 / 614 =	0.3%	RDB3

Recommendation 2 Incorporation of information on frequency of occurrence in the 614 site RIVPACS III dataset, together with information on threat status and rarity is a relatively simple operation and should be implemented as a high priority, given the need for Agency biologists to be familiar with the status of a wide range of freshwater macroinvertebrates

5.7.2 Some wider considerations

The current RIVPACS R & D contract, which incorporates a total of ten separate work packages, includes a number of scoping studies and other investigations, of which as many as six may lead to further developments of RIVPACS in the future.

They are:

- Scoping study on sampling procedures for deep river sites (Wright *et al*. 1999). This led to a new contract involving field trials in which three separate deep water sampling techniques were examined and a marginal habitat technique was developed (Bass *et al*. 2000). This report proposed the future development of new RIVPACS modules for benthic and marginal samples taken at deep water locations;

- Development of new abundance indices (Clarke and Wright, 2000);

- Scoping study on the development of educational RIVPACS (separate package in this report);

- Evaluation of the use of RIVPACS in the context of biodiversity and sustainability (this package);

- New environmental variables for RIVPACS (in progress); and

- Dynamic RIVPACS (in progress).

A two-year contract funded by the Environment and Heritage Service, Northern Ireland, is underway to enlarge the present Northern Ireland RIVPACS III module from 70 to 110 sites by spring 2002. In addition, a further two-year project, funded by the Scottish Environment Protection Agency, to develop two new RIVPACS modules for the Highlands of Scotland and the Western and Northern Isles has just commenced. The concept of developing a headwater stream module of RIVPACS has also been raised (Furse, 2000).

Separate from the above RIVPACS contracts, but of relevance to the current discussion, is research currently underway at CEH Dorset on the LIFE (Lotic-invertebrate Index for Flow Evaluation) system recently developed by Extence *et al*. (1999). Methods have been derived for making RIVPACS predictions of the expected LIFE scores based on family data with abundances (i.e. LIFE F). CEH are assessing the potential of using the O/E ratio of observed to expected LIFE scores as an indicator of flow-related stresses (Clarke *et al*. 2001). The Agency are also proposing to use both expected LIFE score and LIFE O/E ratios as part of an Environmental Weighting system in the River Assessment Methodology (RAM) Framework of the Surface Water Abstraction Licensing Policy (SWALP) for use within the Catchment Abstraction Management Strategy (CAMS).

Thus, with so many actual and potential developments for the future, it is crucial that a strategic view is taken at an early stage, in consultation with the Environment Agency, to ensure that all developments are undertaken in a logical and efficient sequence. As previously stated in this package, our view is that a Windows version of RIVPACS is now essential before major changes are made to the existing software. The cost of developing a Windows version of RIVPACS with the same functionality as the current DOS version, but including many of the outputs as Excel files, is estimated to be in the region of £40K.

5.8 References

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APPENDIX 1

PROVISIONAL LISTING OF MACROINVERTEBRATES IN THE BRITISH ISLES WITH RED DATA BOOK OR NATIONALLY SCARCE STATUS

Notes:

1. This list should not be regarded as definitive, but simply as a working document for updating as appropriate - the status of some species may have changed since it was compiled.

2. The original RDB system applies; as yet the new categories for aquatic Coleoptera (Foster, in press) have not been applied

Species Name	National Status	Species Code
Nemertea		
Prostoma jenningsi Gibson & Young	Red Data Book K	08110102
Ectoprocta		
Lophopus crystallinus Pallas	Red Data Book 3	14130101
Victorella pavida Saville Kent	Red Data Book K	14220101
Gastropoda		
Valvata macrostoma Morch	Red Data Book 2	16130102
Pseudamnicola confusa Frauenfeld	Red Data Book 1	16140201
Marstoniopsis scholtzi Schmidt	Red Data Book 3	16140401
Assiminea grayana Fleming	Nationally Scarce B	16170101
Lymnaea glabra Muller	Red Data Book 2	16220102
Myxas glutinosa Muller	Red Data Book 1	16220201
Anisus vorticulus Troschel	Red Data Book 2	16230203
Gyraulus acronicus Ferussac	Red Data Book 2	16230401
Gyraulus laevis Alder	Nationally Scarce B	16230403
Segmentina nitida Muller	Red Data Book 1	16230701
Catinella arenaria Bouchard-Chantereaux	Red Data Book 1	16320101
Oxyloma sarsi Esmark	Red Data Book 2	16320302
Vertigo angustior Jeffreys	Red Data Book 1	16330201
Vertigo geyeri Lindholm	Red Data Book 1	16330203
Vertigo lilljeborgi Westerlund	Red Data Book 3	16330204
Vertigo moulinsiana Dupuy	Red Data Book 3	16330205
Bivalvia		
Margaritifera margaritifera L.	Nationally Scarce B	17110101
Pseudanodonta complanata Rossmassler	Nationally Scarce B	17120301

Species Name	National Status	Species Code
Sphaerium solidum Normand	Red Data Book 1	17130104
Pisidium conventus Clessin	Nationally Scarce A	17130203
Pisidium moitessierianum Paladilhe	Nationally Scarce B	17130208
Pisidium pseudosphaerium Schlesch	Red Data Book 3	17130213
Pisidium pulchellum Jenyns	Nationally Scarce B	17130214
Pisidium supinum Schmidt	Nationally Scarce B	17130216
Pisidium tenuilineatum Stelfox	Red Data Book 3	17130217
Hirudinea		
Hirudo medicinalis L.	Red Data Book 3	22210201
Anostraca		
Artemia salina L.	Red Data Book 0	27010101
Chirocephalus diaphanus Prevost	Red Data Book 2	27020101
Triops cancriformis L.	Red Data Book 1	28010101
Mysidacea		
Mysis relicta Loven	Red Data Book 1	35110101
Amphipoda		
Corophium lacustre Vanhoffen	Red Data Book 3	37110103
Niphargellus glenniei Spooner	Red Data Book K	37150101
Ephemeroptera		
Heptagenia fuscogrisea Retzius	Nationally Scarce	40130201
Heptagenia longicauda Stephens	Red Data Book 1	40130203
Paraleptophlebia werneri Ulmer	Red Data Book 3	40210203
Potamanthus luteus L.	Red Data Book 2	40310101
Ephemera lineata Eaton	Red Data Book 2	40320102
Plecoptera		
Taeniopteryx nebulosa L.	Red Data Book 5	41110101
Rhabdiopteryx acuminata Klapalek	Nationally Scarce	41110201
Brachyptera putata Newman	Red Data Book 5	41110301
Nemoura dubitans Morton	Nationally Scarce	41120404
Capnia vidua Klapalek	Red Data Book 5	41140103
Isogenus nubecula Newman	Red Data Book 2	41210101
Isoperla obscura Zetterstedt	Red Data Book 0	41210402
Odonata		
Ischnura pumilio Charpentier	Nationally Scarce	42120202
Coenagrion hastulatum Charpentier	Red Data Book 2	42120402

Species Name	National Status	Species Code
Coenagrion mercuriale Charpentier	Red Data Book 3	42120404
Coenagrion pulchellum Van der Linden	Nationally Scarce	42120406
Coenagrion scitulum Rambur	Red Data Book 0	42120407
Ceriagrion tenellum de Villers	Nationally Scarce	42120501
Lestes dryas Kirby	Red Data Book 2	42130101
Gomphus vulgatissimus L.	Nationally Scarce	42210101
Brachytron pratense Muller	Nationally Scarce	42230101
Aeshna caerulea Strom	Nationally Scarce	42230201
Aeshna isosceles Muller	Red Data Book 1	42230204
Cordulia aenea L.	Nationally Scarce	42240101
Somatochlora arctica Zetterstedt	Red Data Book 3	42240201
Somatochlora metallica Van der Linden	Nationally Scarce	42240202
Oxygastra curtisii Dale	Red Data Book 0	42240301
Libellula fulva Muller	Red Data Book 3	42250202
Leucorrhinia dubia Van der Linden	Nationally Scarce	42250401
Hemiptera		
Hebrus (Hebrus) pusillus Fallen	Nationally Scarce B	43120111
Hydrometra gracilenta Horvath	Red Data Book 3	43210101
Microvelia pygmaea Dufour	Nationally Scarce B	43220201
Gerris (Aquarius) paludum Fabricius	Nationally Scarce B	43230122
Micronecta (Micronecta) minutissima L.	Red Data Book 3	43610121
Sigara (Sigara) striata L.	Nationally Scarce B	43610912
Coleoptera		
Peltodytes caesus Duftschmid	Nationally Scarce B	45110201
Haliplus apicalis Thomson	Nationally Scarce B	45110301
Haliplus furcatus Seidlitz	Red Data Book 1	45110306
Haliplus heydeni Wehncke	Nationally Scarce B	45110307
Haliplus laminatus Schaller	Nationally Scarce B	45110309
Haliplus mucronatus Stephens	Nationally Scarce A	45110313
Haliplus variegatus Sturm	Red Data Book 3	45110316
Haliplus varius Nicolai	Red Data Book K	45110317
Hydrovatus clypealis Sharp	Nationally Scarce A	45140201
Bidessus minutissimus Germar	Red Data Book 3	45140501
Bidessus unistriatus Schrank	Red Data Book 1	45140502
Hygrotus decoratus Gyllenhal	Nationally Scarce B	45140601
Hygrotus quinquelineatus Zetterstedt	Nationally Scarce B	45140603
Coelambus novemlineatus Stephens	Nationally Scarce B	45140704
Coelambus parallelogrammus Ahrens	Nationally Scarce B	45140705
Hydroporus cantabricus Sharp	Red Data Book 3	45140802
Hydroporus elongatus Sturm	Red Data Book 3	45140805

Species Name	National Status	Species Code
Hydroporus ferrugineus Stephens	Nationally Scarce B	45140807
Hydroporus glabriusculus Aube	Red Data Book 3	45140809
Hydroporus longicornis Sharp	Nationally Scarce B	45140813
Hydroporus longulus Mulsant	Nationally Scarce B	45140814
Hydroporus marginatus Duftschmid	Nationally Scarce B	45140815
Hydroporus neglectus Schaum	Nationally Scarce B	45140819
Hydroporus obsoletus Aube	Nationally Scarce B	45140823
Hydroporus rufifrons Muller	Red Data Book 2	45140827
Hydroporus scalesianus Stephens	Red Data Book 2	45140828
Stictonectes lepidus Olivier	Nationally Scarce B	45140901
Graptodytes bilineatus Sturm	Red Data Book 3	45141001
Graptodytes flavipes Olivier	Red Data Book 2	45141002
Graptodytes granularis L.	Nationally Scarce B	45141003
Deronectes latus Stephens	Nationally Scarce B	45141201
Potamonectes griseostriatus Degeer	Nationally Scarce B	45141304
Oreodytes davisii Curtis	Nationally Scarce B	45141501
Oreodytes alpinus Paykull	Red Data Book 3	45141504
Scarodytes halensis Fabricius	Nationally Scarce B	45141601
Laccornis oblongus Stephens	Red Data Book 3	45141701
Agabus biguttatus Olivier	Nationally Scarce B	45142003
Agabus brunneus Fabricius	Red Data Book 2	45142005
Agabus chalconatus Panzer	Nationally Scarce B	45142006
Agabus conspersus Marsham	Nationally Scarce B	45142008
Agabus labiatus Brahm	Nationally Scarce B	45142012
Agabus melanarius Aube	Nationally Scarce B	45142013
Agabus striolatus Gyllenhal	Red Data Book 2	45142017
Agabus uliginosus L.	Nationally Scarce B	45142019
Agabus undulatus Schrank	Red Data Book 3	45142021
Agabus unguicularis Thomson	Nationally Scarce B	45142022
Ilybius aenescens Thomson	Nationally Scarce B	45142101
Ilybius fenestratus Fabricius	Nationally Scarce B	45142103
Ilybius guttiger Gyllenhal	Nationally Scarce B	45142105
Ilybius subaeneus Erichson	Nationally Scarce B	45142107
Rhantus aberratus Gemminger & von Harold	Red Data Book 0	45142201
Rhantus frontalis Marsham	Nationally Scarce B	45142204
Rhantus grapii Gyllenhal	Nationally Scarce B	45142205
Rhantus suturalis Macleay	Nationally Scarce B	45142206
Hydaticus seminiger Degeer	Nationally Scarce B	45142402
Hydaticus transversalis Pontoppidan	Red Data Book 3	45142403
Graphoderus bilineatus Degeer	Red Data Book 0	45142501
Graphoderus cinereus L.	Red Data Book 3	45142502
Graphoderus zonatus Hoppe	Red Data Book 1	45142503
Acilius canaliculatus Nicolai	Red Data Book 3	45142601

Species Name	National Status	Species Code
Dytiscus circumcinctus Ahrens	Nationally Scarce A	45142701
Dytiscus circumflexus Fabricius	Nationally Scarce B	45142702
Dytiscus dimidiatus Bergstraesser	Red Data Book 3	45142703
Dytiscus lapponicus Gyllenhal	Nationally Scarce B	45142704
Gyrinus aeratus Stephens	Nationally Scarce B	45150201
Gyrinus distinctus Aube	Red Data Book 3	45150204
Gyrinus minutus Fabricius	Nationally Scarce B	45150206
Gyrinus natator L.	Red Data Book 0	45150207
Gyrinus opacus Sahlberg	Nationally Scarce A	45150208
Gyrinus suffriani Scriba	Red Data Book 3	45150211
Gyrinus urinator Illiger	Nationally Scarce B	45150212
Spercheus emarginatus Schaller	Red Data Book 1	45310101
Hydrochus angustatus Germar	Nationally Scarce B	45310201
Hydrochus brevis Herbst	Red Data Book 3	45310202
Hydrochus carinatus Germar	Red Data Book 3	45310203
Hydrochus elongatus Schaller	Red Data Book 3	45310204
Hydrochus ignicollis Motschulsky	Red Data Book 3	45310205
Hydrochus nitidicollis Mulsant	Red Data Book 3	45310206
Helophorus (Cyphelophorus) tuberculatus Gyllenhal	Red Data Book 3	45310321
Helophorus (Trichelophorus) alternans Gene	Nationally Scarce A	45310331
Helophorus (Atracthelophorus) arvernicus Mulsant	Nationally Scarce B	45310351
Helophorus (Helophorus) dorsalis Marsham	Nationally Scarce B	45310361
Helophorus (Helophorus) fulgidicollis Motschulsky	Nationally Scarce B	45310363
Helophorus (Helophorus) griseus Herbst	Nationally Scarce B	45310365
Helophorus (Helophorus) laticollis Thomson	Red Data Book 2	45310366
Helophorus (Helophorus) longitarsis Wollaston	Red Data Book 3	45310367
Helophorus (Helophorus) nanus Sturm	Nationally Scarce B	45310369
Helophorus (Helophorus) strigifrons Thomson	Nationally Scarce B	45310372
Paracymus aeneus Germar	Red Data Book 1	45311001
Paracymus scutellaris Rosenhauer	Nationally Scarce B	45311002
Limnoxenus niger Zschach	Nationally Scarce B	45311201
Anacaena bipustulata Marsham	Nationally Scarce B	45311301
Laccobius (Macrolaccobius) atratus Rottenburg	Nationally Scarce B	45311421
Laccobius (Macrolaccobius) atrocephalus Reitter	Nationally Scarce B	45311422
Laccobius (Macrolaccobius) sinuatus Motschulsky	Nationally Scarce B	45311426
Helochares lividus Forster	Nationally Scarce B	45311601
Helochares obscurus Muller	Red Data Book 3	45311602
Helochares punctatus Sharp	Nationally Scarce B	45311603
Enochrus affinis Thunberg	Nationally Scarce B	45311701
Enochrus bicolor Fabricius	Nationally Scarce B	45311702
Enochrus isotae Hebauer	Red Data Book 3	45311704
Enochrus melanocephalus Olivier	Nationally Scarce B	45311705
Enochrus ochropterus Marsham	Nationally Scarce B	45311706

Species Name	National Status	Species Code
Enochrus quadripunctatus Herbst	Nationally Scarce B	45311707
Chaetarthria seminulum Herbst	Nationally Scarce B	45312101
Hydrochara caraboides L.	Red Data Book 1	45312201
Hydrophilus piceus L.	Red Data Book 3	45312301
Berosus affinis Brulle	Nationally Scarce B	45312401
Berosus luridus L.	Nationally Scarce B	45312402
Berosus signaticollis Charpentier	Nationally Scarce B	45312403
Ochthebius aeneus Stephens	Red Data Book 0	45410101
Ochthebius auriculatus Rey	Nationally Scarce B	45410102
Ochthebius bicolon Germar	Nationally Scarce B	45410103
Ochthebius exaratus Mulsant	Red Data Book 3	45410105
Ochthebius exsculptus Germar	Nationally Scarce B	45410106
Ochthebius lenensis Poppius	Red Data Book 2	45410107
Ochthebius marinus Paykull	Nationally Scarce B	45410108
Ochthebius nanus Stephens	Nationally Scarce B	45410111
Ochthebius poweri Rye	Red Data Book 3	45410112
Ochthebius punctatus Stephens	Nationally Scarce B	45410113
Ochthebius pusillus Stephens	Red Data Book 3	45410114
Ochthebius viridis Peyron	Nationally Scarce B	45410116
Hydraena minutissima Stephens	Nationally Scarce B	45410203
Hydraena nigrita Germar	Nationally Scarce B	45410204
Hydraena palustris Erichson	Red Data Book 2	45410205
Hydraena pulchella Germar	Red Data Book 3	45410206
Hydraena pygmaea Waterhouse	Red Data Book 3	45410207
Hydraena rufipes Curtis	Nationally Scarce B	45410209
Hydraena testacea Curtis	Nationally Scarce B	45410211
Limnebius aluta Bedel	Red Data Book 3	45410301
Limnebius crinifer Rey	Red Data Book I	45410302
Limnebius nitidus Marsham	Nationally Scarce B	45410303
Limnebius papposus Mulsant	Nationally Scarce B	45410304
Eubria palustris Germar	Red Data Book 3	45610101
Dryops anglicanus Edwards	Red Data Book 3	45620201
Dryops auriculatus Fourcroy	Nationally Scarce B	45620202
Dryops griseus Erichson	Red Data Book 3	45620204
Dryops nitidulus Heer	Red Data Book 3	45620206
Dryops striatellus Fairmaire & Brisout	Red Data Book 3	45620207
Macronychus quadrituberculatus Muller	Red Data Book 3	45630401
Normandia nitens Muller	Red Data Book 2	45630501
Oulimnius major Rey	Nationally Scarce A	45630601
Oulimnius rivularis Rosenhauer	Nationally Scarce A	45630602
Oulimnius troglodytes Gyllenhal	Nationally Scarce B	45630603
Riolus cupreus Muller	Nationally Scarce B	45630701
Riolus subviolaceus Muller	Nationally Scarce B	45630702

Species Name	**National Status**	**Species Code**
Stenelmis canaliculata Gyllenhal	Red Data Book 2	45630801
Macroplea appendiculata Panzer	Red Data Book 3	45710101
Macroplea mutica Fabricius	Nationally Scarce A	45710102
Donacia aquatica L.	Red Data Book 3	45710201
Donacia bicolora Zschach	Red Data Book 2	45710202
Donacia cinerea Herbst	Nationally Scarce B	45710203
Donacia clavipes Fabricius	Nationally Scarce B	45710204
Donacia crassipes Fabricius	Nationally Scarce B	45710205
Donacia dentata Hoppe	Nationally Scarce A	45710206
Donacia impressa Paykull	Nationally Scarce A	45710207
Donacia obscura Gyllenhal	Nationally Scarce A	45710209
Donacia sparganii Ahrens	Nationally Scarce A	45710213
Donacia thalassina Germar	Nationally Scarce B	45710214
Plateumaris affinis Kunze	Nationally Scarce B	45710301
Plateumaris braccata Scopoli	Nationally Scarce A	45710302
Bagous argillaceus Gyllenhal	Red Data Book 2	45810601
Bagous binodulus Herbst	Red Data Book 0	45810602
Bagous cylindrus Paykull	Red Data Book 2	45810603
Bagous glabrirostris Herbst	Nationally Scarce B	45810604
Bagous lutulentus Gyllenhal	Nationally Scarce B	45810605
Bagous petro Herbst	Red Data Book 0	45810607
Hydronomus alismatis Marsham	Nationally Scarce B	45810701
Eubrychius velutus Beck	Nationally Scarce B	45811301
Litodactylus leucogaster Marsham	Nationally Scarce B	45811401
Phytobius waltoni Boheman	Nationally Scarce B	45811601
Drupenatus nasturtii Germar	Nationally Scarce B	45811801
Tapinotus sellatus Fabricius	Nationally Scarce A	45811901
Megaloptera		
Sialis nigripes Pictet	Nationally Scarce B	46110103
Neuroptera		
Sisyra dalii Mclachlan	Nationally Scarce B	47120101
Sisyra terminalis Curtis	Nationally Scarce B	47120103
Trichoptera		
Rhyacophila septentrionis Mclachlan	Nationally Scarce	48110104
Glossosoma intermedium Klapalek	Red Data Book 3	48120103
Hydroptila cornuta Mosely	Nationally Scarce	48130302
Hydroptila lotensis Mosely	Red Data Book 2	48130304
Hydroptila sylvestris Morton	Red Data Book K	48130311
Hydroptila tigurina Ris	Red Data Book K	48130312

Species Name	National Status	Species Code
Hydroptila valesiaca Schmid	Nationally Scarce	48130314
Oxyethira mirabilis Morton	Red Data Book K	48130405
Oxyethira tristella Klapalek	Red Data Book K	48130408
Tricholeiochiton fagesii Guinard	Nationally Scarce	48130501
Ithytrichia clavata Morton	Red Data Book 3	48130601
Orthotrichia tragetti Mosely	Red Data Book 0	48130703
Metalype fragilis Pictet	Nationally Scarce	48220201
Tinodes dives Pictet	Nationally Scarce	48220402
Tinodes pallidulus Mclachlan	Red Data Book 1	48220405
Tinodes rostocki Mclachlan	Nationally Scarce	48220406
Tinodes unicolor Pictet	Nationally Scarce	48220407
Cyrnus insolutus Mclachlan	Red Data Book K	48240102
Plectrocnemia brevis Mclachlan	Nationally Scarce	48240401
Hydropsyche bulgaromanorum Malicky	Red Data Book 0	48250202
Hydropsyche exocellata Dufour	Red Data Book 0	48250204
Hydropsyche fulvipes Curtis	Nationally Scarce	48250205
Hydropsyche saxonica Mclachlan	Red Data Book 1	48250208
Agrypnia crassicornis Mclachlan	Red Data Book 1	48310101
Agrypnia picta Kolenati	Red Data Book K	48310104
Hagenella clathrata Kolenati	Red Data Book 1	48310301
Ironoquia dubia Stephens	Red Data Book 2	48340101
Mesophylax aspersus Rambur	Red Data Book K	48340901
Grammotaulius nitidus Muller	Red Data Book 1	48341602
Limnephilus borealis Zetterstedt	Nationally Scarce	48341705
Limnephilus pati O'Connor	Red Data Book 1	48341724
Limnephilus subcentralis Brauer	Nationally Scarce	48341729
Limnephilus tauricus Schmid	Red Data Book 1	48341731
Nemotaulius punctatolineatus Retzius	Red Data Book 2	48341801
Phacopteryx brevipennis Curtis	Nationally Scarce	48341901
Ernodes articularis Pictet	Nationally Scarce	48360301
Ceraclea senilis Burmeister	Nationally Scarce	48410206
Leptocerus interruptus Fabricius	Red Data Book 3	48410301
Leptocerus lusitanicus Mclachlan	Red Data Book 2	48410302
Adicella filicornis Pictet	Red Data Book 3	48410501
Erotesis sp.	Red Data Book 2	48410600
Ylodes conspersus Rambur	Nationally Scarce	48410801
Ylodes reuteri Mclachlan	Red Data Book 2	48410802
Ylodes simulans Tjeder	Red Data Book 3	48410803
Oecetis notata Rambur	Red Data Book 3	48410903
Setodes argentipunctellus Mclachlan	Red Data Book 3	48411001
Setodes punctatus Fabricius	Red Data Book 2	48411002
Diptera		

Species Name	National Status	Species Code
Prionocera pubescens Loew	Red Data Book 2	50110101
Prionocera subserricornis Zetterstedt	Red Data Book 2	50110102
Tipula (Savtshenkia) cheethami Edwards	Nationally Scarce	50110332
Tipula (Savtshenkia) gimmerthali Lackschewitz	Red Data Book 3	50110333
Tipula (Savtshenkia) grisescens Zetterstedt	Red Data Book 3	50110334
Tipula (Savtshenkia) limbata Zetterstedt	Red Data Book 3	50110335
Tipula (Lindnerina) bistilata Lindstroem	Red Data Book 2	50110381
Tipula (Yamatotipula) coerulescens Lackschewitz	Red Data Book 3	50110411
Tipula (Yamatotipula) marginata Meigen	Red Data Book 3	50110414
Nephrotoma crocata L.	Red Data Book 3	50110502
Triogma trisulcata Schummel	Red Data Book 3	50120101
Phalacrocera replicata L.	Nationally Scarce	50120201
Limonia (Dicranomyia) aperta Wahlgren	Red Data Book 1	50130111
Limonia (Dicranomyia) aquosa Verrall	Nationally Scarce	50130112
Limonia (Dicranomyia) complicata de Meijere	Nationally Scarce	50130115
Limonia (Dicranomyia) consimilis Zetterstedt	Red Data Book 3	50130116
Limonia (Dicranomyia) danica Kuntze	Red Data Book 3	50130117
Limonia (Dicranomyia) distendens Lundstroem	Nationally Scarce	50130119
Limonia (Dicranomyia) frontalis Staeger	Red Data Book 1	50130121
Limonia (Dicranomyia) goritiensis Mik	Red Data Book 3	50130123
Limonia (Dicranomyia) halterella Edwards	Nationally Scarce	50130124
Limonia (Dicranomyia) lucida de Meijere	Nationally Scarce	50130125
Limonia (Dicranomyia) omissinervis de Meijere	Red Data Book 2	50130127
Limonia (Dicranomyia) ornata Meigen	Nationally Scarce	50130128
Limonia (Dicranomyia) stigmatica Meigen	Nationally Scarce	50130131
Limonia (Dicranomyia) ventralis Schummel	Nationally Scarce	50130132
Limonia (Melanolimonia) caledonica Edwards	Nationally Scarce	50130141
Limonia (Melanolimonia) occidua Edwards	Nationally Scarce	50130143
Limonia (Melanolimonia) rufiventris Strobl	Red Data Book 3	50130144
Limonia (Melanolimonia) stylifera Lackschewitz	Red Data Book 2	50130145
Limonia (Geranomyia) bezzii Alexander & Leonard	Red Data Book 2	50130151
Thaumastoptera calceata Mik	Nationally Scarce	50130601
Orimarga juvenilis Zetterstedt	Nationally Scarce	50130701
Orimarga virgo Zetterstedt	Red Data Book 3	50130702
Elliptera omissa Schiner	Red Data Book K	50130801
Helius pallirostris Edwards	Nationally Scarce	50130903
Pedicia (Tricyphona) unicolor Schummel	Nationally Scarce	50131043
Pedicia (Ludicia) lucidipennis Edwards	Nationally Scarce	50131052
Dicranota (Paradicranota) gracilipes Wahlgren	Nationally Scarce	50131522
Dicranota (Paradicranota) robusta Lundstroem	Nationally Scarce	50131524
Dicranota (Paradicranota) simulans Lackschewitz	Red Data Book 3	50131526
Paradelphomyia (Oxyrhiza) ecalcarata Edwards	Red Data Book 2	50131622
Paradelphomyia (Oxyrhiza) fuscula Loew	Red Data Book 2	50131623

Species Name	National Status	Species Code
Paradelphomyia (Oxyrhiza) nielseni Kuntze	Nationally Scarce	50131624
Limnophila (Eloeophila) apicata Loew	Nationally Scarce	50132011
Limnophila (Eloeophila) mundata Loew	Nationally Scarce	50132013
Limnophila (Eloeophila) trimaculata Zetterstedt	Nationally Scarce	50132015
Limnophila (Eloeophila) verralli Bergroth	Nationally Scarce	50132016
Limnophila (Idioptera) fasciata L.	Red Data Book 1	50132021
Limnophila (Idioptera) pulchella Meigen	Nationally Scarce	50132022
Limnophila (Phylidorea) abdominalis Staeger	Nationally Scarce	50132031
Limnophila (Phylidorea) glabricula Meigen	Nationally Scarce	50132033
Limnophila (Phylidorea) heterogyna Bergroth	Red Data Book 1	50132034
Limnophila (Limnophila) pictipennis Meigen	Red Data Book 2	50132051
Pilaria (Pilaria) fuscipennis Meigen	Nationally Scarce	50132622
Pilaria (Pilaria) meridiana Staeger	Nationally Scarce	50132623
Pilaria (Pilaria) scutellata Staeger	Nationally Scarce	50132624
Neolimnophila carteri Tonnoir	Nationally Scarce	50132901
Neolimnophila placida Meigen	Nationally Scarce	50132902
Gonomyia (Protogonomyia) alboscutellata Von Roser	Red Data Book 1	50133121
Gonomyia (Idiocera) bradleyi Edwards	Red Data Book 2	50133131
Gonomyia (Idiocera) connexa Loew	Red Data Book 2	50133132
Gonomyia (Idiocera) punctata Edwards	Red Data Book 2	50133133
Gonomyia (Idiocera) sexguttata Dale	Red Data Book 1	50133134
Gonomyia (Gonomyia) bifida Tonnoir	Nationally Scarce	50133141
Gonomyia (Gonomyia) conoviensis Barnes	Nationally Scarce	50133142
Gonomyia (Prolipophleps) abbreviata Loew	Red Data Book 3	50133151
Rhabdomastix (Sacandaga) hilaris Edwards	Red Data Book 3	50133622
Rhabdomastix (Sacandaga) inclinata Edwards	Red Data Book 2	50133623
Cheilotrichia (Cheilotrichia) imbuta Meigen	Nationally Scarce	50133911
Erioptera (Symplecta) scotica Edwards	Red Data Book 1	50134122
Erioptera (Erioptera) limbata Loew	Red Data Book 2	50134137
Erioptera (Erioptera) meijerei Edwards	Red Data Book 2	50134139
Erioptera (Erioptera) nielseni de Meijere	Nationally Scarce	50134141
Erioptera (Erioptera) nigripalpis Goetghebuer	Red Data Book 3	50134142
Erioptera (Erioptera) sordida Zetterstedt	Red Data Book 3	50134143
Erioptera (Mesocyphona) bivittata Loew	Red Data Book 2	50134161
Erioptera (Psiloconopa) meigeni Zetterstedt	Red Data Book 3	50134171
Erioptera (Psiloconopa) pusilla Schiner	Red Data Book 1	50134172
Arctoconopa melampodia Loew	Red Data Book 2	50134701
Ormosia (Ormosia) aciculata Edwards	Red Data Book 2	50134811
Ormosia (Ormosia) bicornis de Meijere	Red Data Book 2	50134813
Ormosia (Ormosia) staegeriana Alexander	Nationally Scarce	50134819
Scleroprocta pentagonalis Loew	Red Data Book 3	50135001
Scleroprocta sororcula Zetterstedt	Nationally Scarce	50135002
Tasiocera (Dasymolophilus) collini Freeman	Red Data Book 1	50135121

Species Name	National Status	Species Code
Tasiocera (Dasymolophilus) jenkinsoni Freeman	Red Data Book 1	50135123
Tasiocera (Dasymolophilus) laminata Freeman	Nationally Scarce	50135124
Molophilus bihamatus de Meijere	Nationally Scarce	50135304
Molophilus corniger de Meijere	Nationally Scarce	50135306
Molophilus czizeki Lackschewitz	Red Data Book 3	50135308
Molophilus lackschewitzianus Alexander	Red Data Book 3	50135312
Molophilus niger Goetghebuer	Nationally Scarce	50135314
Molophilus propinquus Egger	Nationally Scarce	50135321
Beris clavipes L.	Nationally Scarce	50610101
Beris fuscipes Meigen	Nationally Scarce	50610102
Oxycera analis Meigen	Red Data Book 2	50610301
Oxycera dives Loew	Red Data Book 3	50610302
Oxycera morrisii Curtis	Nationally Scarce	50610305
Oxycera pardalina Meigen	Nationally Scarce	50610307
Oxycera pygmaea Fallen	Nationally Scarce	50610309
Oxycera terminata Meigen	Red Data Book 2	50610311
Vanoyia tenuicornis Macquart	Nationally Scarce	50610401
Odontomyia angulata Panzer	Red Data Book 1	50610501
Odontomyia argentata Fabricius	Red Data Book 2	50610502
Odontomyia hydroleon L.	Red Data Book 1	50610503
Odontomyia ornata Meigen	Red Data Book 2	50610504
Odontomyia tigrina Fabricius	Nationally Scarce	50610505
Stratiomys chamaeleon L.	Red Data Book 1	50610601
Stratiomys longicornis Scopoli	Red Data Book 2	50610603
Stratiomys potamida Meigen	Nationally Scarce	50610604
Atrichops crassipes Meigen	Red Data Book 3	50620201
Chrysops sepulcralis Fabricius	Red Data Book 1	50630103
Haematopota grandis Meigen	Red Data Book 3	50630203
Tabanus bovinus L.	Red Data Book K	50630502
Tabanus cordiger Meigen	Nationally Scarce	50630504
Tabanus glaucopis Meigen	Red Data Book 3	50630505
Helophilus groenlandicus Fabricius	Red Data Book 2	50810501
Anasimyia interpuncta Harris	Red Data Book 3	50810602
Anasimyia lunulata Meigen	Nationally Scarce	50810604
Lejops vittata Meigen	Red Data Book 2	50810701
Parhelophilus consimilis Malm	Red Data Book 2	50810801
Mallota cimbiciformis Fallen	Nationally Scarce	50810901
Eristalis (Eoseristalis) cryptarum Fabricius	Red Data Book 2	50811013
Eristalis (Eoseristalis) rupium Fabricius	Nationally Scarce	50811018
Colobaea bifasciella Fallen	Nationally Scarce	50820101
Colobaea distincta Meigen	Nationally Scarce	50820102
Colobaea pectoralis Zetterstedt	Red Data Book 2	50820103
Colobaea punctata Lundbeck	Nationally Scarce	50820104

Species Name	National Status	Species Code
Pherbellia argyra Verbeke	Red Data Book 2	50820203
Pherbellia brunnipes Meigen	Nationally Scarce	50820204
Pherbellia griseola Fallen	Nationally Scarce	50820209
Pherbellia grisescens Meigen	Nationally Scarce	50820211
Pteromicra glabricula Fallen	Nationally Scarce	50820302
Pteromicra leucopeza Meigen	Red Data Book 2	50820303
Pteromicra pectorosa Hendel	Red Data Book 2	50820304
Sciomyza dryomyzina Zetterstedt	Red Data Book 2	50820401
Sciomyza simplex Fallen	Nationally Scarce	50820402
Antichaeta analis Meigen	Red Data Book 3	50820501
Antichaeta brevipennis Zetterstedt	Red Data Book 2	50820502
Dictya umbrarum L.	Nationally Scarce	50820601
Psacadina vittigera Schiner	Red Data Book 3	50821202
Psacadina zernyi Mayer	Red Data Book 2	50821203
Renocera striata Meigen	Nationally Scarce	50821303
Tetanocera freyi Stackelberg	Red Data Book 3	50821504