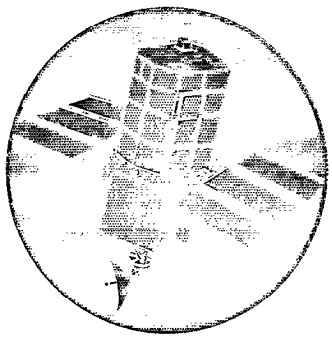
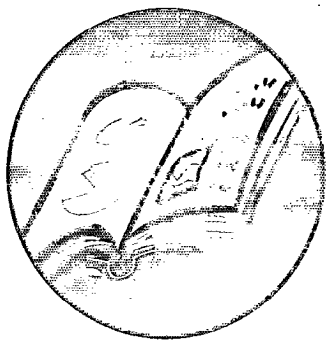
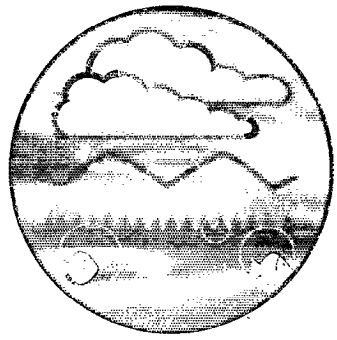
Testing and Further Development of RiVPACS - Phase 3.

Development of New RIVPACS Methodologies - Stage 1

Research and Development

Technical Report
E71

ENVIRONMENT AGENCY

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Testing and Further Development of RIVPACS Phase 3.

Technical Report E71

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Research Contractor:
Institute of Freshwater Ecology

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Statement of Use
This report provides staff with information on the first years work on this project. It includes a report on the International Conference held in Oxford in September 1997, progress on the development of use of abundance data for biological quality assessment and the reviews of methodology for sampling in Deep waters and canals.

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Staff of British Waterways, English Nature and Pond Action all provided useful advice and information and we are grateful to each one of these organisations.

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EXECUTIVE SUMMARY

This three-year project (January 1998 – December 2000) for the development of new RIVPACS methodologies includes a total of ten separate work packages of which four have received attention in year 1 (January – December 1998). The four packages are:

1. The editing of a book resulting from an International Workshop on RIVPACS research, held at Jesus College, Oxford in September 1997.

The book, which includes nineteen edited papers based on oral presentations made at the International Workshop plus the main findings and conclusions from five Workshop discussion groups, is to be published by the Freshwater Biological Association.

Most manuscripts have now been through the full editing procedures and almost 70% have been formally accepted in their revised form. We intend to complete this phase of the work by the end of March 1999. It should then be possible to complete type-setting, proof-reading and production of the book by the end of 1999.

2. Development of the use of abundance data for biological quality assessment. (Year one of a two year study).

The current version of RIVPACS III+ includes a single abundance index (Q14) designed to indicate the first signs of environmental stress prior to major loss of BMWP families. Several additional indices (Q15-Q19) are currently under consideration. To date, Indices Q14-Q17 have been coded directly into a modified version of RIVPACS III+. Critical lower limits for these indices have recently been calculated based on the 614 RIVPACS III+ reference sites. Previously, the critical limit for the Q14 index was based on the 438 sites from RIVPACS II, and was a less sensitive measure of stress.

To test and assess the relative merits of the different indices, it is important to know the extent to which each index is affected by sampling variation and by the errors in the RIVPACS estimates of expected abundance levels due to measures of the environmental variables. Hence, the data available from a previous replicated sampling programme at 16 sites, referred to as BAMS (Biological Assessment Methods Study) is being used to assess uncertainty in the abundance–based quality indices Q14- Q17. (This work has been brought forward from Year 2 because of the benefit of having early access to the results for each index).

A new computer program (EXCLRIVP) has been written to convert EXCEL data files into RIVPACS format. This will simplify the task of getting biological and environmental data files into the correct format for RIVPACS. A trial version is being tested by the IFE and by April 1999, a version will be available for testing by users within the Environment Agency.

3. Scoping study to re-evaluate methods for collecting RIVPACS samples from deep waters.

A review of recent literature on deep-water samplers indicated that there were no new devices that were suitable for use in RIVPACS assessments in deep rivers.

A questionnaire completed by all 26 Areas within the Environment Agency revealed extensive use of long-handled pond-nets and a variety of dredges at deep-water sites. Air-lifts, grabs and other procedures were used by a small number of regions. It was apparent that the detailed sampling protocols varied across the Agency and according to sampling device.

After careful consideration of the current field protocols used in RIVPACS, it was concluded that the procedures required for the appraisal of deep-water sites should be different from the standard protocol used in shallow waters. Essentially, the margins and the benthos should have their own separate field sampling protocols.

In order to have standardised procedures in place for the sampling of deep-water sites during the GQA survey in 2000, it will be necessary to undertake field trials in 1999. The field trials must establish the type of sampling device and detailed protocol required over the full range of deep-water sites. Three devices for sampling the benthos (long-handled pond-net, Medium Naturalist's dredge and Mackey/Yorkshire pattern Air-lift) will be compared at a variety of deep-water sites in order to establish clear guidelines on the method to be used at any given site with stated environmental characteristics. The detailed protocol for pond-netting the margins must also be clarified.

The consequences, for the next version of RIVPACS, of standardising the sampling protocol for the margins and benthos at deep-water sites are considered. There will be a need to collect reference site data using the new protocols as a part of the GQA survey in 2000. The option will then be available for the Environment Agency to choose to assess the biological quality of the margins and benthos of deep-water sites independently. The relative merits of the alternative formats for the next version of RIVPACS are described.

4. Scoping study to consider the development of a RIVPACS methodology for canals.

A brief review of canals and their macroinvertebrate fauna was undertaken with the emphasis on the BMWP families that characterise canals in England and Wales.

A questionnaire was used to obtain information on the types of canals within each area of the Environment Agency and the procedures used in current biological sampling programmes. In general, long-handled pond-nets are used from the bank, although some areas also use dredges. There is no standard protocol at present.

In considering the best way forward, it is essential to take full account of progress made by a separate project undertaken by Pond Action, also funded by the Environment Agency (Biological Techniques of Still Water Assessment). Information collected by Pond Action during a preliminary field trial at a limited set of canal sites in April 1997 has recently been used to demonstrate that a RIVPACS-type classification and prediction system for canals should be feasible. In a new phase of the same project, the field sampling programme on reference sites is now being extended. Hence, the original specification for the IFE scoping study has been partially superseded. In view of this, the IFE scoping study provides suggestions on factors to be taken into account regarding the field and laboratory protocols and offers suggestions for consideration during the analyses.

It is now apparent that a fully-fledged system cannot be in place prior to the GQA Survey in 2000. However, the field protocols developed by Pond Action could be formalised in

consultation with the Environment Agency and used as the basis of the sampling programme for canals during the GQA Survey in 2000. If there is a need to supplement the reference dataset with additional sites, then selected samples collected during the GQA Survey could be passed to a contractor for processing at species level. Once the full dataset is assembled, the classification and prediction exercises can commence, and on completion of an operational system, it should still be possible to make an appraisal of the full range of canal sites sampled during the GQA Survey in 2000.

KEY WORDS

RIVPACS; Biological monitoring; macroinvertebrates; Workshop; Abundance data; deep rivers; canals.

1 INTRODUCTION

1.1 Background

There is now widespread recognition that not only chemical analyses but also biological techniques are required for the assessment of river quality. The enlightened view is that chemical and biological approaches are both important and, in fact, complementary. Biological communities may be viewed as permanent monitors of the river environment and changes in their composition, richness and abundance offer a sensitive tool for detecting changes in the aquatic ecosystems. The role of the Environment Agency, includes not only the promotion of water quality improvements to ensure that waters are suitable for their designated uses, but where possible, to reinstate the natural animal and plant life that existed prior to major changes caused by pollution and other forms of man-induced stress.

The biological status of rivers is currently assessed by examining the macroinvertebrate community of the river-bed. This is a well-established practice and is likely to remain a major source of data in the future. It is therefore vital that the most efficient use is made of these data to ensure effective management of water quality improvements by prioritising expenditure and monitoring the effects of capital spend by the major dischargers.

Investment into research, resulting in the production of RIVPACS III+, has enabled the Environment Agency to use biological data with confidence both in the quality of the data and in the process for the analysis of the data. It is now necessary to build on this success to ensure that previous investment is not squandered. This contract includes ten individual projects of varying size and complexity which are needed to increase our understanding of the effects of environmental stress on animal life and increase that knowledge to encompass other water bodies for which we are responsible.

1.2 Objectives

1.2.1 Overall Objective

The overall objective for the three year project, is as follows:

'To develop methodologies to enhance the use of biological data within the Environment Agency so as to fulfil the requirements of GQA classification and various EC Directives as required by the DoE.'

This project is one of a series that will lead to the fulfilment of the objective above by the production of a revised version of the RIVPACS software.

This project is essentially to determine how improvements should be implemented. The procedures by which small improvements will be made are to be worked out in this project. Where a large amount of further work is needed, including biological survey work, scoping studies only are included in this project, so that a fuller appraisal can be made before committing substantial resources. Work identified in these scoping studies will be undertaken as separate daughter projects. The actual modification of the RIVPACS software will itself be the subject of a separate project.

1.2.2. Programme of Work

The three-year project (January 1998 – December 2000) includes ten separate work packages. Individual packages occupy one or, in some cases, two years and start in different years in order to spread the workload. (Each package was given a number in the PID and this has been retained for the information of Environment Agency staff).

The ten work packages are listed below, together with the year(s) in which they will be undertaken, in order to provide the reader with an indication of the full scope of the project. Chapters 2-5 of this report then provide detailed information on the four topics included in the work programme for year 1.

Programme for Year 1 (Jan 1998 – Dec 1998).

A). To host an International Workshop on RIVPACS for invited scientists from across the world and publish a book based on the talks and workshop discussions, in order to document the current state of RIVPACS research and provide a forum for the discussion of future developments. (In addition, Environment Agency personnel are to organise an Open Seminar on RIVPACS). (Year 1 plus part year 2). (Package 5).

B). To revise the Q14 index of abundance so that the potential utility of abundance data can be evaluated. (Year 1 plus Year 2). (Package 6).

C). To produce a scoping report on the standardisation of sampling methods for deep rivers so that the cost of further work can be estimated and a separate project can be specified. (Year 1 only). (Package 10).

D). To produce a scoping report on the work needed to incorporate canals into RIVPACS so that the cost can be estimated and a separate project can be specified. (Year 1 only). (Package 3).

Programme for Year 2 (Jan 1999 – Dec 1999).

Continuation and completion of topics A). and B). from year 1.

E). To produce a scoping report on the use of RIVPACS for education. (Year 2 only). (Package 4)

F). To investigate ways in which information about trophic structure can be incorporated into RIVPACS in order to widen the Agency needs which RIVPACS is able to fulfil. (Years 2 plus Year 3). (Package 8).

G). To evaluate new environmental variables for predictors to improve the capability and utility of RIVPACS (Year 2 plus Year 3). (Package 9).

H). To investigate how a dynamic model should be developed by producing a pilot model. (Year 2 plus Year 3). (Package 12).

Programme for Year 3 (Jan 2000 – Dec 2000).

Continuation and completion of topics F).,G). and H).

I). To report on the market for a commercial version of RIVPACS in order to determine the market needs for a full version of RIVPACS. (Year 3). (Package 2)

J). To investigate the potential of RIVPACS for assessing biodiversity in order to widen the Agency needs which RIVPACS is able to fulfil. (Year 3). (Package 13).

2 INTERNATIONAL WORKSHOP, BOOK AND OPEN SEMINAR ON RIVPACS

2.1 Introduction

RIVPACS has a proven track record as an operationally efficient tool for the biological quality assessment of rivers and in particular for GQA classifications. In 1990 RIVPACS II was chosen for the biological component of the 1990 River Quality Survey throughout the United Kingdom, and in 1995, a more comprehensive version (RIVPACS III) was used for the GQA survey. This application of the system used only a small fraction of the analytical power of RIVPACS.

The RIVPACS approach is novel, and considerable interest has been shown in the development of similar systems abroad. In considering future directions of RIVPACS development, it was decided that an International Workshop consisting of invited experts would be an effective way of brainstorming current RIVPACS issues and considering new directions for research in order to meet existing and future needs. In addition, an International Workshop would be an effective vehicle for fostering developments in other countries. From the outset, it was decided that the workshop presentations and discussions should form the basis of a book.

Although numerous scientific papers on RIVPACS have been published in journals, RIVPACS itself has not been available for use by British scientists outside of the Environment Agency, the Scottish Environment Protection Agency and the Department of the Environment (Northern Ireland). Recently a β-test version of RIVPACS III has been released for sale, but the price means that the market is likely to be small. Already, a number of prospective buyers from University departments have indicated that the cost is too high. (Note that year 2 of this contract includes a scoping report on the use of RIVPACS for education). In order to provide British scientists with the latest information on RIVPACS, an Open Seminar is to be held in the UK, organised by Environment Agency personnel.

2.2 Objectives

The overall objective is as follows:

'To disseminate information about RIVPACS around the world and within the UK, and to formulate future directions for RIVPACS research'.

The specific objectives are:

1. To hold a prestigious International Workshop comprising invited experts from around the world.

2. To publish a book derived from the invited talks and workshop sessions which documents current RIVPACS procedures in the UK and abroad, and which considers the potential for the future development of this approach.

3. To hold a seminar in the UK to explain about RIVPACS and related work to the scientific community.

2.3 The International Workshop

The concept of an International Workshop was first raised in 1995 and by May 1996, the Environment Agency and the Institute of Freshwater Ecology were actively considering the options. After consultations, it was agreed that the International Workshop would be organised and funded by a consortium of three equal partners: the Environment Agency, the Institute of Freshwater Ecology and an Australian consortium comprising Environment Australia and the Land & Water Research & Development Corporation. During the summer of 1996, a number of practical considerations were aired, including the need for an Organising Committee, ideas on potential delegates, presentations and working group topics, the form of a publication, suitable venues and specific dates for the meeting. Later in the year, a framework for the Workshop was agreed and by January 1997, the Venue and dates had been fixed as Jesus College Oxford, from 16-18 September 1997.

A formal Organising Committee was established including members from the Environment Agency (R.Sweeting, R.Dines, B.Hemsley-Flint, P.Logan, J. Murray-Bligh, J.Steel) the Institute of Freshwater Ecology (J.Hilton, J.Wright, M.Furse) and an Australian representative (P.Davies). The Committee was responsible for organising the scientific, social and financial aspects of the Workshop and for making decisions on the form of the publication resulting from the meeting. Several meetings were held over the next few months at the IFE River Laboratory, in Reading and at Jesus College, Oxford.

The committee selected participants from around the world, comprising scientists working on biological river-quality assessment, classification or modelling systems. Additional participants were invited where it was felt that they could make a positive contribution. The first tranche of invitations went out in February 1997 and the Committee kept in touch with the responses in order to ensure that all available places were filled and as wide a representation of those actively involved or interested in the RIVPACS approach from around the world were invited. The formal presentations were by invitation, but many other delegates offered poster presentations or software demonstrations and these were accommodated in a special evening session.

A series of five parallel workshop sessions were devised by the Committee to include a variety of important and controversial issues. The topics to be covered in each session were then thought out in detail by J.Wright and M.Furse and later approved by the Organising Committee. These workshops were the main vehicles by which ideas about the future directions for research and RIVPACS applications were obtained. The concept was for each workshop to be audio-taped, and directed by a workshop Chairman who was then responsible for the presentation of a brief 15 minute report to the full International Workshop and the production of a short report on the discussions and conclusions of that workshop. To help in this task, each Chairman was allocated a rapporteur to take headline notes during the discussions, ensure that the tape recorder was working and to liaise with the Chairman as necessary to ensure that he was fully briefed.

Following discussions between the Organising Committee Chairman (R.A.Sweeting) and the Director of the Freshwater Biological Association, agreement was reached that the FBA would publish manuscripts based on the eighteen presentations by invited speakers and the synopses of the five Workshop discussions in the FBA Special Publications series. David Sutcliffe would act as copy editor for FBA Publications and J.Wright and M.Furse would take on editorial responsibilities for the scientific content of each manuscript.

Prior to the International Workshop, each author of an invited paper and each workshop chairman was given clear instructions on the format for presentation of the manuscripts, based on information agreed between D.Sutcliffe, J.Wright and M.Furse.

Environment Agency members of the Committee took on a range of responsibilities to ensure that there was good communication with Jesus College, Oxford regarding facilities for the scientific sessions, accommodation, food, including the provision of a Workshop Banquet. A boat trip on the R.Thames to see the sites around and downstream of Oxford was also arranged for the end of the Workshop. Finally, the Environment Agency took responsibility for the Workshop finances and IFE sent out the invitations and follow-up communications to participants.

The International Workshop was attended by approximately 60 participants from 22 countries, supported by a further two 'gophers' charged with the task of helping members of the Organising Committee to ensure that the Workshop ran smoothly. A full list of participants is given in Appendix 1. The final RIVPACS Workshop programme is provided as Appendix 2. The Workshop was generally regarded as a success, both scientifically and socially, and many positive responses were received from participants after the meeting.

The International Workshop itself took place prior to the commencement of this contract, and hence the major input of time within this contract has been on the editing of manuscripts for the book.

2.4 Progress with the book

All eighteen invited speakers at the Workshop agreed to prepare manuscripts based on their presentations. Although the Workshop was concerned primarily with the use of multivariate techniques, some additional procedures were also presented. For example, on the Fraser River in British Columbia, Canada, both the multivariate and the multimetric approach were tested concurrently and reported in the Workshop. In view of this, and the fact that Dr Michael Barbour had presented a poster during the Workshop on the multimetric approach in the USA, he was also invited to prepare a manuscript. This decision was made to help readers become more familiar with the principles behind the multimetric approach and the way in which it is being applied to a wide range of freshwater systems across the USA. The chairmen of the five specialist Workshop sessions also agreed to provide an account of their discussions and conclusions. As a consequence the book will have a total of 24 chapters.

From the list of contents (Table 2.1.) it is apparent that the 24 chapters fall into four main sections. Chapters 1-7 describe the development and operational use of RIVPACS, together with a consideration of the relevance of RIVPACS for non-standard applications. Chapters 8-13 then describe a series of case histories in which the RIVPACS approach has been applied

in different countries. They include rivers throughout Australia (chapters 8-10), the North American Great Lakes and the Fraser River in Canada (chapters 11-13). Next, chapters 14-19 continue with a varied group of papers that offer contrasting approaches to biological assessment in both Britain and abroad. Finally, chapters 20-24 present the findings of the five Workshop discussion groups.

Each of the 19 manuscripts is being subjected to a formal review process involving the editors (J.F.Wright & M.T.Furse), the FBA copy editor (D.W.Sutcliffe) and another referee. After review, each manuscript is being returned to the authors for revision, as necessary, and revised manuscripts are then re-examined by the editors before formal acceptance. A number of the Workshop discussion chapters have been circulated by their authors to participants in their particular Workshop for comment and amendment prior to submission to the editors, who are then taking on the review process before each one is accepted. The current state of progress on the 24 chapters is given in Table 2.2.

Table 2.2 Status of the 24 chapters comprising the book on the RIVPACS International Workshop, as of January 1999.

Milestone	Number out of 24
Number of manuscripts received	23
Number of manuscripts returned to authors after review	21
Number of revised manuscripts received	20
Number of revised manuscripts formally accepted	16

The aim is to have the 24 chapters formally accepted by the end of March 1999. The next stage is for all chapters to be copy edited to ensure conformity through the book prior to typesetting, followed by proof-reading by the printers, authors and editors. It is hoped that final printing will take place before the end of 1999.

2.5 Open Seminar on RIVPACS

The Open Seminar, which is still to be organised, will be based on a selection of the presentations given at the International Workshop. It will be organised by members of the Workshop Committee from the Environment Agency, who will also arrange the venue and format.

A selection of the introductory talks and posters already presented at the International Workshop will be repeated at the Open Seminar to introduce all aspects of RIVPACS and to promote discussion. This is to keep the amount of preparation to a minimum. The seminar will be solely about RIVPACS.

Participants at the Open Seminar will be asked about the market for an abbreviated BMWP-only version of RIVPACS. This aspect of the seminar will be organised by members of the organising committee from the IFE.

Table 2.1. Contents of the book based on the RIVPACS International Workshop held at Jesus College, Oxford between 16 and 18 September 1997.

CONTENTS

3 DEVELOPMENT OF THE USE OF ABUNDANCE DATA FOR BIOLOGICAL QUALITY ASSESSMENT

3.1 Introduction

3.1.1 Background

Existing methods of biological quality assessment which are used by the Environment Agency (and SEPA and DoE Northern Ireland) are based on information about the presence and absence of taxa. The most commonly used quality indices are the ratios (O/E) of observed (O) to expected (E) values of BMWP score, number of BMWP taxa and ASPT based on RIVPACS predictions. Information on the absolute or relative abundance of individual taxa is also used by freshwater biologists in river quality assessments at individual sites. The use of additional data on the abundance levels of individual taxa should lead to better definitions of river quality, and in particular should enable the effects of mild enrichment to be detected in cases where sensitive taxa have declined in abundance, but few if any have been lost from the site.

RIVPACS is able to predict the expected abundance of individual macroinvertebrate families for standard 3-minute RIVPACS samples in the absence of environmental stress or pollution. RIVPACS predictions are based on the use of log abundance categories (Table 3.1) and calculated as detailed in Table 3.2. These predictions are only currently available for single season samples.

Table 3.1 Log abundance categories used to store raw family abundance data

Log abundance category	Number of individuals in sample
0	0
1	1-9
2	10-99
3	100-999
4	1000-9999
5	10000-99999

Table 3.2 Method of calculating the expected log abundance of individual taxa

The expected log abundance for a particular taxa j in a sample from a site is calculated as follows:

(i) From the site's environmental characteristics, RIVPACS predicts the probability P_i of the site belonging to RIVPACS site group i (RIVPACS III has 35 groups – see User Manual).

(ii) Let A_{ij} denote the mean of the log abundance categories of taxa j for the RIVPACS reference sites in site group i.

(iii) The expected log abundance E_{Aj} of taxa j is then estimated by: $E_{Aj} = \sum_{i=1}^{35} (P_i \, . \, A_{ij})$

In the previous phase of RIVPACS development, a number of different quality indices involving a comparison of the observed and predicted log abundance categories of families were devised and assessed (Wright *et al.* 1995 - R&D Note 453). Several of these had useful attributes, but the one showing most promise was the Q14 Index. Q14 is a measure of the overall proportional loss of expected abundance of taxa with a BMWP score of 4 or more. The index appears to be highly discriminatory amongst sites at the higher end of the quality spectrum, which suggests that it may more effective at detecting the early effects of stress before loss of taxa leads to lower O/E ratios (also referred to as EQIs). Q14 was incorporated into RIVPACS III (Cox *et al.* 1995 – R&D Note 454) to allow users to test it and comment on its value. A lower limit for Q14 was devised to distinguish sites of high biological quality from all others; this limit was based on the lower 5 percentile value of Q14 for all the single season samples of the 438 reference sites on which RIVPACS II was based. If the value of Q14 falls below the critical value, this is taken as indicative of environmental stress.

3.1.2 Objectives

The overall aim is to refine the Q14 index or derive a better alternative abundance-based index.

The specific objectives are:

1 To re-calculate the critical limits for the Q14 index based on the more recent data set of 614 sites on which RIVPACS III is based.

2 To propose one or two alternatives indices of the form W(B1,B2) for testing.

3 To add the products of the objectives above to a test version of the abundance component of RIVPACS III for testing alternative indices. This is to include a program to convert data held as taxa-samples matrices in EXCEL, saved in comma-separated format "x.CSV" into biological and environmental files formatted for use with RIVPACS, so that it can be used with existing data, and sufficient documentation to enable users to undertake tests and a questionnaire to elicit feedback.

4 To help the project board to organise testing by users in the Environment Agency, SEPA and DoE Northern Ireland.

5 To collect feedback on the utility of these developments.

6 To undertake a BAMS-type assessment (using the 16 sites for which replicate samples are available) to examine within-site variation to be expected at a series of sites which vary in type and quality.

7 To produce a report on the assessment and views from the users about the utility of these developments. To produce a report on the (quality *index*) system or systems to be incorporated into the operational version of RIVPACS

8 To produce a project plan for the introduction of the system identified in specific objective 7 into a new version of RIVPACS, as an appendix in the report. This plan must include realistic timescales, a description of the work which is needed, and an estimate of the costs for each item of work.

3.2 Development of abundance-based indices

3.2.1 Restriction to BMWP family level

Although family abundance predictions in the RIVPACS software package are made for all families of macroinvertebrates, all the previous and proposed abundance-based quality indices have been developed using abundances at BMWP family level only. This was done for three reasons:

(i) BMWP family-level (hereafter referred to as BMWP taxa) is the most common standard level of identification for freshwater macroinvertebrate samples in the UK.

(ii) Indices can be calculated for any site for which BMWP O/E indices can be, or already have been calculated, providing that the abundances or log abundance classes of individual BMWP taxa were also recorded. The relationships between quality indices based on abundance and those based on O/E indices using only presence-absence data can then be assessed, perhaps leading to an integrated measure of site quality involving both types of index.

(iii) The adherence to BMWP family-level ensures that such abundance-based indices can be used to assess site quality for the Environment Agency's national surveys in 1990, 1995 and that planned for 2000, maintaining a standardisation of methodology over time.

Table 3.3 BMWP scores of all taxa in RIVPACS III

Score	No. of taxa	Taxa		
10	22	Aphelocheiridae	Beraeidae	Brachycentridae
		Capniidae	Chloroperlidae	Ephemerellidae
		Ephemeridae	Goeridae	Heptageniidae
		Lepidostomatidae	Leptoceridae	Leptophlebiidae
		Leuctridae	Molannidae	Odontoceridae
		Perlidae	Perlodidae	Phyrganeidae
		Potamanthidae	Sericostomatidae	Siphlonuridae
		Taeniopterygidae		
8	10	Aeshnidae	Astacidae	Calopterygidae
		Cordulegasteridae	Corduliidae	Gomphidae
		Lestidae	Libellulidae	Philopotamidae
		Psychomyiidae		
7	5	Caenidae	Limnephilidae	Nemouridae
		Polycentropodidae	Rhyacophilidae	
6	9	Ancylidae	Coenagriidae	Corophiidae
		Gammaridae	Hydroptilidae	Neritidae
		Platycnemididae	Unionidae	Viviparidae
5	21	Corixidae	Dendrocoelidae	Dryopidae
		Dytiscidae	Elmidae	Gerridae
		Gyrinidae	Haliplidae	Hydrometridae
		Hydrophilidae	Hydropsychidae	Hygrobiidae
		Mesovelidae	Naucoridae	Nepidae
		Notonectidae	Planariidae	Pleidae
		Scirtidae	Simuliidae	Tipulidae
4	3	Baetidae	Piscicolidae	Sialidae
3	10	Asellidae	Erpobdellidae	Glossiphoniidae
		Hirudinidae	Hydrobiidae	Lymnaeidae
		Physidae	Planorbidae	Sphaeriidae
		Valvatidae		
2	1	Chironomidae		
1	1	Oligochaeta		

All the proposed indices are to be based on a comparison of the observed log abundance classes of individual BMWP taxa with the expected log abundance as predicted by RIVPACS. This influences the mathematical forms of index that can be defined.

3.2.2 Indices of the form $W(B_1,B_2)$

For the majority of taxa, pollution and other forms of environmental stress lead to lower abundances than expected or their total disappearance from the site. However, a few pollution-tolerant BMWP taxa, such as Chironomidae, Oligochaeta and Asellidae etc., tend to become more common when site quality declines. The following indices try to incorporate both of these indicators of stress.

Suppose all taxa with a BMWP score of at most B_1 are treated as pollution-tolerant, while all taxa with a BMWP score of at least B_2 are considered pollution-intolerant. Then define for any site i

O_{ij} = observed log abundance category of taxa j ; E_{ij} = expected log abundance of taxa j

$A_1 = \sum(O_{ij} - E_{ij})$, where summation is restricted to taxa with BMWP score $\leq B_1$ and $O_{ij} > E_j$
i.e. the excess of abundance above that expected, for "low" scoring taxa

$A_2 = \sum(E_j - O_j)$, where summation is restricted to taxa j with BMWP score $\geq B_2$ and $O_{ij} < E_j$
i.e. the deficit of abundance below that expected, for "high" scoring taxa

$E_{T1} = \sum E_{ij}$, where the summation is restricted to taxa j with BMWP score $\leq B_1$
i.e. the sum of expected abundances for "low" scoring taxa

$E_{T2} = \sum E_{ij}$, where the summation is restricted to taxa j with BMWP score $\geq B_2$
i.e. the sum of expected abundances for "high" scoring taxa

Then a general quality index is defined by:

$$W(B_1,B_2) = 100 \times (1 - (A_1 + A_2)/(E_{T1} + E_{T2}))$$

This index measures the combined proportional loss of expected abundance of high scoring taxa and the excess of expected abundance of low scoring taxa. There are many possible choices for B_1 and B_2. At one extreme, with $B_1=0$ and $B_2=1$, W(0,1) treats observed abundances less than expected for any taxa as indicative of pollution. In the previous phase of RIVPACS development (Wright *et al.* 1995 - R&D Note 453) three choices of $W(B_1,B_2)$ were assessed :

Q12 = W(2,3) ie $B_1 = 2$ and $B_2 = 3$

Q13 = W(3,7)

Q14 = W(0,4)

Q12 involved all the taxa and treats only Chironomidae and Oligochaeta as "low" scoring pollution-tolerant taxa. Q13 adds in three-scoring taxa (which includes Asellidae,

Erpobdellidae etc.) as pollution-tolerant and restricts "high" scoring taxa to the 37 families with a BMWP score of at least seven.

Q14, the most promising of these three indices, only involves the proportional deficit of observed abundances below those expected for taxa with a BMWP score of at least four. Q14 ignores any excess of abundance of low scoring taxa.

Following internal discussion, we propose to test the follow indices (Objective 2):

Q14 : the index currently in RIVPACS III
Q15 = W(3,4) : combined proportional loss of expected abundance of taxa with BMWP≥4 and the excess of expected abundance of taxa with BMWP≤3
Q16 = W(0,0) : proportional loss of expected abundance of all BMWP taxa, regardless of their score

The general index $W(B_1,B_2)$, and hence also Q14-Q16, have been constrained to have a maximum possible value of 100 indicating perfect agreement between observed and expected abundances. If B_1 is greater than zero, it is possible to get small negative values of $W(B_1,B_2)$ if the only taxa present are "low" scoring taxa which occur in much larger numbers than expected. However, negative values should be set to zero, which is the value indicative of the poorest quality. $W(B_1,B_2)$ should also always be set to zero when no taxa are present.

In practice, indices of the form $W(B_1,B_2)$ normally take values less than 100, even for very high quality sites with higher than expected abundances for several high scoring taxa. The mean values of each index for the RIVPACS III reference sites are included in Table 3.4.

3.2.3 Alternative forms of index

Alternatives to the $W(B_1,B_2)$ form of index have recently been devised. Indices Q17 and Q18 are abundance-based equivalents of the O/E ratios for number of taxa and ASPT respectively. The weights (or importance) given to each taxa in determining the index value are obtained from the taxa's observed and expected log abundances. For any site i:

let O_{ij} and E_{ij} denote the observed and expected log abundances;
and let S_j denote the BMWP score for taxa j; then:

$Q17 = \Sigma_i O_{ij} / \Sigma_i E_{ij}$

= Sum of all observed log abundances / Sum of all expected log abundances

$Q18 = O_{AW} / E_{AW}$

where $O_{AW} = \Sigma_i(O_{ij}S_j)/ \Sigma_i O_{ij}$ = abundance-weighted observed ASPT
and $E_{AW} = \Sigma_i(E_{ij}S_j)/ \Sigma_i E_{ij}$ = abundance-weighted expected ASPT

Other alternatives under consideration are:

$Q19 = R_O / R_E$, where

Ratio R_O = sum of observed log abundance categories of taxa scoring 4 or more / sum of observed log abundance categories of taxa scoring 3 or less

Ratio R_E = sum of expected log abundances of taxa scoring 4 or more / sum of expected log abundances of taxa scoring 3 or less

Q19 is based on the idea that as quality declines so the ratio of abundances of high scoring to low scoring taxa will decline. Q19 above defines low scoring taxa to be those with BMWP score or 3 or less. Dividing by the expected ratio R_E enables us to standardise the index so that the RIVPACS reference sites (and other high quality sites) will have a value for Q19 of around unity.

3.3 Modifications and additions to RIVPACS software (objective 3)

3.3.1 RIVPACS Test code for new abundance-based indices

At present, indices Q14-Q17 have been coded directly into a modified version of RIVPACS III+ (to be called RIVPACS III++) for testing on both the 614 sites and the BAMS replicated sites (Furse et al.1995 – R & D Note 412). During trials, code has only been written to output the values of the new indices to what is known in RIVPACS III as the Q14 abundance index output file.

Code for indices Q18 and Q19 will be added between January and March 1999.

3.3.2 Program to convert EXCEL data files into RIVPACS format

The RIVPACS software package usually reads the biological and environmental data on each of a sequence of sites from ASCII text data files. The information must be stored in a very strict format, first developed for RIVPACS II in the 1980s. Users have found it cumbersome to input their data in this format. Rather than change the format of the files that can be read into RIVPACS, it was agreed that, as part of this project, IFE would provide a program to help RIVPACS users get their biological and environmental data files into the correct format (see objective 3).

Program EXCLRIVP, in FORTRAN (as is RIVPACS) has been written to allow the user to prepare their data in a spreadsheet. The biological data can then be laid out as a matrix with sites as rows and taxa as columns, or vice versa. It is also possible to use the program to make RIVPACS format biological files from data stored as records of three fields:

site, taxa code, abundance code (0/1 for presence-absence data);

this format is often the easiest to use for data extracted from relational databases, such as MS-ACCESS.

The environmental data can be stored in a spreadsheet with sites as rows and variables as columns.

A listing of the documentation file EXCLRIVP.INF giving precise details of the required data layout and how to use the program EXCLRIVP are given in Appendix 3.

A trial version of program EXCLRIVP is being tested within the IFE River Laboratory and a copy has already been given informally to Ian Humpheryes of the Environment Agency Southern Region for testing and comments. By April 1999 a version will have been sent out for testing by users within the Environment Agency, as agreed with the Project Board.

3.4 Critical lower limits of indices for the RIVPACS III reference sites (objective 1)

In developing band limits for number of taxa, BMWP score and ASPT using O/E values, IFE suggested using the lower 10 or 5 percentile limits of the frequency distribution of these indices for the RIVPACS reference sites as a means of defining the critical cut-off point for sites to be classified in the top quality band. The critical lower limit for Q14 was previously set to the lower 5 percentile value of the overall distribution of values for all the single season samples for the 438 RIVPACS II reference sites; this was equal to 34. Objective 1 of this study requires the critical value of Q14 to be re-calculated from the frequency distribution of its values for the 614 reference sites in RIVPACS III. Table 3. gives the lower 5 percentile limits for each of indices Q14-Q17; this is given separately for each season and then for the overall distribution of all 1842 (3 x 614) single season samples. Each index had similar percentile limits for each season such that a single critical value can be used for any particular index, namely the 5 percentile value for the overall distribution (Table 3.4). A site with an index value **less than** the critical limit, should be an indication that the site is not as expected and is subject to some degree of environmental stress.

Thus the critical value for Q14 has risen from 34 to 42, a significant increase. The reason for this is that, as part of the selection of reference sites for RIVPACS III, 52 of the reference sites in RIVPACS II were dropped, mostly because they had low O/E values for number of BMWP taxa. Thus the poorest quality reference sites in RIVPACS II were eliminated from RIVPACS III, thus increasing the lower percentile limits for indices of site quality.

Table 3.4 The critical lower 5 percentile values of the abundance-based indices Q14-Q17 for each of the three single seasons samples for the 614 RIVPACS III reference sites. Spr=Spring, Sum=Summer, Aut=Autumn. Also given is the lower 5 percentile, mean, median (50%), inter-quartile range (25-75 percentiles) and maximum of the overall distribution of values for all the samples regardless of season.

Index	lower 5 percentile			Overall distribution					
	Spr	Sum	Aut	**5%**	mean	25%	50%	75%	max
Q14	43	42	38	**42**	64	56	65	74	95
Q15	50	48	45	**58**	67	61	68	74	90
Q16	48	47	46	**47**	67	60	67	75	96
Q17	60	61	59	**60**	101	82	99	117	214

3.5 Assessment of effects of sampling variation on the values of abundance-based quality indices (objective 6)

It was decided that, in order for both the IFE and the Environment Agency to test and assess the relative merits of different proposed indices, it would be useful to have knowledge of the extent to which each index is affected by sampling variation and by the errors in the RIVPACS estimates of expected abundance levels due to measuring the environmental variables. This work is part of objective 6 (Section 3.1.2) and not originally due to start until January 1999, but has been brought forward.

It was agreed in the project specification (objective 6) that the assessment of these effects was to be based on data from the same sites for which replicated biological sampling and replicated measurement of environmental variables was undertaken in a previous project by the IFE for the then NRA (Furse *et al.* 1995). That project, referred to as BAMS (**B**iological **A**ssessment **M**ethods **S**tudy) was based on a study of 16 sites. The 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 (Table 3.5; see Furse *et al.* 1995 for further details)

In each of the three RIVPACS seasons at each of the 16 BAMS sites, three replicate samples were taken, two by an IFE biologist and one by a local NRA biologist. RIVPACS biological abundance files have been made for all possible combinations of samples at each site in each season.

In addition, the person who took any particular biological sample is assumed to have estimated the RIVPACS environmental variables values for that site in each of the three RIVPACS seasons. It is the average of their values across Spring, Summer and Autumn which are used to derive the environmental data values to be used to make RIVPACS predictions of the expected abundance levels. This logic enables us to incorporate errors in the various abundance-based indices due to errors in measuring the environmental variables. Notice that because the proposed indices will probably not be simple O/E measures, it is not possible to completely separate errors/variation in O from that in E. However, most importantly, this approach has provided an estimate of the overall sampling variation plus errors (collectively termed "uncertainty") in each abundance index.

The uncertainty in the abundance-based quality indices Q14-Q17, as represented by their standard deviation or coefficient of variation within the 16 BAMS sites, is shown in Tables 3.6-3.9 respectively.

We have also begun assessing whether the level of uncertainty in a particular index changes systematically with its values and hence which statistical transformation may be required in the statistical simulations to be included in RIVPACS III++ to derive uncertainty confidence limits for the chosen abundance-based indices. Table 3.10 summarises regressions of log replicate variance against log replicate mean for the four indices. Regression slopes around zero indicate no relationship between the degree of uncertainty (i.e. replicate variance) and the estimated site quality (i.e. replicate mean). A regression slope of around one suggests that the square roots of the index value with have roughly constant levels of uncertainty, while a slope of around two suggests replicate variance of the log of index values will not vary with the index estimate of site quality. Table 3.10 suggests a square root transformation of index values will help us simplify the representation and simulation of uncertainty in each of the

Table 3.5 Characteristics of the stratified random selection of the 16 BAMS study sites in terms of their (a) quality bands as defined by range of O/E BMWP quality index values; and (b) RIVPACS group environmental 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 mean value of environmental variable	site type group			
	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

indices Q14-Q17, although a log transformation might be best for Q14. Such a square root transformation is used in RIVPACS III+ to help simulate sampling variation in the observed number of BMWP taxa as part of the process of estimating uncertainty in O/E values based on number of BMWP taxa (Clarke *et al.* 1997).

Table 3.11 and Figure 3.1-3.3 show the correlation and relationship between each of the abundance-based indices Q14-Q17 and O/E ratio for number of BMWP taxa or O/E for ASPT based on just the presence-absence of taxa.

Initial analyses revealed that the new Q15 index, which we thought would be an improvement on Q14, has inappropriately increased in value (supposedly suggesting higher quality) when only taxa scoring 3 or less remain, but are decreasing in abundance from greater to less than expected numbers. This lead to the idea of Q16 which treats the loss in abundance (below expectation) of any taxa as indicating a reduction in quality. Q17 was devised as the nearest abundance-based O/E analogue to the current O/E (EQI) index based on number of BMWP taxa. Q17 is the only index of the above six which has the attraction of being centred around unity for the RIVPACS reference sites (the others are all below unity)

Table 3.6 Mean, standard deviation (SD) and coefficient of variation (%CV = SD/mean) of the values of the abundance-based quality index Q14 observed in replicate single season samples for each BAMS study site. The mean number of BMWP taxa observed at the site in single season samples is given for reference.

Site	Site / River	BMWP TAXA	Mean	SD	CV
1	South Domaford / River Okement	20.0	58.3	6.0	10.4
2	Tantons Plain / River Darracott	15.4	32.7	6.6	20.1
3	Croxdale House / Croxdale River	13.0	26.5	5.5	20.7
4	B6313 / Twyzell Burn	9.0	27.8	5.5	19.7
5	Haslingbourne Bridge / Petworth Brook	17.9	44.3	2.6	5.9
6	Woodford Bridge / Sheppey River	18.8	47.7	4.1	8.6
7	Bowlish / Sheppey River	12.0	27.1	3.8	13.9
8	PTC Bedford Brook / Moss Brook	5.8	5.3	1.7	32.6
9	Seend Bridge / Summerham Brook	19.7	55.5	5.9	10.6
10	Swarkestone / Cuttle Brook	11.9	8.7	3.0	35.0
11	Jenny Mill / Poulshot Stream	12.8	29.3	2.6	8.9
12	Dewsbury / Spen Brook	5.9	3.4	2.2	66.3
13	Brigg / Old River Ancholme	18.6	42.3	4.4	10.4
14	Ferry Sluice / Broad Rife	8.6	6.8	2.9	43.6
15	U/S Skellingthorpe /Skell. Main Drain	15.0	29.8	6.0	20.2
16	Cherry Cob / Keyingham Drain	3.1	0.5	0.8	173.2

Further analysis is needed to understand and summarise the 'natural' levels of uncertainty in each of these indices and to quantify their relative precision as indices of biological quality or condition.

Table 3.7 Mean, standard deviation (SD) and coefficient of variation (%CV = SD/mean) of the values of the abundance-based quality index Q15 observed in replicate single season samples for each BAMS study site. The mean number of BMWP taxa observed at the site in single season samples is given for reference.

Site	Site / River	BMWP TAXA	Mean	SD	CV
1	South Dornaford / River Okement	20.0	60.9	4.2	6.9
2	Tantons Plain / River Darracott	15.4	34.4	6.1	17.8
3	Croxdale House / Croxdale River	13.0	32.7	8.7	26.5
4	B6313 / Twyzell Burn	9.0	35.7	3.9	11.0
5	Haslingbourne Bridge / Petworth Brook	17.9	54.1	2.2	4.0
6	Woodford Bridge / Sheppey River	18.8	60.4	2.1	3.5
7	Bowlish / Sheppey River	12.0	36.6	5.0	13.7
8	PTC Bedford Brook / Moss Brook	5.8	33.0	2.4	7.3
9	Seend Bridge / Summerham Brook	19.7	69.2	3.3	4.7
10	Swarkestone / Cuttle Brook	11.9	35.5	4.3	12.1
11	Jenny Mill / Poulshot Stream	12.8	52.1	4.2	8.0
12	Dewsbury / Spen Brook	5.9	31.1	2.1	6.9
13	Brigg / Old River Ancholme	18.6	63.9	1.6	2.4
14	Ferry Sluice / Broad Rife	8.6	44.9	1.2	2.6
15	U/S Skellingthorpe /Skell. Main Drain	15.0	56.2	1.9	3.4
16	Cherry Cob / Keyingham Drain	3.1	45.1	1.5	3.4

Table 3.8 Mean, standard deviation (SD) and coefficient of variation (%CV = SD/mean) of the values of the abundance-based quality index Q16 observed in replicate single season samples for each BAMS study site. The mean number of BMWP taxa observed at the site in single season samples is given for reference.

Site	Site / River	BMWP TAXA	Mean	SD	CV
1	South Dornaford / River Okement	20.0	62.5	5.8	9.3
2	Tantons Plain / River Darracott	15.4	44.4	5.7	12.7
3	Croxdale House / Croxdale River	13.0	38.1	4.8	12.6
4	B6313 / Twyzell Burn	9.0	34.9	4.8	13.6
5	Haslingbourne Bridge / Petworth Brook	17.9	50.8	3.4	6.7
6	Woodford Bridge / Sheppey River	18.8	54.8	4.5	8.3
7	Bowlish / Sheppey River	12.0	36.7	3.8	10.3
8	PTC Bedford Brook / Moss Brook	5.8	17.0	1.8	10.6
9	Seend Bridge / Summerham Brook	19.7	61.6	5.8	9.4
10	Swarkestone / Cuttle Brook	11.9	36.7	5.8	15.8
11	Jenny Mill / Poulshot Stream	12.8	47.4	2.4	5.1
12	Dewsbury / Spen Brook	5.9	21.0	2.6	12.5
13	Brigg / Old River Ancholme	18.6	57.5	2.9	5.0
14	Ferry Sluice / Broad Rife	8.6	30.8	3.6	11.7
15	U/S Skellingthorpe /Skell. Main Drain	15.0	48.3	7.1	14.6
16	Cherry Cob / Keyingham Drain	3.1	14.1	2.0	14.2

Table 3.10 Regression of Log variance against Log mean for each abundance-based quality index (Each regression is based on n= 16 sites x 3 single seasons = 48 observations). Log Variance = a + b Log Mean; r^2 = % of variation in Log variance explained, p = significance probability for test of b=0.

Index	Name	a ± SE(a)	b ± SE(b)	r^2	p
Q14	W(0,4)	0.22 ± 0.50	0.72 ± 0.16	31%	<0.001
Q15	W(3,4)	8.14 ± 2.92	-1.62 ± 0.77	9%	0.04
Q16	W(0,0)	-1.11 ± 1.50	0.99 ± 0.41	11%	0.02
Q17	Σ Obs Abund / Σ Exp Abund	-1.75 ± 1.50	1.32 ± 0.38	21%	0.001

Table 3.9 Mean, standard deviation (SD) and coefficient of variation (%CV = SD/mean) of the values of the abundance-based quality index Q17 observed in replicate single season samples for each BAMS study site. The mean number of BMWP taxa observed at the site in single season samples is given for reference.

Site	Site / River	BMWP TAXA	Mean	SD	CV
1	South Dornaford / River Okement	20.0	77.2	9.8	12.7
2	Tantons Plain / River Darracott	15.4	61.4	7.4	12.0
3	Croxdale House / Croxdale River	13.0	58.2	6.9	11.8
4	B6313 / Twyzell Burn	9.0	47.8	10.6	22.2
5	Haslingbourne Bridge / Petworth Brook	17.9	70.9	4.4	6.2
6	Woodford Bridge / Sheppey River	18.8	72.1	9.1	12.7
7	Bowlish / Sheppey River	12.0	57.6	7.9	13.6
8	PTC Bedford Brook / Moss Brook	5.8	22.1	2.2	9.8
9	Seend Bridge / Summerham Brook	19.7	79.4	9.5	12.0
10	Swarkestone / Cuttle Brook	11.9	50.0	9.1	18.3
11	Jenny Mill / Poulshot Stream	12.8	61.4	5.4	8.8
12	Dewsbury / Spen Brook	5.9	31.4	4.2	13.5
13	Brigg / Old River Ancholme	18.6	69.8	5.1	7.3
14	Ferry Sluice / Broad Rife	8.6	36.1	5.0	13.9
15	U/S Skellingthorpe /Skell. Main Drain	15.0	59.7	10.0	16.8
16	Cherry Cob / Keyingham Drain	3.1	15.9	2.1	13.2

Table 3.11 Correlation of each abundance-based quality index with O/E for number of BMWP taxa and O/E for ASPT (based on n=16 sites x 3 single seasons = 48 observations).

Index	Name	O/E Taxa	O/E ASPT
Q14	W(0,4)	0.91	0.86
Q15	W(3,4)	0.63	0.71
Q16	W(0,0)	0.94	0.88
Q17	Σ Obs Abund / Σ Exp Abund	0.94	0.82

Figure 3.1 Abundance-based quality indices Q14-Q17 for the 16 BAMS study sites: Plot of index value against O/E for number of BMWP taxa for all individual single season samples (16 sites x 3 samples x 3 seasons = 144 observations).

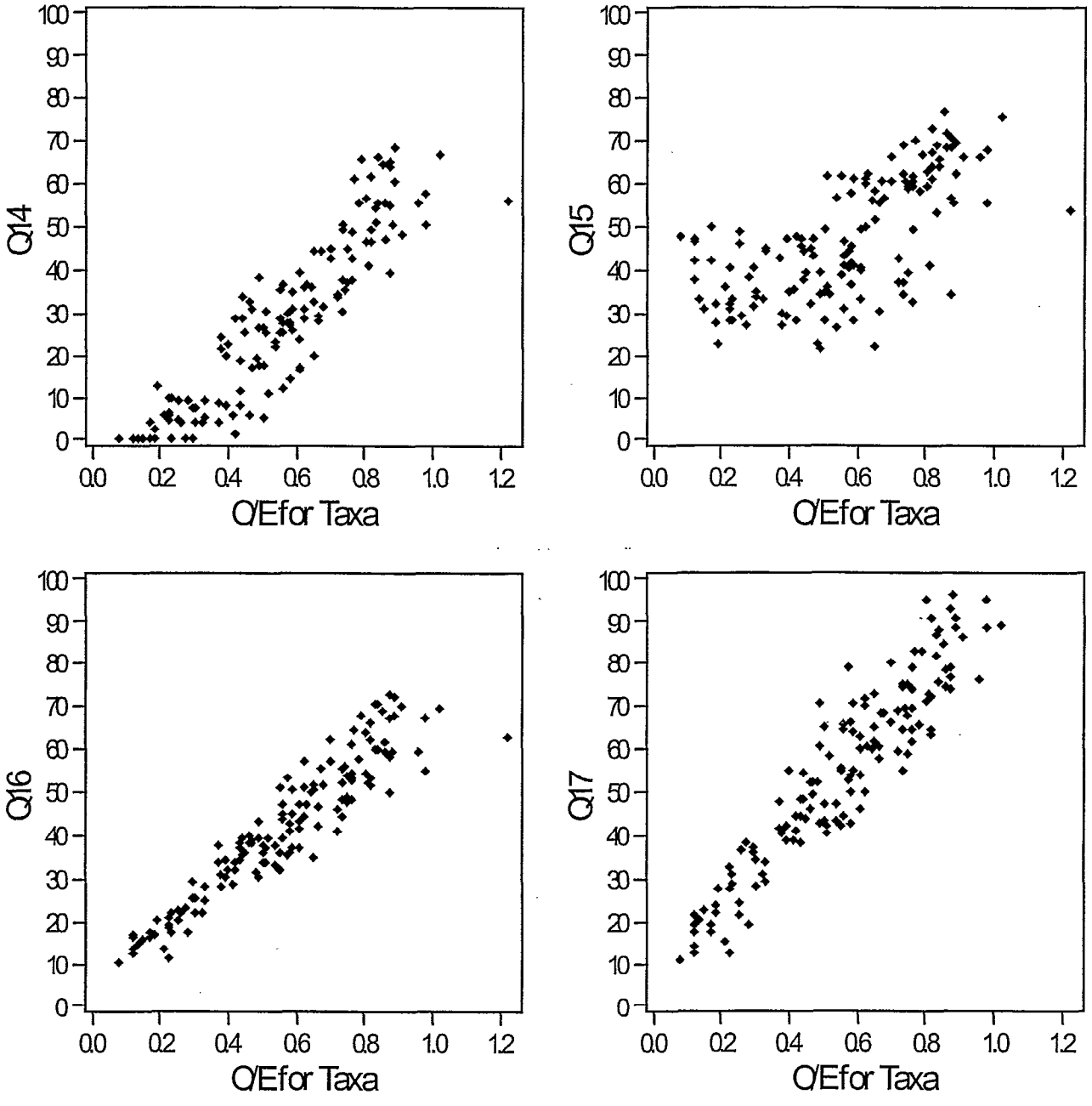


Figure 3.2 Abundance-based quality indices Q14-Q17 for the 16 BAMS study sites: Plot index value against O/E for ASPT for all individual single season samples (16 sites x 3 samples x 3 seasons = 144 observations).

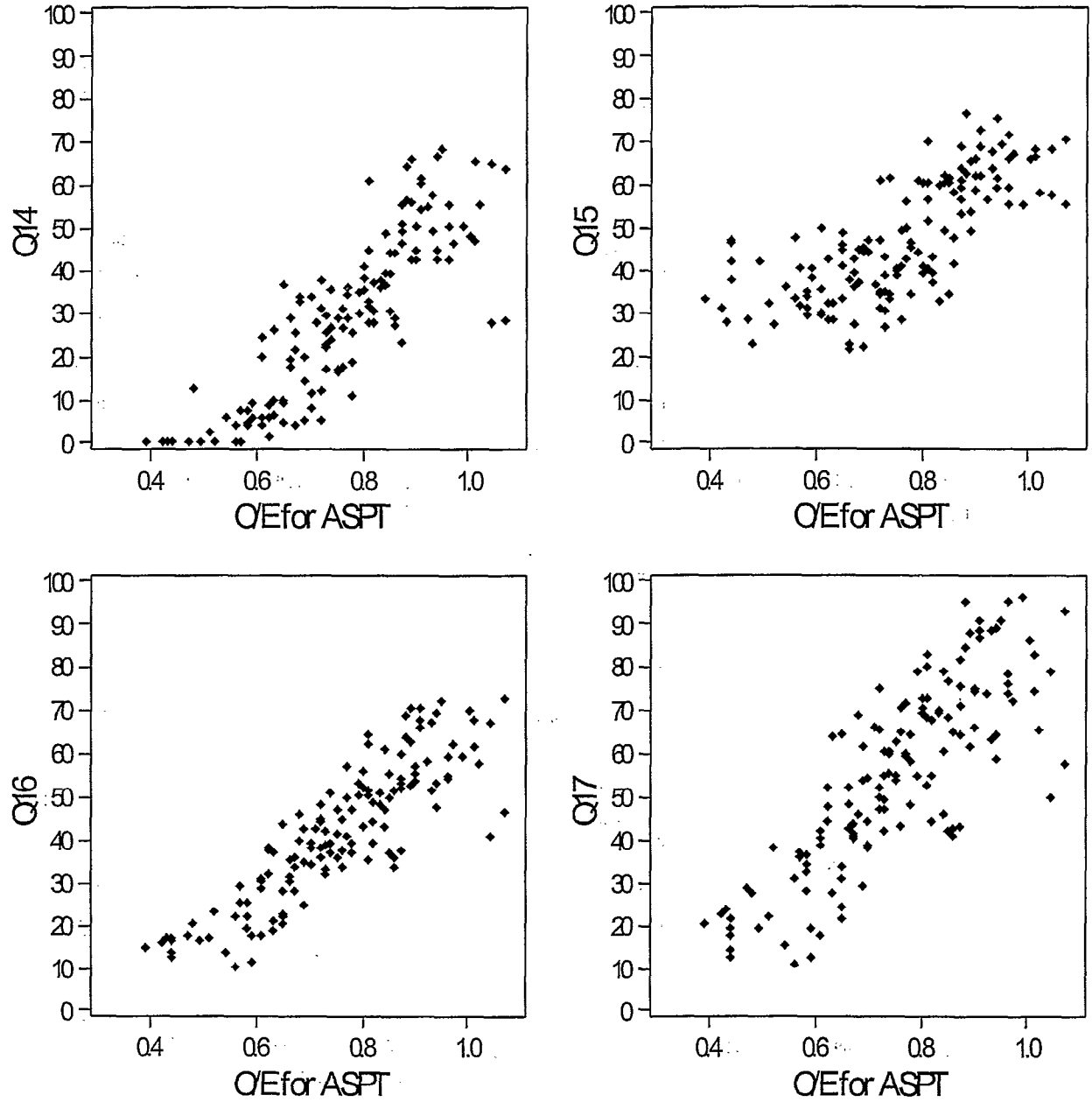
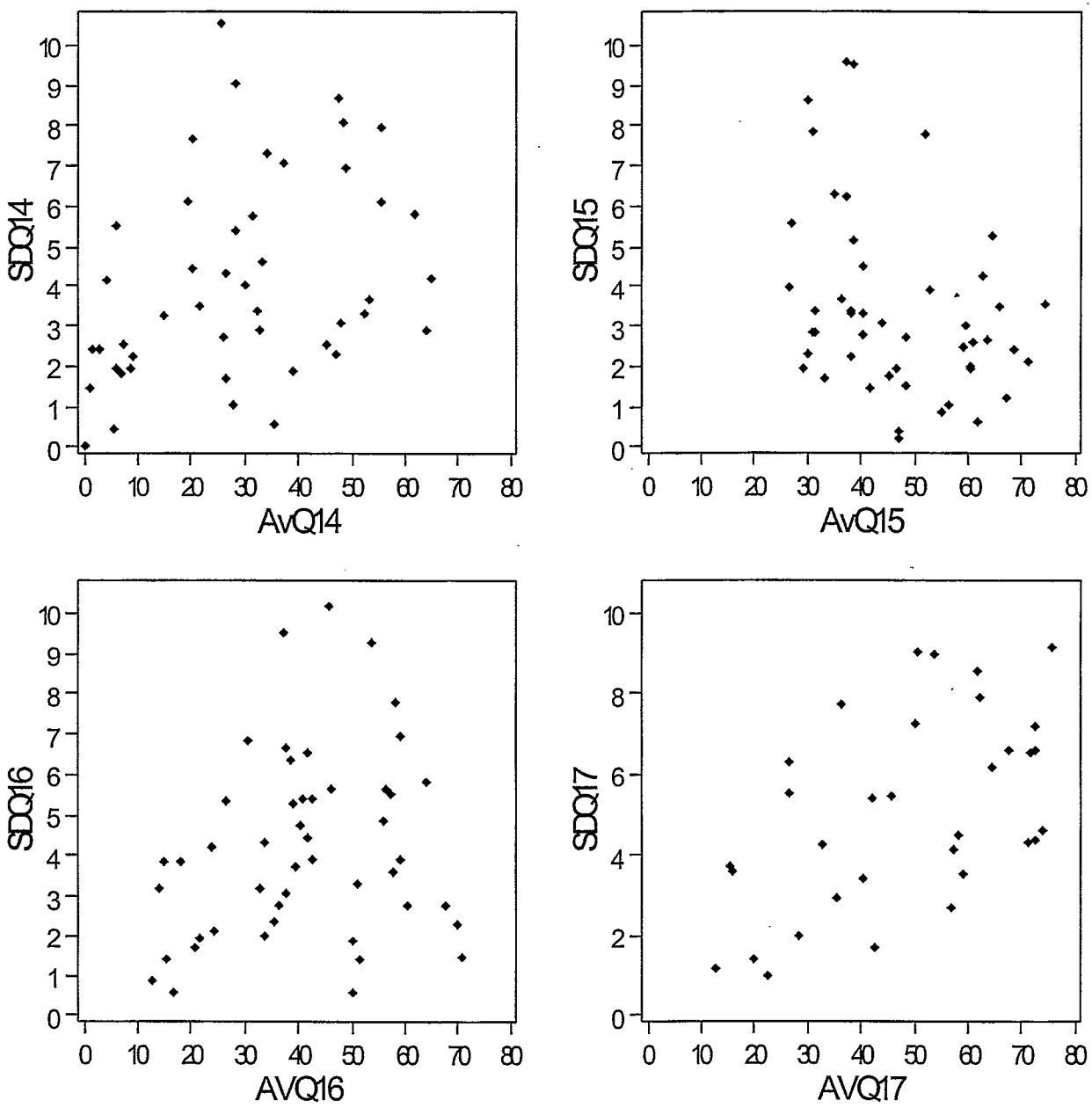


Figure 3.3 Abundance-based quality indices Q14-Q17 for the 16 BAMS study sites: Plot of uncertainty standard deviation (SD) against mean value (16 sites x 3 single seasons = 48 observations). Uncertainty is due to both sampling variation and errors in measuring the environmental predictor variables.



4 RE-EVALUATION OF METHODS FOR COLLECTING SAMPLES FROM DEEP WATERS FOR RIVPACS - A SCOPING STUDY

4.1 Introduction

Standardisation of the sampling procedures used in RIVPACS is critical to ensure that the observed data for a site is comparable with the predictions made for that site by RIVPACS.

The methodology for sampling shallow sites is comparatively simple with the result that a high degree of standardisation is possible, given the variety of habitats to be included within the protocol. Considerable effort has already been devoted to documenting and reducing sources of error from sampling variation, sorting and identification in order to improve the precision of the technique.

However, sampling deep waters is inherently more difficult, hazardous and time-consuming. The biologist has much less control of the sampling device and in consequence it is difficult to sample all invertebrate habitats in proportion to their occurrence.

Use of a long-handled pond-net from the river-bank to sample deep water sites was recommended for the 1995 GQA survey on practical and safety grounds. Unfortunately, this does not allow all habitats to be sampled in proportion to their occurrence. Less of the main channel will be sampled than it should, with the result that mid-channel species will be under-represented.

More appropriate devices for sampling in deep water, such as dredges and air-lifts are more time-consuming to operate than pond-nets and usually require more people, resulting in an increase in costs. In addition, the sampling effort expended when using a dredge or air-lift cannot be standardised to the same degree as a pond-net used in shallow water.

As a consequence, the methods for sampling in deep waters have never been particularly well defined and no comparisons of the methods used within the Environment Agency for deep-water sampling have been undertaken. The current methods need to be reviewed in this study, and consideration should be given to the possible need for further investigations involving different techniques at a range of different deep water sites in order to clarify whether one or more procedures are needed

4.2 Objectives

The overall objective is as follows.

'To produce a written report 'Sampling deep waters for RIVPACS' which scopes further investigations that are needed for the existing site types in RIVPACS and canals. This should be written in a form that can be understood by Agency biologists and managers'.

The specific objectives are:

1. To review the literature to identify any new sampling devices or protocols which could be useful for sampling in deep waters for RIVPACS.
2. To make a preliminary assessment (and classification) of the range of deep water sites sampled by Agency biologists and the methods used.
3. To assess whether any new devices or protocols would be better for sampling any of the deep water sites types identified in 2, bearing in mind practical and safety issues as well as sampling effectiveness.
4. To make a preliminary assessment of the differences between samples collected in different deep-water sites using sampling devices currently used in RIVPACS. Include new devices or protocols only if the equipment is available. This assessment is solely to identify whether full field trials are necessary, and if so, what should be included in them and how the trials should be designed.
5. To prepare a project plan for field trials identified in objective 4 in which the number of samples, types of sites, and costs and timescales are described and justified.
6. To recommend, if possible, a sampling device for all deep waters, or sampling devices for different types of deep waters.
7. To make a preliminary assessment of the variability between operators using the sampling devices investigated in 4, in order to decide whether a full BAMS type assessment is needed, and if so, what should be included in such a study.
8. To produce a project plan for measuring the variability between operators using deep water sampling methods for the purposes of assessing errors in the compare module of RIVPACSIII+, if preliminary investigations indicate that variation between field staff is substantially different to the estimates made for pond-net samples described in R & D note 412 (The variability of data used for assessing the biological condition of rivers). This plan is to include a description of the number of samples, types of sites, costs, time scales and justification. The plan should take account of any trials described in objective 5 above.
9. If substantial differences are observed between samples collected by recommended (or different) sampling devices and those used to collect samples for the RIVPACS data set, estimate the cost of re-analysing samples from deep water sites for this data set, and the cost of incorporating this data into RIVPACS (as part of a software upgrade project). Where possible, assume that samples will be collected by the Agency in the 2000 national survey, but include the cost of sampling from sites not included in the 1995 national survey, collecting summer samples in each Agency Area, SEPA and the DoE Northern Ireland, and identifying all the samples to species.
10. To assess the need for collaboration with other organisations. This must include IRTU and SEPA.
11. After consultation with the project board, produce an overall project plan for further field investigations, including realistic timescales, to enable sampling devices and protocols to be decided in time for the 2000 national survey.

4.3. Literature review of sampling devices and protocols for deep rivers

In FBA Occasional Publication No. 30 entitled '*A new bibliography of samplers for freshwater benthic invertebrates*', Elliott *et al.* (1993) present an updated bibliography of devices used for sampling benthic invertebrates from the natural substrata of rivers and streams. The bibliography includes papers published up to the end of December 1992 and provides the starting point for the current review of literature on new sampling devices or protocols that may be useful for sampling in deep waters for RIVPACS. Elliott *et al.* (1993) emphasise that their bibliography does not include references to colonisation samplers using artificial or natural substrata, or to light traps, or to traps for catching drifting invertebrates, upstream-moving invertebrates and the emerging imagines of aquatic insects. These guidelines have been maintained in the current literature review.

Literature searches using the Biological Records Online (BIOSIS) were undertaken in March and November 1998 to identify papers published since Elliott *et al.* (1993) on sampling devices and protocols for deep rivers. Supplementary searches were also undertaken using BIDS Academic Services in November 1998. The following keywords were used in different combinations in order to extract relevant publications:

Deep rivers, large rivers, lowland rivers, running waters, canals, navigable waterways, survey, sampler, sampling device, sampling apparatus, sampling protocols, fauna, invertebrates, macroinvertebrates, benthic invertebrates, benthic macroinvertebrates, benthos.

These searches yielded over 50 'hits' but after further appraisal, very few of the publications were found to relate to deep-water sampling devices or protocols in rivers. The more relevant articles from the computer searches, together with a small number of additional references gleaned from other sources are listed in Appendix 5. It is immediately apparent that many of these references offer methods that would be inappropriate for RIVPACS sampling in deep rivers (e.g. artificial substrate samplers, freeze-core methods, use of pupal exuviae etc.)

In view of the current lack of standardised protocols for sampling macroinvertebrates in deep waters, the absence of a significant breakthrough in sampling methodology over the past six years is disappointing, but not unexpected. Hence in Section 4.6 of this report, it will be necessary to focus on the merits of the various deep-water sampling devices referred to in Elliott *et al.* 1993. Those considered to be of particular relevance to deep-water sampling for RIVPACS are listed below:

Downing, J. A. and Rigler, F. H. (eds.) (1984). *A manual on methods for the assessment of secondary productivity in fresh waters.* IBP Handbook No. **17**. Blackwell, Oxford.

Drake, C. M. and Elliott, J. M. (1982). A comparative study of three air-lift samplers used for sampling benthic macro-invertebrates in rivers. *Freshwater Biology*, **12**, 511-533

Drake, C. M. and Elliott, J. M. (1983). A new quantitative air-lift sampler for collecting macroinvertebrates on stony bottoms in deep rivers. *Freshwater Biology*, **13**, 545-559

Elliott, J. M. and Drake, C. M. (1981). A comparative study of seven grabs used for sampling benthic macroinvertebrates in rivers. *Freshwater Biology*, **11**, 99-120

Elliott, J. M. and Drake, C. M. (1981). A comparative study of four dredges used for sampling benthic macroinvertebrates in rivers. *Freshwater Biology*, **11**, 245-261

Elliott, J. M., Drake, C. M. and Tullett, P. A. (1980). The choice of a suitable sampler for benthic macroinvertebrates in deep rivers. *Pollut. Rep. Dep. Environ. U.K.* No. **8**, 36-44.

Flannagan, J. F. (1970). Efficiencies of various grabs and corers in sampling freshwater benthos. *Journal of the Fisheries Research Board of Canada.* **27**, 1691-1700

HMSO (1984). Methods of biological sampling: Sampling of benthic macroinvertebrates in deep rivers 1983. Methods for the examination of waters and associated materials. *HMSO, London.* 16pp.

Humpesch, U. H and Elliott, J. M. (eds.) (1990). Methods of biological sampling in a large, deep river - the Danube in Austria. *Wasser Abwasser (Suppl.)* **2/90**, 83pp.

Mackey, A. P., Cooling, D. A. and Berrie, A. D. (1984). An evaluation of sampling strategies for qualitative surveys of macro-invertebrates in rivers, using pond nets. *Journal of Applied Ecology*, **21**, 515-534

Pearson, R. G., Litterick, M. R. and Jones, N. V (1973). An air-lift for quantitative sampling of the benthos. *Freshwater Biology*, **3**, 309-315

In addition, the following articles published after 1993 and taken from Appendix 5 are also considered to have potential relevance:

Benjamin, J. (1998). A comparative study of methods for sampling macroinvertebrates in Sussex Rifes. Unpublished report to Environment Agency, Southern Region. 103pp.

Humphries, P., Growns, J. E., Serafini, L. G., Hawking, J. H., Chick, A. J and Lake, P. S (1998). Macroinvertebrate sampling methods for lowland Australian rivers. *Hydrobiologia* **364** (2), 209-218.

Murray-Bligh, J. A. D., Furse, M. T., Jones, F. H., Gunn, R. J. M., Dines, R. A. and Wright, J. F. (1997). *Procedure for collecting and analysing macroinvertebrate samples for RIVPACS.* Institute of Freshwater Ecology & Environment Agency, 155pp.

Williams, P., Biggs, J., Whitfield, M., Corfield, A., Fox, G. and Adare, K, (1998). *Biological techniques of still water quality assessment. 2. Method development.* Report to the Environment Agency, R 7 D Technical Report E56. 158pp.

Wright, J.F., Winder, J.M., Gunn, R.J.M., Blackburn, J.H., Symes, K.L. & Clarke, R.T. (submitted) The macroinvertebrate fauna of the R.Thames in the vicinity of Didcot Power Station.

4.4 Current Environment Agency procedures for deep rivers

4.4.1 Introduction

In order to become familiar with the current protocols used by the Environment Agency for sampling deep rivers, a questionnaire was sent to all Area Biologists. A copy of the questionnaire may be found in Appendix 3. Fundamental to the problem of sampling in deep waters was a question on the definition of a "deep water site". Then followed a series of questions designed to obtain information, not only on sampling methods and protocols, but also to elicit information on the criteria used in selecting a given sampling method and the views of the Agency biologists on the different methods, based on their practical experiences. An excellent response was obtained and replies were received from all 26 Agency Areas.

In addition, questionnaires were sent to each region of the Scottish Environment Protection Agency (SEPA), with copies for distribution to each of their laboratories and also to the Industrial Research and Technology Unit (IRTU) in Northern Ireland. Replies were received from 3 of the 7 SEPA laboratories and also from IRTU. These are referred to as "Others" in the summaries to the questionnaire answers.

4.4.2 Definition of a deep river

Question 1 – Definition.

How would you define the term 'deep water site' as applied to rivers?

	Agency	Others
Site too deep to take a reliable kick/sweep sample?	23	4
Site too deep to sample full width with a pond-net?	7	1
Site with main channel deeper than 50 cm	2	
Site with main channel deeper than 60 cm	1	
Site with main channel deeper than 70 cm	1	
Site with main channel deeper than 80 cm	1	
Site with main channel deeper than 100 cm	4	2
Site with main channel deeper than 150 cm	1	
Site with entire width deeper than 40 cm	1	
Site with entire width deeper than 50 cm	2	1
Site with entire width deeper than 60 cm	1	
Site with entire width deeper than 70 cm	2	
Site with entire width deeper than 100 cm	8	2

Many respondents gave more than one answer in order to define a deep-water site. By far the most frequent response was the first option, relating to an inability to take a reliable sample using the standard protcol used in shallow streams and rivers (i.e. kick/sweep sample with a pond-net). Of the 26 replies from Agency biologists, 23 selected this response. In addition, all 4 non-Agency contributors selected this definition (i.e. 90% of all respondents).

Twelve biologists (10 from the Agency) specified a water depth for the main channel as part of their definition. These ranged from 50 cm to 150 cm, the most common value being 100 cm (specified 6 times). More popular was the option to select a depth for the entire river width. Seventeen biologists (14 from the Agency) suggested depths ranging from 40 cm to 100 cm. Again, the most common value was 100 cm (specified 10 times). Two biologists suggested that the critical depth is dependent upon the height of the sampler, and this may be implicit in many of the replies. The range of depths listed may be related to variation in height of the biologists currently in post.

Many definitions were qualified with additional comments. Nine biologists (7 from the Agency) specified Health and Safety considerations in qualifying their definitions and a further nine (7 from the Agency) commented on substratum type, in particular soft sediments underlying otherwise shallow water).

4.4.3 Sampling procedures used in deep rivers

Question 2 – Sampling method

Do you use kick sampling with a pond-net at all your sampling sites? Yes / No

	Agency	Others
Yes	1	
No	25	4

Of the 25 Agency laboratories answering "No", there were three Areas where the biologists indicated that they retained the use of standard kick/sweep sampling for all but one or two non-routine samples. For those who selected "No", the details of the methodologies used are shown in Table 4.1.

Respondents were also asked whether deep-water sampling involved the use of a boat, whether sampling took place from a bridge and the total number of personnel involved in field sampling:

	Agency	Others
Sampling involving use of a boat	7	1
Sampling involving use of a bridge	3	

Most laboratories send one or two workers to sample their deep-water sites, presumably dependent upon the nature of the site and safe working practices. Occasionally, three workers are employed when sampling involves the use of a boat.

Only one respondent stated that *all* samples taken by biologists from that laboratory were collected using kick/sweep techniques with a pond-net. Three others indicated minimal use of other techniques for just one or two non-routine sites.

Table 4.1 Sampling methods for deep river sites employed by each area of the Environment Agency as reported in the response to Question 2. Information for Scotland and Northern Ireland is also given. (NR indicates not routinely).

Region	Area	Sweep	Distur-bance	Dredge	Airlift	Grab	Marginal Kick	Search	Artificial Substrate
Anglian	Eastern	+	+	+					
	Central	+	+						
	Northern	+	+			NR			
Midland	Upper Severn	+							
	Lower Severn	+	+	+					
	Upper Trent	+	+	+			+		
	Lower Trent	+	+						
North East	Dales	+		+	+				
	Ridings	+	+	+	+				
	Northumbria	+			NR				
North West	Northern	+	+						
	Central	+	+						
	Southern								
Southern	Kent	+	+	+					
	Sussex	+	+	+					
	Hants & IOW	+	+	+					
South West	Cornwall	+		+					
	Devon	+		+					
	North Wessex	+	+	+					NR
	South Wessex	+		+					
Thames	North East	+	+	+				+	
	South East	+	+						
	West	+	+	+	+				
Welsh	North	+	+	NR					
	South East	+	+						
	South West	+		NR					
SEPA	North	+				+			
	Dumfries			+		+			
	East Kilbride	+	+						
N. Ireland		+	+	NR			+		
Totals		26+3	18+2	16+2	4	1+2	1+1	1	1

All the remaining 25 Area laboratories (plus three 'others') took marginal sweep samples in deep rivers. In addition, 20 laboratories (18 from the Agency) use a long-handled pond net to disturb the substratum of the riverbed itself.

Of the various devices specifically designed for use in deep-water including mid-river, if necessary, the dredge (used by 16 Agency laboratories and two 'others') was the most frequently used sampling apparatus. However, four Agency laboratories use an airlift sampler (one not routinely) and one laboratory uses a grab for non-routine sampling. A grab is also employed by two of the non-Agency laboratories.

Additional minor methods listed by respondents included marginal kicks (one Agency and one non-Agency laboratory), the use of an artificial substrate (one Agency laboratory, but only for non-routine investigations) and an extended search of large, retrievable objects, such as boulders and traffic cones, (one Agency laboratory).

Seven of the 26 Agency laboratories and one of the other respondents routinely use a boat for deep-water sites. Both dredge and airlift samples were frequently taken from a boat, but sometimes a boat was also used for taking long-handled pond-net samples. Two Agency laboratories sometimes make use of a bridge when operating an airlift sampler and one when using a dredge.

4.4.4 Field protocols used in deep rivers

Question 3 – Field Protocol

For each deep-water sampling method identified in question 2, please provide details of the field sampling protocol. It would also be helpful if you can specify the particular model/make of dredge/ airlift/grab etc used for deep-water sampling.

	Agency	Others
All sites selected for ability to kick-sample in marginal shallows	1	
Marginal sweep in vegetation	6	1
Active disturbance, wading where possible, long-handled net where too deep to wade + marginal sweep if vegetation present	15	2
Medium Naturalist's Dredge, dimensions & method as BT001	9	1
Medium Naturalist's Dredge, dimensions as BT001, towed from boat	0	1
Medium Naturalist's Dredge, 2 kg, thrown from bank or towed from boat	1	
Medium Naturalist's Dredge, 3 kg, thrown from bank + marginal sweep	1	
Medium Naturalist's Dredge, 7 kg, thrown from bank + marginal sweep	2	
Medium Naturalist's Dredge, unspecified weight, thrown from bank	3	1
Yorkshire Airlift + marginal sweep	2	
FBA Airlift + marginal sweep	1	
Standard Ekman Grab on soft sediments for quantitative samples	0	1
Mini Van-Veen Grab	0	1

The responses listed above are the methods used routinely to collect 'RIVPACS-compatible' biological samples. Additional methods used on isolated occasions for particular experiments are not included here, although they are flagged in the answers to Question 2.

It is apparent that a combination of the marginal sweep coupled with the use of a long-handled pond-net to sample the substratum was the most generally favoured approach. However, the use of a dredge, typically thrown from the bank (and occasionally coupled with the use of a marginal sweep) was also used quite frequently. However, there was considerable variation in the weight of dredge used and hence limited standardisation.

4.4.5 Criteria for selection of sampling method

Question 4 – Criteria used for selection of sampling method

Can you define the conditions under which you select a given procedure for sampling in deep water? (Non-Agency labs in brackets)

Marginal sweep with pond-net	
Always forms at least part of procedure if appropriate habitats available	23 + (1)
When access to main channel is impossible	1
When depth too great to kick sample	1
When depth >40 cm	1
When depth >100 cm	3 + (1)
When depth >150 cm	2
When depth >200 cm	1
Active disturbance of substratum with a long-handled pond-net	
Always forms at least part of procedure	2
Where it is impossible to wade	3
Where water is deep but main channel narrow	1
When soft sediments predominate	8 + (1)
When depth 40-80 cm	1
When depth >50 cm	5 + (1)
When depth >100 cm	3 + (1)
When depth >150 cm	1
When depth >200 cm	1
Use of a dredge	
Used where no alternative is available	2 + (1)
Where main channel forms significant proportion of site	1
When depth >50 cm	4
When depth >100 cm	4 + (1)
When depth >150 cm	2
Single samples, depth >150 cm, width >20 m	1
When width >5 m	1
Man-made banks (marginal sweep impractical)	1
Excluding sites with large boulders	2
Use of an Airlift	
When depth >150 cm	1
When depth >200 cm	1
Multiple samples, depth >150 cm, width >20 m	1

Use of a Grab

When depth >100 cm	0 + (1)
When soft sediments predominate	0 + (1)

Kick sampling in deep water

Marginal kick-sampling wherever possible	1
When depth 70-100 cm (chest-waders)	1
When depth <100 cm	1

Use of marginal pond-net sweep sampling is normally the first approach to sampling in deep waters when appropriate habitats are available. This is frequently supplemented with active disturbance of the substratum with a long-handled pond-net when the bottom sediments are soft or the water depth exceeds 50 cm. However, water depths above 50 cm are sampled using a dredge by a significant number of laboratories. In contrast, the regular use of airlifts is limited to just three laboratories within the Environment Agency and is reserved for use at deep water sites (>150 cm). Grabs are rarely utilised.

4.4.6 Relative merits of different sampling techniques

Question 5 – Practical experience of sampling in deep water

Please comment on the advantages and disadvantages of the methods used for deep water sampling in your area. We would be particularly interested in your views on:

Ease of use of equipment in the field	(simple/moderate/complex)
Your views on the efficiency of the sampling device	(poor/moderate/good)
Time required for field operation	(short/moderate/long)
Time required for subsequent laboratory processing	(short/moderate/long)

Where one answer was provided for "time in field/lab", it was assumed that the same answer referred to both field and laboratory operations. Where the answer to a question was not specific (e.g. moderate – long), the extreme case (i.e. long in this example) was adopted; where a non-specific answer included the full range of options (e.g. short - long), the median option was adopted. The responses are given in Table 4.2.

A number of clear patterns emerged in the answers to this question on the practical experience of biologists in sampling deep waters. However, it is important to bear in mind that all responses must be viewed in context. Thus, opinions expressed on the ease of use or efficiency of a procedure are limited to the context for sampling (i.e. use of a marginal sweep or a dredge can only be appraised in relation to the marginal areas or river bottom respectively).

In general, the marginal sweep technique was viewed as a simple, and efficient means of obtaining a BMWP family list for a site which entailed a short time in the field and only moderate time for subsequent laboratory processing.

Table 4.2 Responses to Question 5 on some of the practical advantages and disadvantages of alternative procedures for sampling in deep water. Note that the numbers below include non-routine samples. (Figures in brackets indicate responses from non-Agency laboratories.)

Sampling Method	Ease of Use	Efficiency	Time in field	Time in lab
Marginal sweep only	simple 14 + (3) moderate 5 complex 1	good 11 + (1) moderate 6 + (2) poor 2	short 12 + (2) moderate 5 + (1) long 1	short 7 moderate 8 + (3) long 4
Disturbance of substrate	simple 7 + (3) Moderate 7 complex 1	good 3 + (1) Moderate 11 + (2) poor 1	short 6 + (2) Moderate 7 + (1) long 2	short 2 Moderate 10 + (3) long 3
Dredge	simple 4 + (1) moderate 8 complex 6	good 4 moderate 8 poor 6 + (1)	short 7 moderate 6 + (1) long 5	short 1 moderate 5 + (1) long 12
Airlift	moderate 2 complex 1	good 1 moderate 1 poor 1	moderate 2 long 1	long 3
Grab	simple (1) moderate (1)	good (1) moderate (1)	moderate (1) long (1)	moderate (1) long (1)
Marginal kick	simple 2	good 1 moderate 1	short 1 moderate 1	short 1 moderate 1
Deep water kick	simple 1	good 1	short	short

Sampling Method	Ease of Use	Efficiency	Time in field	Time in lab
	complex	poor	long	moderate
Artificial substrate				
	1	1	1	1
Hand search of boulders etc	simple	good	short	short
	1	1	1	1

The long-handled pond-net technique for sampling the river bottom was also regarded as simple to use, but frequently of only moderate efficiency, sometimes involving more time in the field than marginal sweep sampling and moderate time in the laboratory for sample processing.

Dredges were regarded as moderately easy to use in the field and reasonably efficient at collecting the fauna, albeit with a view range of responses from good, through moderate to poor. Time in field also varied considerably, with a relatively even response from short, through moderate to long. Laboratory processing of dredge samples was more widely regarded as taking a long time. Although the number of responses for airlifts was low, the available information tended to follow a similar pattern to the dredge, with moderate ease of use, efficiency and time in field, followed by long period for laboratory processing of samples. Although additional protocols are listed, the number of responses is very limited and it would be unwise to attempt to draw any firm conclusions.

4.4.7 Conclusions

The biologists who responded to the questionnaire took a pragmatic view when they were asked for a definition of a deep-water site. Essentially, their definition of a deep-water site was one in which the standard kick-sweep technique, as used in shallow streams and rivers, could not be used to obtain a reliable sample. The precise depth for defining a deep-water site varied between laboratories. In addition, the substratum type and current speed were recognised as factors that could compromise safety in such rivers.

In the HMSO (1984) publication entitled "Methods of biological sampling: Sampling of Benthic macroinvertebrates in Deep Rivers 1983", deep rivers were defined as "those deeper than 1 metre ie. those in which a pond net or shallow-water quantitative sampler cannot be used". Hence, the respondents to the IFE Questionnaire largely confirmed this definition, albeit with a tendancy for some to give depths between 50 and 100 cm within their definition of deep rivers.

The most common protocol used in deep rivers was a marginal sweep with a pond-net (28 laboratories). At 20 of these laboratories the substratum of the riverbed itself (typically adjacent to the river margin) was also actively disturbed with a long-handled pond-net. Of the genuine deep-water sampling devices, the dredge (18 laboratories) was favoured for routine sampling more frequently than the air-lift (4) or grab (3).

When sampling took place from the bankside, a marginal sweep, coupled with active disturbance of the adjoining substratum with a long-handled pond-net, was the most frequently employed protocol. When a dredge was used, there was considerable variation

from one laboratory to another in the dimensions and weight of dredge, the detailed field protocol and the use of supplementary techniques for sampling the river margin.

The various procedures used by biologists within the Environment Agency, SEPA and IRTU for sampling in deep water have their own advantages and disadvantages. The marginal sweep was simple to use, regarded as efficient for collecting the fauna and did not involve excessive time in the field or laboratory. However, it failed to provide information on the fauna of the riverbed itself, and for this reason was typically employed as a method of supplementing the taxon list obtained from the riverbed by the use of a long-handled pond-net. The latter was simple to use, although of only moderate efficiency in collecting the fauna. The long-handled pond-net can be difficult to control in deep water, particularly in strong currents or on compacted/clay substrata and the extent to which it can be expected to collect a comprehensive benthic sample, when used from the bank, may be in doubt. However, one or two Agency biologists took the view that a marginal sample can provide all the information required for a reliable assessment in certain situations (e.g. fenland drains).

Qualitative sampling devices such as dredges, which may also be used from the bank, are seen by many Agency biologists as a way of overcoming the limitations of the long-handled pond-net. The experience of many biologists was that they were moderately easy to use, reasonably efficient but inevitably involved a higher investment of time per sample both in the field and in the laboratory. As before, a marginal sweep was generally used to supplement the dredge sample. Despite the widespread use of dredges within the Environment Agency, a small minority of laboratories were strongly opposed to their use on Health and Safety grounds (dredge too heavy for some biologists to operate safely).

So far, few laboratories have used air-lifts to obtain benthic samples. This equipment involves additional preparation time before sampling and is frequently undertaken from a boat with consequent manpower implications. Biologists familiar with the use of air-lifts gave similar ratings on ease of use, efficiency and sampling times as those who used dredges. However, as with dredges, there are risks associated with air-lift samplers and these must be taken into account before deciding to use this sampling technique.

In conclusion, it is apparent that a wide range of different procedures are currently in use for collecting samples of macroinvertebrates in deep rivers. Clearer guidelines are required on the protocol(s) required for collecting RIVPACS-compatible samples.

4.5 Appraisal of future options

4.5.1 Introduction

Murray-Bligh *et al.* (1997) provide detailed information on the various procedures for collecting and analysing macroinvertebrate samples for RIVPACS. The field sampling protocol for use in shallow streams and rivers has been set out in detail (based on a 3 minute pond-net sample plus one minute manual search) and has been shown to offer a reliable basis for comparing the fauna observed at a site with the expected fauna, as determined by a site-specific RIVPACS prediction (Furse *et al.* 1995).

In deep watercourses where kick-sampling is inappropriate, Murray-Bligh *et al.* (1997) recommend the use of a pond-net (with an extension if necessary) to obtain a sweep sample of the marginal vegetation plus a sample of the fauna from the river bed in the main channel. The manual indicates that this procedure is to be preferred to the use of a dredge or air-lift sample, both of which are less easily controlled and may be less efficient on very soft river beds.

However, the manual also states that if it is not possible to obtain material from the main channel with a long-handled pond-net, then a dredge or air-lift sample must be obtained. A one-minute sweep, using a pond-net in the marginal areas and shallows close to the banks, accompanies all samples collected by dredge or air-lift, in addition to a one-minute manual search. The protocols given for the field use of dredges and air-lifts and the subsequent processing of the samples are described in the manual as interim procedures, which may be subject to future change.

From the answers to the questionnaire, it is apparent that, whereas a majority of Environment Agency biologists use long-handled pond-nets to sample the river bed in deep rivers, almost as many have used dredges. In contrast, few have employed air-lifts. The results of the questionnaire also revealed considerable variation in the detailed specification and use of the various devices, providing further evidence that current RIVPACS procedures for deep water sites are in need of standardisation.

4.5.2 Some basic considerations

The basic concept in RIVPACS sampling is that it is effort dependant and encompasses all available habitats in proportion to their occurrence. The sampling regime therefore generates qualitative data from which a taxon list may be derived. The fauna at all the original reference sites in RIVPACS was identified to 'species' level but test sites in national or regional monitoring programmes may be identified to BMWP family-level or other taxonomic levels as required. Because the sampling protocol is effort-dependant, supplementary information on the sample may be derived by assigning crude categories of abundance (Log categories) at family-level only.

This sampling approach has been applied in a consistent manner in the collection of the original RIVPACS reference site data over a wide range of shallow water sites throughout the UK. In collecting comparable samples during GQA and local routine sampling programmes, RIVPACS III can be used with confidence to provide an expected target fauna against which the observed fauna at a test site can be compared.

Early in the project which led to the development of RIVPACS, deep rivers were largely excluded because of the problems inherent in devising a suitable sampling technique and finding high quality reference sites in some areas. Once the concept of using the reference sites to predict the target fauna of a test site had been demonstrated, the need to extend the system to include a wider range of rivers, including deep rivers, became clear. A number of deep river sites on lowland rivers were sampled by the FBA team using a combination of marginal sweep and dredge sampling. They included a small number of sites on the River Thames, Great Ouse, Severn, Wye, Exe and Dorset Stour. These sampling operations were successful in generating taxon lists for a range of new reference sites but at the same time demonstrated a number of practical problems inherent in sampling in deep rivers:

- The additional time required to obtain field samples and process material derived from deep rivers
- The problem of standardising sampling effort when using dredges or air-lifts
- The additional manpower resources required to minimise risks when working in potentially hazardous conditions

Although RIVPACS III has been used to determine the biological grade (on a scale from a-f) of both shallow and deep water sites in the 1995 GQA Survey, the reliability of the sampling technique has only been demonstrated explicitly in the case of the shallow sites (Furse *et al.* 1995) which, in practice, form the great majority of the sites monitored in the survey.

A similar level of confidence in the grading of deep river sites in the UK requires a reappraisal of the detailed protocol undertaken at such sites, both for the collection of reference site data and the routine monitoring of all deep water sites. This may result in the need for a new deep-water module in RIVPACS III, in which all reference site data are collected under a new protocol and with the same techniques applied to all routine monitoring.

Whatever the final decision on the possible need for a new deep-water module, a useful starting point is consideration of whether it is realistic to attempt to have a seamless transition from the standard protocol used in shallow streams and rivers through to the protocol(s) required in deep rivers. For this compatibility to be retained, the deep-water protocol needs to be ***qualitative, inclusive of all major habitats*** and ***effort dependent***, as for the shallow water protocol.

The need to retain the qualitative approach to sampling in for deep-water sites is not in doubt.

In contrast, retention of the concept of including all the habitats at a deep-water site and, more specifically, attempting to sample them in proportion to their occurrence, raises both practical and other issues. For example, imagine a river 2 m deep and 50 m in width, the width including a 1 m wide margin of vegetation along each bank. In theory, a sampling transect across the river would comprise 4% of sampling effort in marginal vegetation and 96% for the benthic sample.

The Environment Agency protocol (Murray-Bligh *et al.* 1997) currently recommends a one minute marginal sweep with a pond-net (plus a one minute manual search for individual invertebrates on the water surface and on solid marginal objects) plus 3-5 dredge trawls covering all habitats (or an air-lift transect over all habitats) where the sampling of both the margins and benthos with a long-handled pond-net is impossible. This appears to be a disproportionately large sampling effort in the marginal areas, which goes against the spirit of sampling in proportion to the occurrence of each habitat. However, the logic of this approach is obvious, given the importance of the marginal habitat as an important food source and as a refuge for the biota. In times of high discharge or when a slug of pollution passes down the river, the margins can be critical for the survival of some taxa. In contrast, although there is little information on subtle differences in faunal composition across the width of British rivers, it seems unlikely that there is justification for spending 96% of sampling time on the benthos in the above example in order to maximise taxon richness for the full transect.

In view of the need to obtain reliable information on the biological quality of deep rivers it is possible to question the adequacy of a one minute marginal sweep (plus 1 min manual search) when undertaken in conjunction with the use of a dredge or airlift to sample the benthos. Given the range of marginal habitats to be found in many lowland rivers, it may be possible to justify a full three minutes for marginal sweep-sampling. This suggestion can only be evaluated by reference to information in Section 4.5.7 and/or the use of detailed field trials in 1999.

The third criterion, that of ensuring that all samples are effort-dependant, is also problematic in deep waters, and specifically in relation to the benthic component of the sampling procedure. Again, the literature to be reviewed in section 4.5.6 provides valuable guidance and further information should be available if detailed field trials are undertaken in 1999.

The fact that the margins and the benthos may be viewed as discrete habitats which can be sampled separately also raises the question of whether there is more to be gained by keeping these components separate, rather than retaining them as a single entity for the site, as done in shallow streams and rivers. Some of the pros and cons of this suggestion, which would make a basic change in strategy between shallow and deep-water sites, are considered in section 4.6.2 of this report.

In considering these criteria, it is also important to emphasise that the RIVPACS approach, when used in the periodic GQA assessments, is essentially a rapid biomonitoring approach undertaken at several thousand sites in order to obtain a national snapshot of the 'health' of the nation's rivers. Low O/E ratios, indicating environmental stress, may be the result of one or more forms of pollution and/or poor habitat quality.

When problems occur in deep rivers and detailed investigations are required, then more intensive qualitative or quantitative sampling involving many replicate sampling units may be necessary with a consequent increase in expenditure of time and effort. A routine RIVPACS appraisal may reveal the need for such an investigation and a RIVPACS prediction undertaken at species rather than BMWP family level may provide further information, but it cannot be a substitute for a comprehensive investigation.

In theory, a RIVPACS sampling programme for deep river sites could involve sampling:

1. Margins only
2. Benthos only
3. Margins and benthos treated as one
4. Margins and benthos treated separately

Adoption of Options 1 or 2 would contradict both the strategy in current use for shallow waters and the deep-water protocol advocated in Murray-Bligh *et al.* (1997). In addition, to sample the margins only (Option 1) would focus attention on marginal habitat quality, which can vary between adjacent banks due to management (see section 4.5.7) whilst ignoring the benthos, which should provide an indication of river quality.

Option 3 is essentially the strategy adopted in shallow rivers and therefore the protocol which should, in theory, retain an acceptable level of compatibility between shallow and deep-water sites if the overall level of sampling effort in deep-water sites (i.e. margin plus benthos) can

be standardised. However, this stance has been questioned earlier in this section. Information is required on taxon accretion with increasing sampling effort in order to investigate this question further. (see sections 4.5.6 & 4.5.7).

Option 4 deserves further consideration. Although it may be inappropriate in some situations, such as deep but narrow fenland drains which can be sampled using the shallow water protocol with a long-handled pond-net, it is possible to defend this approach in deep, wide rivers, where the margins and benthos are well-defined. A potential advantage would be the separate appraisal of each habitat in turn, allowing a distinction to be made between the fauna of marginal habitat (which may be influenced by bankside management) and the fauna within the benthos (influenced by river quality). An inevitable consequence of this strategy would be the need for a new reference site database holding marginal and benthic data separately for a subset of deep-water sites together with new subclassifications and prediction procedures.

The opportunity to distinguish marginal from benthic impacts in Option 4 is attractive. However, the River Habitat Survey technique offers an independent assessment of habitat quality which might possibly help with the interpretation of RIVPACS outputs if Option 3 were to be adopted to maintain a greater level of compatibility with the shallow water protocol.

Once the shallow-water protocol involving the use of a standard pond-net within the stream or river is inappropriate, then a series of progressively more time-consuming options are available. It is logical and sensible for these to come into play sequentially, in order to minimise the time and manpower required to obtain a sample, with the proviso that the collection of a reliable sample must be the criterion for determining the sampling protocol.

The basic sequence of possible sampling approaches might be as follows

A. Bankside sampling. Pond-net (with long handle if necessary) for sampling the margins (sweep sampling) and also for sampling the benthos.

B. Bankside sampling. Pond-net (with long handle if necessary) for sampling the margins (sweep sampling) plus an alternative device (e.g. dredge, air-lift) for sampling the benthos.

C. Bankside and/or within river sampling from a boat. Pond-net (with long handle if necessary) for sampling the margins (sweep sampling) from the bank (or infrequently from a boat). Sampling of the benthos using a device (e.g. pond-net, dredge, air-lift, grab etc) from a boat.

It may be possible to sample a narrow fenland drain effectively (margins and benthos) with a long-handled pond-net (Option A) without the need to resort to dredges and airlifts. In this case, it may be argued that the full site is available for sampling using the standard 3-minute sampling effort as used in shallow water and therefore it should be included within the shallow-water section of RIVPACS. Clearly, if in future there is to be a basic difference in the level of sampling effort (and in the sampling protocols used) in shallow and deep rivers, then it is essential to have firm guidelines on the circumstances in which the different protocols apply. Whereas Option A may remain within the shallow-water section of RIVPACS, Options B and C are firmly within the deep-water section.

Option B has already been used extensively within the Environment Agency, where dredge samples taken from the bank have been supplemented with a long-handled pond-net marginal sweep. In addition, some air-lift samples have been taken from a bridge, but this practice is not recommended.

Option C, in which a boat is required, has been used for both dredge and air-lift samples. The airlift is more likely to require operation from a boat in order to reach the appropriate sampling area. In contrast, the dredge is more likely to be used from a boat when the height of the bank or other obstructions/features mean that operation from the bank is ineffective or hazardous.

In general, it would appear to be unnecessary to use a boat simply to reach mid-river in order to obtain a reliable sample i.e. one that includes most BMWP families which occur in the benthos. Samples taken from a location nearer the bank (whether using a boat or a dredge thrown from the bank) should provide the range of families that occur in the river.

In this section of the report a number of important issues have been raised in relation to sampling at deep-water sites. They include not only sampling devices and protocols but topics such as the standardisation of sampling effort (in both margins and the benthos) and the later treatment of results. Before addressing the need for a detailed field trial in1999, it is important to make an appraisal of the information already available in the literature and elsewhere in order to solve some of the problems and devise an effective field trial to obtain reliable information on the questions which remain.

Four main sources of information were used in this assessment. They were:

- Information in the scientific literature (e.g. Elliott *et al.* (1993) and later publications)
- Information in the grey literature (unpublished reports etc)
- Datasets collected and analysed by the IFE
- Further experience and results gained during a preliminary field trial of deep-water sampling devices at two sites in the North East Region of the Agency.

In order to focus on the most critical aspects of deep-water sampling for RIVPACS, the available information will be reviewed under a series of specific questions.

4.5.3 Are any new deep-water sampling devices appropriate for RIVPACS sampling?

The direct answer to this question is "no". The requirement that a RIVPACS sample should be qualitative, inclusive of all major habitats and effort-dependant imposes severe limitations on the choice of sampling device(s). Essentially, this dictates that the device(s) should be simple to operate and appropriate for use over a wide range of conditions. In deep rivers, it is already accepted that two different devices may be required to obtain the requisite information (i.e. the fauna of the marginal vegetation and fauna on the river-bed).

In practice, simple qualitative procedures for these two basic habitat types have been used over many years, albeit without an acceptable level of standardisation in sample collection and processing, as required for RIVPACS. After a detailed search of recent literature (post

Elliott *et al.* 1993) it was apparent that all new devices and protocols or variations to existing systems for sampling in deep rivers related to the development of quantitative procedures, artificial substratum samplers, more specialised apparatus (e.g. freeze corers) or procedures designed for use on specific habitat types (e.g. submerged wood) or for particular components of the macroinvertebrate fauna (e.g. Chironomid pupal exuviae). Hence it is necessary to focus on the use of some of the deep-water sampling devices referred to in Elliott *et al.* (1993) and in particular those devices in current use within the Environment Agency which have been subjected to detailed appraisal by Elliott and co-workers.

4.5.4 Which device(s) perform satisfactorily over the range of RIVPACS deep-water sites?

In order to perform satisfactorily, a device must be capable of collecting the full range of taxa occurring on and within the river-bed to ensure that a representative taxon list can be obtained. The sampling device should also be capable of providing information on the relative abundance of taxa on the river-bed. There is no requirement for quantitative samples at specific locations. Instead, the sampling device should operate at a variety of locations in the river in an attempt to integrate local physical variations on the river-bed and the fauna associated with this local heterogeneity. Ideally, the sampling method used should give the maximum yield of taxa for the effort expended (Mackey *et al.* 1984).

The information presented in this section is derived from two main sources. First, scientific literature and additional sources within the grey literature and second, from practical experience gained by IFE staff during deep-water surveys, including the recent preliminary field trial undertaken within this project.

Evidence from the literature

At the beginning of the 1980's a comprehensive assessment of seven grabs (Elliott & Drake 1981a), four dredges (Elliott & Drake 1981b) and three air-lift samplers (Drake & Elliott 1982) was undertaken by members of FBA staff at the Windermere Laboratory. This was a prelude to the development of the FBA Air-lift sampler (Drake & Elliott 1983), which was capable of taking quantitative samples on substrata ranging from fine gravel (modal size 0.5-4 mm) to large stones (modal size 128-256 mm), although it was not recommended for use on mud.

Drake & Elliott (1982) include a summary of qualitative and quantitative samplers suitable for different types of substratum in deep rivers. The section of the table dealing with qualitative samplers is reproduced here as Table 4.3. Note that the original Medium Naturalist's dredge referred to in Elliott and Drake (1981) weighed 9 kg. Although a variety of lower weights ranging from 3-7 kg have been used within the Environment Agency, the 5 kg model is preferred, because it is sufficiently light to throw without risk of injury and sufficiently heavy to dig into the substratum. The Yorkshire pattern air-lift, as described in Murray-Bligh *et al.* (1997), is essentially based on the Mackey Air-lift (Mackey 1972). Therefore Table 4.3 offers a comparison of the two genuine deep water sampling devices in most frequent use by the Environment Agency (see responses to Questions 2 & 3 of the Questionnaire). In addition, the Mini Van-Veen grab, the Ekman grab, and the FBA Air-lift (not featured in Table 4.3) have been used on occasions by Agency staff (see responses to Question 3). However, each of these last three devices take small, and in the case of the

Ekman grab and FBA Air-lift, quantitative, samples of substratum and are therefore inappropriate for RIVPACS sampling.

Table 4.3 indicates that the Medium Naturalist's dredge is suitable for sampling substrata ranging from fine gravel to large stones. However, it is unsuitable for sampling mud and sometimes fails when used on river-beds with very large stones. In contrast, the Mackey Air-lift was suitable for use on a range of substrata ranging from mud to small stones. Hence these two sampling devices, although individually deficient on mud (Medium Naturalist's dredge) and large/very large stones (Mackey Air-lift), offer overlapping procedures to ensure that the full range of substrata in deep rivers are amenable to qualitative sampling. As a result, there appears to be no need to consider additional genuine deep-water sampling devices when designing field trials to determine the future RIVPACS sampling protocol.

However, when sampling from a boat in a deep slow-flowing watercourse, the use of a long-handled pond-net may still be a viable option.

Table 4.3 Summary of qualitative samplers suitable for different types of substrata in deep rivers. + = sampler is suitable; F = sampler sometimes fails. Air-lift samplers used at an airflow >200 l min^{-1}. (Data from Table 4 in Drake and Elliott 1982).

	Substratum					
	Mud	Fine Gravel	Fine gravel + small stones	Small stones	Large stones	Very large stones
Modal particle size (mm)	<0.1	0.5-4	0.5-4 + 16-32	16-32	64-128	128-256+
Van Veen grab	+	+	+F			
Ponar grab	+	+	+F			
Weighted Ponar grab	+	+	+			
Birge-Ekman grab (pole-operated)	+	+F				
Allan Grab (pole-operated)	+					
Large Naturalist's dredge		+	+	+	+	+F
Medium Naturalist's dredge		+	+	+	+	+F
Irish dredge*		+	+	+	+	+F
Fast dredge*				+	+	+F
Mackey Air-lift	+	+	+	+		
Pearson *et al.* Air-lift	+	+	+	+		

*Note that large numbers of samples must be taken when using the Irish and Fast dredges.

Benjamin (1998) compared standardised methods in use within the Environment Agency for sampling the macroinvertebrate fauna of Sussex Rifes (deep drainage ditches) to determine whether the methodology influenced the results and therefore the perceived water quality.

Seven techniques involving the use of pond-nets, dredges, grabs and artificial substrates were used at two sites (3-7 m in width). The techniques which collected the widest range of taxa combined with high abundance for a given sampling effort were kick-sweep, pond-net and bank sweep/dredge. In general these methods also produced the highest biotic scores. Nevertheless, there were sometimes substantial differences in the results obtained by these three methods. Overall, the results justified the use of a bank-sweep plus dredge sample because there were large faunal differences between these components and therefore both components were required in order to ensure a representative sample.

This suggests that the retention of a shallow-water protocol based solely on a long-handled pond-net (See Option A in Section 4.5.2) should be restricted to very narrow drainage ditches and that a deep-water protocol must be used in wider channels.

Evidence based on IFE experience

A). Dredge sampling on the R. Thames

In July 1996 the IFE were commissioned to undertake a biological survey of the macroinvertebrate fauna of the R.Thames in the vicinity of Didcot Power Station (Wright *et al.* submitted). Dredge sampling was undertaken in order to obtain a listing of the BMWP families present in the benthos and for the calculation of BMWP score, number of scoring taxa and the Average Score per Taxon (ASPT). Marginal pond-net samples were also taken, but these are not directly relevant to this section on the benthos. Details of the protocol employed during dredge sampling are given below.

A total of 30 dredge sampling units were taken (15 from each bank) over a distance of less than1 km. A 5 kg Medium Naturalist's dredge with a 46 x 20 cm aperture and fitted with a 1 mm mesh collecting net was used. When sampling from a given bank, the dredge was thrown as far as possible into the main channel of the river. It was then retrieved by trawling it for a distance of 5 m along the bed of the river diagonally in an upstream direction towards the bank. This was achieved by pulling the rope from close to the water surface in a series of short tugs, thus maximising the chance of the edge of the dredge digging into the substratum. When 5 m of rope had been recovered, the angle of pull was maximised and the dredge retrieved at speed.

After retrieval, the sample was photographed, reduced in volume by transferring small aliquots to a pond-net, which was then dipped in the river to allow fine particles through the mesh. Large mineral or vegetable particles were removed before the sampling unit was transferred to a polythene bag and fixed with formaldehyde.

It was considered that a representative sampling unit would constitute a volume of material within the range 0.5 – 2.0 litres. When a sampling unit was smaller than 0.5 litres in volume a further trawl was made and the two parts of the sample were combined. On no occasion was more than two trawls required to achieve a representative sampling unit. When the dredge volume exceeded 2.0 litres it was washed through two large stacked sieves (mesh size 1.7 mm and 0.355 mm) and a subsample taken from each sieve to produce a final volume not exceeding 2.0 litres.

Of the 30 dredge sampling units collected at Didcot, just six required two separate trawls to obtain a representative unit. Only one of the 30 units required subsampling to reduce the volume of material.

The dominant substratum varied with the sampling unit and ranged from clay through silt, detritus and sand to gravel, pebbles and cobbles. At several locations, including some dominated by clay, gravel, pebbles or cobbles, the substratum was compacted. However, most sites had a wide range of particle sizes.

Individual sampling units from the left bank had between 20 and 28 BMWP families, contributing to a total of 39 families in the 15 sampling units. Individual sampling units from the right bank had between 5 and 27 BMWP families, although only 4 units had less than 20 families. The taxon-poor sampling units were, in part, due to a very localised impact. The total number of BMWP taxa recorded in dredge samples from the right bank was 37 and the grand total for all 30 dredge sampling units was 41 BMWP families.

These outline results indicate that dredge sampling was very successful for collecting a representative range of BMWP families from a wide range of substratum types at Didcot on the R.Thames. Further details of this study may be found in Wright *et al.* (submitted). It should, however, be noted that where 'silt' was the dominant substratum, other coarser particles were also present and hence a dredge did not have to sample very fine particles alone where, it might become clogged and inefficient (see Table 4.3, where the Medium Naturalist's dredge was found to be ineffective on mud).

Finally, it should be pointed out that some members of the RIVPACS team gained extensive experience in the use of the Mackey Air-lift during an extensive survey of the R.Thames in the 1970s (Furse 1978). The Air-lift was chosen for this early survey because it had previously been shown by Mackey to be effective on the R.Thames at Reading and a boat was available for the extensive 1970s survey. The boat provided an ideal means of obtaining access to many miles of river without the need for bankside access at each sampling point. Thus, both dredge and air-lift samplers have been used with success in the R.Thames for surveys with different objectives.

B). Preliminary Field Trials, October 1998.

It was important for members of the present IFE team to see the Yorkshire pattern Air-lift in action at one or two locations where it is the preferred technique for routine monitoring and where dredge sampling is recognised as inadequate. Two sites in the North East Region of the Environment Agency (R.Calder at Methley Bridge and the R.Aire at Allerton Bywater) were visited on 8 October 1998. This also provided an opportunity to see each device in action and to make some very superficial comparisons.

The sampling procedures undertaken at each site were as follows. Three replicate marginal sampling units (each of three minutes duration) were taken with a pond-net. These were followed by three replicate sampling units of the benthos collected by each of three different techniques (long-handled pond-net, Yorkshire pattern Air-lift and Medium Naturalist's dredge. All sampling units were returned to the River Laboratory for sorting and identification at BMWP family level.

R.Calder at Methley Bridge

This site posed a number of practical sampling problems because large blocks had been placed in the river as reinforcement against erosion due to boat traffic. The long-handled pond-net sample was obtained by sweeping the deep river bed from a shallow marginal location. In contrast, the air-lift was deployed from a bridge across the river and successive replicates sampled different segments of the width of the river. Finally, the dredge was used from the bank. The weak link on the dredge broke several times during the sampling operation but eventually, three replicates were obtained. The substratum collected by the dredge was an oily ooze and contrasted with the stony substratum sampled by the air-lift next to the bridge. The area of river-bed sampled by the air-lift was somewhat greater than the 5 m trawl taken with the dredge. However, the time required to deal with the dredge samples exceeded that for the air-lift samples because some of the rinsing of the air-lift sample takes place with the flow of air through the collection net during the sampling operation itself.

Table 4.4 gives the raw data for each sampling method (three replicates per method). A total of only 12 BMWP families (BMWP score = 44) were recovered, confirming that this site was of poor quality. The margin held the most taxa (8-9 per replicate). Of the deep-water samplers, replicates for the air-lift held both the lowest (4) and highest (8) number of BMWP taxa, possibly due to the different locations chosen during sampling from the bridge.

Table 4.4 R.Calder at Methley Bridge Raw data for each sampling method employed in a preliminary field trial on 8.10.98

	Margin			L-h p n			Air lift			Dredge		
	1	2	3	1	2	3	1	2	3	1	2	3
Planariidae/Dugesiidae			+						+			
Dendrocoelidae									+			
Planorbidae		+	+									
Ancylidae/Acroloxidae					+				+			
Sphaeriidae	+	+	+	+	+	+				+		+
Oligochaeta	+	+	+	+	+	+	+	+	+	+	+	+
Glossiphoniidae	+	+	+	+	+	+	+	+	+		+	+
Erpobdellidae	+	+	+	+	+	+	+	+	+	+	+	+
Asellidae	+	+	+	+	+	+	+	+	+	+	+	+
Corixidae	+	+	+									
Dytiscidae/Noteridae	+											
Chironomidae	+	+	+	+	+	+		+	+	+	+	+
BMWP Score	25	23	28	15	21	15	10	12	28	12	12	15
No. of Taxa	8	8	9	6	7	6	4	5	8	5	5	6
ASPT	3.1	2.9	3.1	2.5	3.0	2.5	2.5	2.4	3.5	2.4	2.4	2.5
% of total taxa at site	67	67	75	50	58	50	33	42	67	42	42	50

When the three replicates for the margin were combined in turn with the three replicates from each of the deep water sampling techniques (Table 4.5) only the margin + air-lift combined retrieved all 12 BMWP families. Closer inspection of Table 4.4 reveals that only air-lift replicate 3 collected Dendrocoelidae at this site. The margin + long-handled pond-net and margin + dredge collected 11 and 10 BMWP families respectively. An ideal test would have deployed each of the techniques in the same way (i.e. from the bank or from a boat) in order to avoid sampling from the bridge with the air-lift where different substrata were encountered. However, it was clear that, the dredge was difficult to use at this site and generated large samples that took time to process.

Table 4.5 R.Calder at Methley Bridge The taxa from three replicate marginal sweep samples combined with the taxa from each of the other three sampling methods

	Margin only	**L-h p n + Margin**	**Air lift + Margin**	**Dredge + Margin**
Planariidae/Dugesiidae	+	+	+	+
Dendrocoelidae	o	o	+	o
Planorbidae	+	+	+	+
Ancylidae/Acroloxidae	o	+	+	o
Sphaeriidae	+	+	+	+
Oligochaeta	+	+	+	+
Glossiphoniidae	+	+	+	+
Erpobdellidae	+	+	+	+
Asellidae	+	+	+	+
Corixidae	+	+	+	+
Dytiscidae/Noteridae	+	+	+	+
Chironomidae	+	+	+	+
BMWP Score	33	39	44	33
No. of Taxa	10	11	12	10
ASPT	3.3	2.7	3.7	3.3
% of total taxa at site	83	92	100	83

R.Aire at Allerton Bywater

At this site the long-handled pond-net was again used from the marginal shallows in order to obtain a representative sample. In contrast, the dredge was used from the bank and the air-lift sampling units were taken from a boat. This site also had large blocks on the river-bed, but they were far more compacted than on the R.Calder. Again, the dredge was difficult to operate and bounced over the surface of the river-bed. The material of the protective skirt

surrounding the net became shredded during the trawling process and several throws were required to obtain each sampling unit.

The raw data (Table 4.6) indicates that just 13 BMWP families were recovered at this site. Of the three deep-water samplers, the air-lift (deployed from a boat) was more effective than the dredge or the long-handled pond-net. When marginal replicates were combined with the deep water replicates (Table 4.7), only the margin + air-lift generated all 13 BMWP taxa, because only the air-lift captured Sphaeriidae (Table 4.6). The margin + dredge and the margin + long-handled pond net captured 12 and 11 BMWP families respectively. However, this site was unsuitable for dredge sampling because of the character of the substratum and therefore an air-lift or a long-handled pond-net should be used to recover the limited macroinvertebrate fauna more efficiently.

Table 4.6 R.Aire at Allerton Bywater Raw data for each sampling method employed in a preliminary field trial on 8.10.98

	Margin			**L-h p n**			**Air lift**			**Dredge**		
	1	2	3	1	2	3	1	2	3	1	2	3
Planariidae/Dugesiidae		+	+				+	+	+		+	
Dendrocoelidae							+	+	+		+	
Hydrobiidae/Bithyniidae	+	+					+	+	+			
Planorbidae			+					+	+			
Ancylidae/Acroloxidae			+			+		+	+	+	+	
Sphaeriidae								+	+			
Oligochaeta	+	+	+	+	+	+	+	+	+	+	+	+
Glossiphoniidae	+	+	+		+	+	+	+	+	+	+	+
Erpobdellidae	+	+	+	+	+	+	+	+	+	+	+	+
Asellidae	+	+	+	+	+	+	+	+	+	+	+	+
Coenagriidae		+										
Corixidae	+	+	+									
Chironomidae	+			+		+	+			+	+	+
BMWP Score	20	29	29	9	10	18	25	35	35	18	28	12
No. of Taxa	7	8	8	4	4	6	8	10	10	6	8	5
ASPT	2.9	3.6	3.6	2.3	2.5	3.0	3.1	3.5	3.5	3.0	3.5	2.4
% of total taxa at site	54	62	62	31	31	46	62	77	77	46	62	38

Table 4.7 R.Aire at Allerton Bywater 8.10.98 The taxa from three replicate marginal sweep samples combined with the taxa from each of the other three sampling methods

	Margin only	L-h p n + Margin	Air lift + Margin	Dredge + Margin
Planariidae/Dugesiidae	+	+	+	+
Dendrocoelidae	o	o	+	+
Hydrobiidae/Bithyniidae	+	+	+	+
Planorbidae	+	+	+	+
Ancylidae/Acroloxidae	+	+	+	+
Sphaeriidae	o	o	+	o
Oligochaeta	+	+	+	+
Glossiphoniidae	+	+	+	+
Erpobdellidae	+	+	+	+
Asellidae	+	+	+	+
Coenagriidae	+	+	+	+
Corixidae	+	+	+	+
Chironomidae	+	+	+	+
BMWP Score	40	40	48	45
No. of Taxa	11	11	13	12
ASPT	3.6	3.6	3.7	3.8
% of total taxa at site	85	85	100	92

4.5.5 Can the effort be standardised for the benthic component of a RIVPACS sample?

As indicated at the beginning of Section 4.5.4, each deep-water sampling device should be capable of collecting the full range of taxa on the river bed and should also provide an indication of the relative abundance of taxa in the benthos. In order to achieve these objectives, each individual sampling device should operate in a standard manner on the range of substrata for which it is recommended. This in itself is difficult to judge, given that each device operates in deep-water out of the operator's vision. The situation becomes more complex when it is necessary to specify different sampling devices in order to obtain representative taxa lists in different types of river (eg substratum predominantly mud, gravel or cobbles).

Within the 1999 sampling trails, consideration should be given to the practicality of standardising the area of the bed over which each deep-water sampling device operates. Again, this poses problems because of the basic differences in mode of operation of the dredge and air-lift. If the case is made for sampling with a long-handled pond-net in some deep, slow-flowing watercourses, it should be possible to mimic the 5 m strip of river bed

trawled by a dredge. In contrast, the Yorkshire model Air-lift is "bounced" to prevent it digging into the river bed. Thus, there may be a tendency for it to sample a wider area of river bed and if the bed is very heterogeneous, the sampler may encounter a wider range of taxa than those encountered in a 5 m trawl. Care will be needed in the specification of the field protocol to minimise these potential problems.

A number of workers have recognised the difficulties inherent in comparing taxon richness and the relative abundance of the fauna based on collections from deep-water samplers. For example, Elliott & Drake (1981b) undertook field trials with four dredges, including the Medium Naturalist's Dredge, at three different sites. Five sampling units were taken with each device at each site. Each dredge was pulled against the current for a distance of 5 m to obtain each sampling unit. They noted large variation in the volume of substratum taken by a given dredge, both between sampling units at a given site and between sites. Differences between sites were partially related to differences in the modal size of the substratum. At a given site there was high variability between sampling units and hence a lack of precision in the estimates of mean number of invertebrates per sample. This confirmed that dredges cannot be used as quantitative samplers. However, there was a clear relationship between the number of taxa and the number of invertebrates taken at each site and this relationship was well described by a power law.

This suggests a possible approach for comparing samples, based on the number of taxa per standard number of individuals. Thus Odum (1967) measured species richness using the number of taxa per 1000 individuals and Sanders (1968) used a similar approach for marine benthos. Elliott & Drake (1981b) found that the power-law equation relating the number of taxa to the number of individuals was essentially similar for the four dredges that they examined. Hence the operator had the choice of taking many sampling units with the Irish or Fast Dredges or a progressively smaller number of sampling units with the Medium or Large Naturalist's Dredge in order to collect sufficient individuals to obtain a representative sample.

They also concluded that the power-law relationship between number of taxa and number of individuals probably applied to samples taken with other equipment used for qualitative sampling (e.g. pond-nets, colonisation samplers etc). These conclusions suggest that to obtain representative deep-water samples for the determination of taxon richness and relative abundance, it will be necessary to specify the collection of a standard number of individuals. Again, the formulation of a detailed protocol will be a component of the 1999 field trial.

4.5.6 What is the relationship between the marginal and benthic fauna?

The importance of the marginal zone and the tendency to focus on the fauna of the margins at the expense of the benthic fauna has already been highlighted in Section 4.5.2. Because the margins in deep rivers are visually discrete from the river bottom, there is logic in separating the two, whereas in shallow streams and rivers, the transition from margin to midstream is less abrupt and the opportunity for the development of distinct assemblages is less apparent.

In considering a RIVPACS module for deep rivers it is important to know the extent to which different taxa occur in the margins and in the benthos. It is also important to know if the information obtained on log categories of abundance at family level after a standard sampling protocol differs between the margins and the river-bed. This highlights a practical problem

because if the qualitative protocol differs between the margin and river-bed, and normally this will be the case, standardisation of sampling effort for the two procedures will be difficult to achieve. Hence, there is a strong argument in favour of treating the margins and benthos separately during the sampling regime and when assessing biological quality based on predictions using RIVPACS. The logic of this approach will be reinforced if differences are demonstrated between taxon occurrence and/or log categories of abundance at the family level when the margins and river-bed are compared.

Data collected by the IFE team at six sites on the R.Thames in 1984 for later use in RIVPACS will be used in the assessment. Each site was sampled in spring, summer and autumn and on each occasion a three-minute marginal kick/sweep was collected together with a dredge sample (consisting of between 2 and 7 trawls).

Table 4.8 Families of macroinvertebrates in margin (kick/sweep) and benthic (dredge) samples at six sites along the R.Thames in 1984. Numbers for each taxon represent the sum of the log categories of abundance from samples taken in spring, summer and autumn.

	3 min Kick/sweep at margin						Dredge in main channel					
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Neritidae	4	2		1		1	6	6	1	5	3	
Viviparidae								4	5	3		
Valvatidae	2	4	4	7	8	6		2	8	6	10	
Hydrobiidae/Bithyniidae	7	7	6	7	5	7	8	7	8	8	8	4
Lymnaeidae	3	1	2	4	4	4	2	1	1	4	6	1
Physidae		2	3	5	3					2	1	
Planorbidae	6	4	3	3	3	2	3	5	4	6	7	
Ancylidae/Acroloxidae	3	4	2		1	4	3	4	2	4		
Succineidae			1									
Unionidae		1	2			1		6	7	4		1
Sphaeriidae	6	7	7	5	9	6	6	8	9	7	9	7
Dreissenidae										2		
Oligochaeta	9	9	9	8	10	6	7	9	11	9	9	7
Piscicolidae			1					1				
Glossiphoniidae	3	2	2	2	5	4	3	6	7	6	7	3
Erpobdellidae	1	1	2	5	5	2	1		3	5	5	2
Hydracarina	1	3	3	2	2	1	3	3	4	1	3	
Asellidae	1	3	5	5	7	4	2	2	8	8	8	4
Corophiidae		1	6	4	3	5	1	2	8	8	9	10
Gammaridae/Crangonyctidae	5	4	4	4	5	5	2	1	4	5	7	2
Baetidae	5	8	5	3	3	1	7	3	4	3	4	
Heptageniidae			1	1						1		
Leptophlebiidae	1											
Ephemerellidae	1			1	1			1		2	3	
Ephemeridae	2		2		3	1	3	1	4	1	3	
Caenidae	6	3	2	6	5	6	9	8	8	9	9	5
Platycnemididae		1										

	3 min Kick/sweep at margin						Dredge in main channel					
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Coenagriidae	1	2	2	1		1	1		4	1		
Calopterygidae	2	1	1	1			3	1	1	1	1	1
Gomphidae								2	3	1	1	
Aphelocheiridae								1			1	1
Notonectidae	1	1	1									
Corixidae	2	2	4	1	5	1	1				4	
Haliplidae	4	3	4	1		1	2	1				
Dytiscidae/Noteridae	3	3	3	2	2	2	3	3	2		5	
Gyrinidae	2		1				1					
Hydrophilidae/Hydraenidae			1			1						1
Elmidae	5	1	1	1		2	6	5	4	4	3	
Sialidae	3		1		2		3	2	2		1	1
Sisyridae		1										1
Polycentropodidae	3	1		1	3	3	8	8	3	5	6	
Psychomyiidae/Ecnomidae	1			2	2	4	1	1	3	5	4	
Hydropsychidae	1											
Hydroptilidae	2						4	1	1		3	
Phryganeidae	1	1					2	1	1		2	
Limnephilidae	2		1	1			2	2	3	1	3	1
Molannidae	1				3	1	2	1	4	1	6	1
Leptoceridae	5	5	3	3	3	3	5	6	6	4	6	4
Goeridae	2						2					
Lepidostomatidae	1											
Brachycentridae			1									
Tipulidae		1	1					1				
Chironomidae	7	7	5	7	10	8	9	10	9	10	12	10
Other Diptera	4	2	2	1	2	2	4	5	3	4	3	1
Number of taxa in sample	39	33	37	30	27	30	34	37	34	34	34	21

A total of 54 families were collected (Table 4.8) of which just four were only retrieved by dredge sampling, and seven were only taken in kick/sweep samples. However, examination of the results for individual sites reveals that there were some substantial differences between the individual families taken in marginal kick/sweep samples (combined results for spring/summer and autumn) and those retrieved in benthic samples (Table 4.9).

Some sites had many families which were only recorded from marginal kick/sweep samples (e.g. 11 and 14 families at sites 3 and 6 respectively) whilst at others, the benthic samples (e.g. sites 2, 3 and 5) included between 8 and 11 families not recovered from corresponding marginal samples.

Table 4.9 Number of families of macroinvertebrates in margin (kick/sweep) and benthic (dredge) samples at six sites along the R.Thames in 1984 (three seasons combined)

Site Number	1	2	3	4	5	6
Total number of families (K/S + dredge)	40	44	45	37	35	35
No. families in kick/sweep	39	33	37	30	27	30
No. families in dredge	34	37	34	34	34	21
No. families confined to kick/sweep at site	6	7	11	3	1	14
No. families confined to dredge at site	1	11	8	7	8	5

In view of the level of sampling effort at each of these sites, it is apparent that the margins and river bed were providing substantially different information on taxon occurrence.

Table 4.8 also provides information on the log categories of abundance of each family. The log category values recorded in spring, summer and autumn for each family have been added together to provide a crude indication of the abundance of the family at each site for each sampling method. As previously indicated, there are problems in comparing two qualitative sampling methods where the standardisation of the sampling effort between the two methods is difficult to achieve. Nevertheless, some differences in abundance between margins and benthos were anticipated, and these appear to be indicative of genuine differences in preferred habitat.

Thus, whilst some Mollusca favour the margins (Physidae), others are predominantly or exclusively in the benthos (Viviparidae, Unionidae, Dreissenidae). Further examples may be found in the Ephemeroptera, Odonata, Hemiptera, Coleoptera and Trichoptera.

This provides further evidence of the benefits to be gained by keeping margin and benthic samples separate.

4.5.7 Is there merit in increasing the marginal sweep sample from one to three minutes?

Ideally, a series of one-minute replicate sampling units are required at a series of sites in order to obtain a balanced view to this question. This will be an element of the 1999 field trial.

The survey of the R.Thames at Didcot undertaken in July 1996 involved 15-sec marginal pond-net sampling at 15 locations on each bank. In practice, the section of river of interest was divided into three zones (A, B, C) and in each zone five 15-sec replicates were taken on each bank. For simplicity, the replicates for each zone and bank have been merged to give a series of 1.25 min samples. The total number of BMWP taxa per bank and zone, together with the total per bank are given in Table 4.10

The left bank had a greater variety of habitats than the right bank with respect to the dominant substrata and macrophytes and was considered more natural than the right bank, which was subjected to more disturbance by fishermen. Statistical analysis (ANOVA)

indicated that there were significant differences between the number of BMWP taxa in the left and right bank samples (Wright *et al.* submitted).

Table 4.10 Total number of BMWP taxa collected by pond-netting (5 x 15 sec sampling units combined) in three zones and both banks of the R.Thames at Didcot.

Bank	Zone A	Zone B	Zone C	Totals
Left Bank	36	33	32	41
Right Bank	25	29	24	36

This example demonstrates that bankside management and/or interference can affect the marginal habitat and, in consequence, the macroinvertebrate fauna. This needs to be recognised when undertaking and interpreting survey results.

When the results for zones A+B (2.5 min sample) and zones A+B+C (3.25 min) were pooled for each bank the number of BMWP taxa recorded were as follows:

	Zone A	Zone A+B	Zone A+B+C
Left bank	36	39	41
Right bank	25	32	36

Although the fifteen 15-sec replicates for a given bank represent over three minutes of sampling effort expended over a much longer length of riverbank than would be appropriate for a RIVPACS site, taxon accretion did occur and was particularly notable on the right bank.

It would, therefore, seem wise to take a 3-min marginal pond-net sample for RIVPACS in each of three seasons to ensure that a reasonably comprehensive taxon list can be acquired for the site. This would be particularly relevant if samples from the margins and the benthos are to be treated separately in the future.

4.5.9 Conclusions

The current contract requires the IFE to determine whether or not further investigation is likely to yield information that would affect the sampling methods recommended for RIVPACS in deep waters. If the answer to this question had been 'no', then a new section on equipment specification and sampling protocol for the procedures manual (Murray-Bligh *et al.* (1997) would be required in order to provide the necessary standardisation of the deep water methodologies.

In the event, it is apparent that there is a need for a full-scale field trial in order to set standard sampling protocols. The appraisal of relevant literature and unpublished data-sets has offered some useful guidance on future sampling protocols required for deep-water sampling, but at present, some questions remain unresolved.

For example, there are differing views on the range of substrata over which the Medium Naturalist's Dredge and the Mackey (Yorkshire pattern) air-lift perform satisfactorily. In the

case of the Medium Naturalist's Dredge, Drake and Elliott (1982) found that the 9 kg model was inappropriate for use on mud, but performed satisfactorily from fine gravel to large stones (Table 4.3) On very large stones it could be satisfactory, but sometimes failed. In contrast, the IFE (Wright *et al.* submitted) used a 5 kg dredge and the same model is recommended for use by the Environment Agency (Murray-Bligh *et al.* 1997) because it is easier and safer to use. It may be that the lighter 5 kg dredge can be used effectively in mud and Murray-Bligh *et al.* (1997) whilst accepting that the mesh may become blocked when sampling silt or peat, does not exclude it as an acceptable technique. The preliminary field trial in the North East Region of the Agency demonstrated the limitations of the dredge when sampling a river-bed consisting of very large stones, boulders and also concrete blocks added as a defence against erosion. (rip-rap). Here the dredge failed to penetrate the substratum, and the skirt was damaged during the trawling operation. In addition, the weak link broke on several occasions.

In the case of the Mackey Air-lift, Drake and Elliott (1982) recommend it for use from mud to small stones. In contrast, Murray-Bligh *et al.* (1997) suggested that air-lifts are unsuitable for sampling muddy river-beds because the collecting-net rapidly fills with mud. There is agreement between Drake and Elliott (1982) and Murray-Bligh *et al.* (1997) that the air-lift does not operate effectively on river-beds with boulders. However, it was in such rivers (R.Calder and R.Aire) that North East Region of the Agency demonstrated that the Yorkshire pattern Air-lift was able to suck material from and between the very coarse substratum and in so doing generates slightly more comprehensive taxon lists than alternative methods.

Appendix 6 lists the 24 sites in RIVPACS III at which either dredge samples (16 sites) or air-lift samples (8 sites) were taken. Dredge samples were taken at sites which fell into seven classification groups and air-lift samples occupied four classification groups. Eleven of the 24 sites were located in Classification group 35. Both samplers were used on a very wide range of river widths and depths. Of the 24 sites, just two had a substratum dominated by boulders and cobbles (1 air-lift; 1 dredge), at eight sites pebbles and gravel were dominant (2 air-lift; 6 dredge), at just two sites sand dominated (2 air-lift) and finally, of the 12 sites dominated by silt and clay three were sampled by air-lift and nine by dredge.

Clearly, further studies are required on the deep-water methods to be recommended for RIVPACS sampling in specified deep-water locations. This research must also extend to a consideration of the standardisation of effort in order to get comprehensive samples from different sampling devices with respect to taxon richness and relative abundance.

Finally, there is a need to demonstrate that a three-minute, rather than a one-minute marginal pond-net sample is more appropriate for RIVPACS, particularly if the margins and the benthos are to receive separate appraisal.

4.6 Proposals for future sampling in deep rivers

4.6.1 Proposal for detailed field trials in 1999

The contract specifies the need for future field trials to address two separate requirements. The first and primary objective is to standardise the deep-water sampling protocols. The second requirement is to measure the variability between operators using deep-water

sampling methods for the purpose of assessing errors in the compare module of RIVPACS III+. Note that this second requirement is only necessary if there is evidence that variation between field staff is substantially different from the estimates made for pond-net samples described in R & D Note 412 (Furse *et al.* 1995) on the variability of data for assessing the biological condition of rivers.

The first priority must be to clarify the position over the particular deep-water sampling derice and protocol to be undertaken in each category of deep river site with specified environmental characteristics. This will be a substantial piece of work and is to be undertaken in a new contract in 1999. To ensure that data obtained for the comparison of different sampling devices at a given site has maximum validity, it would be wise to use a very restricted group of operators who are thoroughly familiar with the use of each technique. This has some potential for conflict with a BAMS-type study in which the objective is to measure between-operator variability.

In view of the fact that the deep-water protocol is to be in place before the GQA survey in 2000, it must take precedence over a BAMS-type exercise. In order to obtain early evidence on whether inter-operator variability for deep-water protocols exceeds that for pond-net sampling (and therefore whether a full BAMS-type exercise is required in 2000) it may be possible to undertake a very limited sampling exercise within the 1999 deep-water sampling programme. This could focus on inter-operator variability in dredge sampling at a site that is regarded as suitable for dredge sampling and a similar exercise at a different site where an air-lift is the preferred technique. Appraisal of this preliminary data-set would be used in an overall assessment of the need or otherwise for a full BAMS-type sampling programme.

Considering first the development of sampling protocols, the field trial should examine the most appropriate technique(s) for use in sampling the benthos and also the margins.

Benthic sampling should assess the relative merits of:

- Long-handled pond-net
- Medium Naturalist's dredge
- Mackey/Yorkshire pattern Air-lift

for the collection of qualitative samples of macroinvertebrates from the benthos over a range of deep-water sites. The results should lead to the formulation of guidelines on the sampling device to be used in a given type of river (as specified by width, depth and substratum type).

The macroinvertebrate data obtained from the deep-water sampling units collected during the field trial should be used to formulate a standard RIVPACS protocol for use when sampling the benthos by each deep-water device.

The field trial must also determine whether there is benefit in taking a 3-minute pond-net sample from the river margins in preference to a 1-minute marginal sample.

The second major objective of the field trial is to obtain information on sampling variability, equivalent to that obtained for a series of shallow water sites (Furse *et al.* 1995).

The method or methods chosen for use in deep-waters must be scientifically defensible, and they must take account of a number of practical issues such as manpower, equipment, and time constraints. In addition, Health and Safety issues must, at all times, be of paramount concern and the detailed Agency protocols given in Murray-Bligh *et al.* (1997) must be followed.

In formulating a plan of action for the 1999 field trials, a series of interrelated decisions must be taken in order to obtain the necessary information. Deep-water sampling is expensive in time and manpower, as is the processing of deep-water samples. Therefore it is essential to devise a strategy that is capable of generating reliable data but at the same time is not excessively time-consuming.

The following proposals are offered as a starting point. We anticipate the need for refinement and clarification of the details, after discussion with the Project Board. Only then will it be possible to produce a final project plan for the field trials.

Number and location of sites

The sites selected for field trials should encompass the broad range of deep-water sites to be included in RIVPACS. Poor quality sites should only be included if they represent a river type for which there are no sites of high quality. It is unrealistic to include more than 4-6 sites within the field programme. They should include one site from some of the following rivers:

*Yorkshire Ouse
*Aire/Calder
Yorkshire Derwent
*Severn
Lower Exe
*River on Somerset levels
Thames
Dorset Stour
*Great Ouse
*A Fenland Drain

*IFE suggestions (maximum number 6 sites)

Season(s) of sampling

In view of the magnitude of the sampling programme at each site, and the substantial amount of material to be examined in the laboratory, it will only be possible to sample in one season. The season for sampling should be summer, to allow sufficient time for planning the sampling regime and, just as critical, to enable sample processing and analysis to be completed in time for decisions to be made on the deep-water sampling protocols required on each river type prior to the GQA in 2000.

Deep water sampling devices for the benthos

The long-handled pond-net, the 5 kg Medium Naturalist's Dredge and the Mackey/Yorkshire pattern Air-lift have been proposed for testing. Ideally, each of these three devices should be

tested on each site. It is recognised that in certain rivers, a given device will fail to function satisfactorily, in which case that particular test will be abandoned. The specific reason(s) for the failure will be recorded.

The long-handled pond-net will only be used from the bank in cases where the operator can sample the benthos close to the middle of the river/drain (i.e. in very narrow water-courses). In all other cases, it will be used from a boat to ensure that it samples similar locations to those sampled by the alternative devices.

The Medium Naturalist's Dredge will normally be used from the bank. Only when the height of the bank, the presence of a wide strip of marginal vegetation or another factor make bank sampling inappropriate, will the dredge be used from a boat. The dredge will not be used from a bridge.

The air-lift will normally be used from a boat, in such a way that the sampling area is similar to that available to an operator using a dredge from the bank. It will not be deployed from a bridge.

Note that these differences in protocol between dredge and airlift are designed a) to take advantage of the fact that the dredge can usually be operated effectively from the bank, thereby saving on time and manpower and b) to ensure that both devices are sampling comparable areas of the river bed.

Sampling protocol for each device

This includes two separate elements. First, the field procedure to be carried out when using a given device and the indicators which confirm that a valid sampling unit has been obtained. Second, the number of sampling units required for each device at each site.

We propose that a 5 m trawl followed by the protocol used on the R.Thames as described in Section 4.5.4 (see also Wright *et al.* submitted) is used to confirm that a representative sampling unit has been taken.

The long-handled pond-net sample should aim to include an area of riverbed equivalent to that taken by the dredge (i.e. 5 m x 0.46 m in total area). The net will need to be emptied on several occasions during collection of the sampling unit.

The Air-lift should also aim to cover a similar area. Murray-Bligh *et al.* (1997) indicate that each sampling replicate normally takes 3-4 min to collect.

We propose that three sampling units are taken for each device at each sampling site.

Note that the definitive procedure to be adopted at each site cannot be determined until the sampling units have been processed. This will involve an examination of the number of taxa in relation to the number of individuals in the separate sampling units. It should then be possible to determine whether one or more representative sampling units are required to obtain the necessary information for a given type of site, based on a particular sampling device.

Sampling protocol for marginal pond-net samples

A minimum of three 1-min pond-net sampling units should be taken at each site. There is an argument for repeating this protocol on the opposite bank, if accessible.

Laboratory processing of benthic and marginal samples

All sampling units will be processed to family level only. The following protocol is offered for the processing of all benthic samples. Each benthic sampling unit (i.e. from each sampling device and each site) will be divided into 2 or 4 sub-units using a sample splitter. Each separate sub-unit will then be sorted and identified in order to accumulate a family listing with estimated abundance of each family. By progressively adding the 2 or 4 sub-units together from each of the 3 sampling units, a taxon accretion curve will be generated. This procedure will be repeated for each sampling device at a given site. It will then be possible to compare the different devices with respect to the number of families per 500, 1000, etc individuals accumulated. It will also be possible to determine whether 1, 2 or 3 sampling units are required for a given device in order to accumulate a representative sample and whether one or more devices fail to collect a reasonably comprehensive listing of families at a given site.

These findings will be used to determine the sampling device(s) and detailed sampling protocol to be recommended for benthic sampling in specified river types.

The marginal sampling units will be processed at family level to accumulate taxon listings. Taxon accretion will then be examined by combining the sets of three 1-min sampling units.

All samples will be retained for more detailed examination at species level in the future, if required.

Scale of the field sampling and laboratory sorting/identification operation

The precise number of sampling units to be collected and examined will depend upon the final programme to be agreed between the Environment Agency and the IFE.

The provisional calculations presented below give an idea of the scale of the exercise.

If six sites are examined and at each one, three deep-water devices are tested such that three sampling units are collected per device, then a total of 54 sampling units will be collected. Each of the 54 units will then be divided into 2 or 4 separate sub-units for which family level listings with estimated abundances (i.e. numbers and not simply log. categories) are required.

In addition, three (or possibly six) 1-min pond-net sampling units at each of six sites will result in 18 (or 36) sampling units for laboratory processing at family level (presence/absence only for this exercise).

A preliminary assessment of inter-operator variability

This exercise will be confined to an appraisal of biological sampling variability based on dredge and air-lift samples at one site only in each case.

In the original BAMS project (Furse *et al.* 1995) three pond-net sampling units were processed for each site. (In that project, samples were taken in three seasons at a total of 16 sites in the full sampling design). The programme to establish the appropriate sampling technique for a range of deep-water sites already includes the need to take three sampling units per sampling device.

At each of the two sites where inter-operator variability is to be examined in one season, there will be a need for two additional individuals to collect three sampling units each. That is:

Site 1. Location where dredge is already regarded as a reliable technique and where 3 sampling units have been taken by operator A. Three sampling units to be taken by each of operators B and C.

Site 2. Location where air-lift is already regarded as a reliable technique and where 3 sampling units have been taken by operator A. Three sampling units to be taken by each of operators B and C.

The individuals who take the samples may be from either the IFE or the Agency, but in each case, they should be thoroughly familiar with the sampling techniques and have had prior experience of using the sampling devices.

There will be a total of three operators x three sampling units for each device and the sampling units will be divided into sub-units as previously described. Analyses will determine whether there are significant difference between operators for each device.

4.6.2 Strategy for biological assessment of deep rivers using RIVPACS

The current three-year contract (January 1998 – December 2000) includes several packages which may eventually lead to modifications in RIVPACS III+. They include the further development of abundance indices (Package 6), incorporation of information on trophic structure into RIVPACS (Package 8), evaluation of new environmental variables for prediction (Package 9), in addition to the standardisation of sampling methods for use in deep rivers (Package 10). The current project is to investigate these topics and determine how improvements should be implemented. However, the modification of the RIVPACS software will be the subject of a separate contract.

At this stage it is not possible to produce a definitive statement on the best procedure for improving the assessment of the biological quality of deep-water sites. This will, in part, depend upon the results of the field trials to be undertaken in 1999. However, it is possible to sketch out some of the options now, to provide adequate time for the Environment Agency to consider the merits of each option.

The strategy of merely standardising the future sampling protocol for deep-river sites has already been rejected because it ignores the fact that a strict protocol was not in place when the original reference sites were sampled. It is important to emphasise that there is good

evidence that the taxon listings for deep-water reference sites used in RIVPACS III are capable of setting high standards in terms of the expected Number of Taxa and ASPT values. However, the variation in the reference site sampling protocols must inevitably lower the reliability of the current evaluation procedure for deep-water sites. In addition, as further developments take place in the use of family-level log abundance indices for early detection of stress prior to major loss of family richness, the need for a standard protocol for deep water sites increases.

When a new version of RIVPACS is developed, in which the protocols for both shallow and deep-water sites are standardised, then three main options are possible as follows:

A). Two-module version of RIVPACS
i). Shallow-water sites plus deep water sites (margin samples only)
ii). Deep-water sites (benthic samples only)

B). Two module version of RIVPACS
i). Shallow-water sites only
ii). Deep-water sites (margin samples) plus deep-water sites (benthic samples) combined

C). Three module version of RIVPACS
i). Shallow-water sites only
ii). Deep-water sites (margin samples only)
iii). Deep-water sites (benthic samples only)

Each option has potential advantages and disadvantages.

Option A includes all the RIVPACS sites within module Ai but only includes the marginal sample at deep-water sites. Hence, the framework for the biological assessment changes between shallow and deep-water sites from a full to a partial assessment. The benthic sample for each deep-water site is considered in a separate module (Aii). This has the advantage that the taxon richness and also the log abundance categories at family level can be assessed independently of the marginal sample.

Option B separates the shallow-water sites (module Bi) from the deep-water sites (module Bii), thus effectively separating the different sampling protocols into different modules. By combining the marginal and benthic samples from the deep-water sites into module Bii, the deep-water sites are assessed as a single unit, as in the shallow site module Bi. However, in combining marginal and benthic samples in the deep-water module (Bii), the potential for interpreting impacts acting on the margin or benthos is reduced.

Option C not only retains the shallow-water sites in one module (Ci) but keeps the margin (Cii) and benthic (Ciii) elements of the deep-water sites separate, thus maximising the potential for interpretation of impacts at the deep-water sites.

The detailed field trials in 1999 will determine the sampling protocol to be adopted for the margins and benthos at deep-water sites with specified characteristics. These protocols will be implemented in the GQA survey in 2000. A subset of the GQA 2000 deep-water sites which are known to be of high quality will be selected as reference sites for the deep-water module(s) for the next version of RIVPACS.

The marginal and benthic samples for these reference sites will need to be forwarded to the IFE team for processing and species level identification. A decision will also be required from the Environment Agency on whether samples for the reference sites are to be collected in just two or all three seasons. Only by taking samples in each of spring, summer and autumn will there be full compatibility with all previous RIVPACS samples and the added flexibility of predicting the expected fauna in each of the individual seasons. Furthermore, this would produce a more robust prediction system.

Once all sample processing and identification is complete and the site taxon lists and family level abundance categories have been transferred to computer and verified, the appropriate analyses will commence, depending on which of the options (A-C above) is chosen by the Environment Agency. Both classification and prediction analyses are required before development of the software can begin.

5 DEVELOPMENT OF RIVPACS METHODOLOGY FOR CANALS – A SCOPING STUDY

5.1 Introduction

In 1995 the Environment Agency used RIVPACS III on rivers throughout England and Wales for the biological component of the General Quality Assessment (GQA) scheme. RIVPACS III was developed for use on rivers and, in its current form, is inappropriate for use on canals. The purpose of this scoping study is to consider whether it is feasible to develop a RIVPACS module for canals and what action is required to achieve this objective.

Although canals are artificial waterbodies constructed during the 18th and 19th centuries, they have now developed into a series of unique habitats which, by nature of their channel profile, are unlike rivers or natural still-water habitats. The uniform channel shape and substrate offers an opportunity to compare invertebrate faunal assemblages over a wide geographic area and to relate differences to factors other than some of those used in RIVPACS. The concept of distance from source does not apply to canals and because width, depth and substratum are more uniform than in rivers, these attributes may be unsuitable as predictors of the fauna. Habitat diversity is likely to be a major influence on community structure in the absence of chemical pollution and the development of a method of categorising habitat diversity may be an important element in developing a prediction system for canals.

The concept of applying the RIVPACS approach to canals was first discussed in correspondence between the IFE and the NRA in March 1995 and developed in further detail in correspondence with the Environment Agency in October 1996. However, the current project encompassing ten separate topics on RIVPACS, and including the canal scoping study, did not commence until January 1998.

During the intervening period, the Environment Agency commissioned a project from Pond Action of Oxford Brookes University entitled 'Biological Techniques of Still Water Assessment'. A wide-ranging Phase 1 scoping study has been published (Williams *et al.* 1996) which includes a proposal for a biological assessment method relevant to still waters (lakes, canals, ponds, ditches, temporary waters and brackish lagoons). In September 1998, the Phase 2 Method Development report (Williams *et al.* 1998) was published. This report presents the results of two pilot studies on ponds and canals in which the RIVPACS multivariate predictive approach has been combined with the multimetric approach currently favoured in the USA as a procedure for measuring ecological integrity. In view of the progress already made in the biological evaluation of canals as outlined in these reports, it is essential that this research is taken into account within the current scoping study.

5.2 Objectives

The overall objective is as follows.

To produce a written report 'Development of RIVPACS methodology for Canals' This should be written in a form that can be understood by Agency biologists and managers.

The specific objectives are:

1. To make a preliminary assessment of the likely range of canal types and invertebrate communities in canals, by reviewing the literature and existing data.

2. To make a preliminary assessment of additional physical (and chemical) environmental variables which are likely to be important predictors of the invertebrate communities found in canals, independent of water quality, and which would be included in full field trials.

3. To make a preliminary assessment of the sampling procedures which are likely to be appropriate for canals. If trials of different sampling equipment are considered necessary, these trials should be described and costed. The investigation of sample collection methods for deep rivers undertaken as another part of this project should be taken into account.

4. If it is necessary to collect samples from a range of canal types in order to undertake objectives 2 and 3, the number of samples, types of sites, and the costs should be described.

5. To describe the cost and additional analytical and programming work, and, if necessary, the collection of additional samples. This is to include a consideration of the most cost effective strategy for collecting reference data from canals for RIVPACS.

6. To assess the scope for collaboration with other organisations. This should include DoE Northern Ireland, the Scottish Environmental Protection Agency, English Nature and British Waterways.

7. To produce an overall project plan, including realistic timescales, for the expansion of RIVPACS to cover canals. This should take account of the Agency's desire to classify canals biologically in the 2000 National River Quality survey.

5.3 Brief review of canals and their macroinvertebrate fauna

5.3.1 Canals in England & Wales

British Waterways administers a total of approximately 3,320 km of canals and navigable rivers in England, Wales and Scotland. A number of additional canals in England and Wales are not administered by British Waterways. The total length of canals in England and Wales has been estimated as 2,474 km (National Rivers Authority, 1991) and Table 5.1 presents the length of canal in each Environment Agency Region. Over 63% of the total canal length is represented in two regions of the Environment Agency, namely the industrialised North West Region and the Midlands Region. The North East, Thames and Welsh Regions comprise a further 25.5% of the total length, but Anglian, South West and Southern Region have little more than 11% of the total.

Table 5.1 also includes the 1990 RQS chemical classification for each Region, expressed as percentage of canal length in each class. Based solely on chemical criteria, it is apparent that

in North West Region only 17% of canal length was of Good quality, whereas in Thames Region the figure was much higher at 61%. All regions, with the exception of South West and Thames Region had a higher percentage of canal length in the Fair class than in any other class. In fact, North East Region had joint highest percentage canal length in the Fair and Poor classes, whereas all other Regions had a much lower representation in the Poor class. Whereas South West Region had a high representation of Good class length, it also had 16% of canal length in the Bad class. This wide range of chemical quality amongst canals within the South West Region results from the amalgamation of two former NRA Regions (South West and Wessex) in which NRA South West had just 10% of canal length in the Good and Fair Classes combined, whereas Wessex had 100% of canal sites in the Good and Fair Classes combined.

Table 5.1 Total length of canals in each Environment Agency Region, together with an indication of chemical quality, based on the 1990 RQS scheme and results. (Adapted from National Rivers Authority, 1991).

Region	Total length (km)	Percentage of canal length in each class				
		Good		Fair	Poor	Bad
		1a	1b	2	3	4
Anglian	125	0	40	60	0	0
Midlands	990	2	32	59	6	0
North East	268	1	31	32	32	4
North West	577	5	12	79	4	0
Southern	41	0	26	74	0	0
South West	111	9	46	22	7	16
Thames	210	18	43	35	4	0
Welsh	152	0	37	45	17	0

Although the Environment Agency (formerly the National Rivers Authority) have responsibilities for the periodic appraisal of the quality of canals, other organisations have statutory responsibilities placed upon them for the administration of canals and for the conservation of their flora and fauna.

During the period of decline of waterborne freight, pressure was exerted on the Government by the Inland Waterways Association to maintain the canal system for purposes other than just the carriage of freight. This pressure was very influential in the formation of the British Waterways Board (BWB) in the 1960s. The 1968 Transport Act classified the nationalised canals and defined the role of the British Waterways Board (now British Waterways) in relation to the type of canal as follows:

Commercial - to be maintained for the handling of freight

Cruising - to be principally available for cruising, fishing and other recreational purposes

Remainder - to be dealt with in the most economical manner possible, consistent with the requirements of public health and the preservation of amenity and safety.

Subsequent campaigning has resulted in the successful prevention of infilling of some canals, the redevelopment of many derelict and disused canals and also the restoration of many formerly unnavigable 'remainder' canals to cruising standard.

The British Waterways Act 1995 places a duty upon BW to further conservation on all its canals and an Environmental Code of Practice is in place to enable the implementation of this duty whenever works are carried out.

Canals provide a unique environment for a wide range of freshwater organisms. Even in the last century, it was recognised that they provide a habitat for the spread of a wide variety of aquatic macrophytes including many rare, unusual and alien species, and their associated invertebrates.

Following the formation of the Nature Conservancy in 1949, many lengths of canal were notified as Sites of Special Scientific Interest (SSSIs), principally because of their diverse aquatic and emergent flora.

These measures were designed to protect sites with conservation interest and the current list of SSSIs now includes 23 stretches on 19 canals totalling 167 km (English Nature, 1995). The distribution of SSSIs by Environment Agency Region is given in Table 5.2. Additional SSSIs have been notified on canal-associated habitats such as feeder reservoirs and adjacent land. Note that there are no canal SSSIs within Anglian Region.

Table 5.2 Estimated length and number of canal SSSIs designated primarily for their channel interest (English Nature, 1995) in each Environment Agency Region.

Region	Length in Km	Number of Sites
Midland	62	9
North East	26.5	5
North West	11	2
Southern	11	1
South West	4.5	2
Thames	43	1
Welsh	9	3

5.3.2 Invertebrate communities in canals

As soon as it was recognised that canals were important habitats for the aquatic flora and fauna, they became the subject of study. For example, in the last century, records of aquatic macrophytes in canals were included in many county Floras and Morgan (1887-91) listed the aquatic molluscs of the Montgomery Canal.

To date there have been relatively few published papers on the invertebrate communities of canals compared to rivers. Most studies have been conducted on high quality canals already recognised as SSSIs for their aquatic macrophytes e.g. Montgomery Canal (Briggs, 1988) or have been the subject of environmental impact assessments made in response to proposed developments e.g. Grand Union Canal (Kelcey 1979), Lancaster Canal (Burrow 1975). Other

macroinvertebrate studies have focused on single alien species e.g. the amphipod crustacean *Corophium curvispinum* Sars (Pygott & Douglas 1989), the flatworm *Dugesia tigrina* (Girard)(Wright 1987), the gastropod *Ferrisia wauterii* (Mirolli)(Norris 1982), the Turkish crayfish *Astacus leptodactylus* Eschscholz (Ingle & Clark 1989) or major invertebrate groups e.g. Mollusca (Cooke 1989; Watkin & Morphy 1976; Morphy *et al.* 1977; Morphy & Clarkson 1978).

In the last few years the National Rivers Authority (NRA) and the Environment Agency (EA), have undertaken more extensive monitoring programmes. The 1990 River Quality Survey carried out by the NRA includes data from 351 samples taken at 174 canal sites in England and Wales. The sites are distributed between the eight Environment Agency Regions as shown in Table 5.3.

Table 5.3 Allocation of 174 canal sites sampled during the 1990 River Quality Survey to the eight Regions within the Environment Agency.

EA Region	Number of 1990 RQS canal sites
Anglian	25
Midlands	76
North East	25
North West	1
Southern	5
South West	6
Thames	25
Welsh	11

The full list of sites and season(s) of sampling is given in Appendix 6, together with the BMWP scores, Number of taxa and the Average Score Per Taxon (ASPT) for each season. The BMWP families recorded at these sites are presented in descending order of frequency of occurrence in Table 5.4.

In general, as would be expected, the more pollution tolerant low-scoring families occur at a higher frequency among the 174 canal sites than the high-scoring families. Some of the pollution-sensitive families of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are entirely absent from the canal sites due largely to their requirements for fast-flowing well-oxygenated water over stony riffles e.g. Perlidae, Odontoceridae, or the sites being outside of their geographic or altitudinal range e.g. Siphlonuridae, Capniidae. Some families belonging to these major groups do occur, albeit at very low frequencies e.g. Heptageniidae, Taeniopterygidae, Perlodidae and Brachycentridae. Their unexpected presence in seemingly unsuitable canal sites could be explained by a number of factors e.g. proximity to a river or atypical conditions at a site such as flowing water making the canal more riverine in nature.

Some notable pollution-sensitive high-scoring families do occur at relatively high frequencies in the 174 sites. The caddisfly families Leptoceridae and Phryganeidae (both scoring 10) do contain a number of species which are most commonly found in still or slow-flowing water. The presence of these and certain other high or medium scoring families such as the

damselflies Calopterygidae and Coenagriidae is likely to indicate unpolluted sites with well developed marginal vegetation.

In contrast, some of the more pollution-tolerant taxa which are almost ubiquitous in rivers e.g. Hydropsychidae (caseless caddis) and Simuliidae (Blackflies) occur at relatively low frequencies in the canal sites, due to their specific requirements as filter feeders in flowing waters.

Table 5.4 Frequency of occurrence of BMWP families at 174 canal sites.

BMWP Taxa	Frequency of occurrence	BMWP Score
OLIGOCHAETA	169	1
ASELLIDAE	162	3
CHIRONOMIDAE	158	2
GAMMARIDAE	143	6
SPHAERIIDAE	133	3
HYDROBIIDAE	111	3
ERPOBDELLIDAE	109	3
LYMNAEIDAE	104	3
COENAGRIIDAE	102	6
GLOSSIPHONIIDAE	100	3
CORIXIDAE	94	5
PLANORBIDAE	94	3
BAETIDAE	83	4
DYTISCIDAE	81	5
HALIPLIDAE	79	5
PHYSIDAE	74	3
SIALIDAE	73	4
PLANARIIDAE	71	5
VALVATIDAE	62	3
LEPTOCERIDAE	59	10
CAENIDAE	55	7
PISCICOLIDAE	53	4
UNIONIDAE	52	6
LIMNEPHILIDAE	45	7
NOTONECTIDAE	45	5
ANCYLIDAE	43	6
COROPHIIDAE	43	6
GERRIDAE	40	5
ELMIDAE	34	5
HYDROPHILIDAE	33	5
TIPULIDAE	31	5
POLYCENTROPODIDAE	29	7
VIVIPARIDAE	26	6
DENDROCOELIDAE	23	5

BMWP Taxa	Frequency of occurrence	BMWP Score
PHRYGANEIDAE	21	10
HYDROPTILIDAE	20	6
CALOPTERYGIDAE	16	8
GYRINIDAE	14	5
NERITIDAE	11	6
PSYCHOMYIIDAE	10	8
HYDROMETRIDAE	9	5
SIMULIIDAE	8	5
EPHEMERELLIDAE	7	10
HYDROPSYCHIDAE	7	5
MOLANNIDAE	7	10
NEPIDAE	7	5
AESHNIDAE	6	8
NAUCORIDAE	6	5
PLATYCNEMIDIDAE	6	6
EPHEMERIDAE	5	10
LIBELLULIDAE	5	8
RHYACOPHILIDAE	5	7
LEPTOPHLEBIIDAE	4	10
NEMOURIDAE	4	7
PLEIDAE	4	5
SERICOSTOMATIDAE	4	10
GOERIDAE	3	10
HIRUDINIDAE	3	3
LEPIDOSTOMATIDAE	3	10
HEPTAGENIIDAE	2	10
HYGROBIIDAE	2	5
LEUCTRIDAE	2	10
MESOVELIDAE	2	5
SCIRTIDAE	2	5
ASTACIDAE	1	8
BRACHYCENTRIDAE	1	10
PERLODIDAE	1	10
TAENIOPTERYGIDAE	1	10

Table 5.5 presents the full BMWP list of families from high to low scores with attached information on the frequency of occurrence of the families in the canal dataset. This method of presenting the results helps to emphasize the absence of many of the high-scoring riverine taxa and the high frequency of occurrence of many of the low-scoring taxa.

Table 5.5 Full listing of BMWP families with frequency of occurrence of each family at 174 canal sites in England and Wales from the 1990 RQS dataset. (>50% occurrence indicated in bold underlined; >25-50% in bold; >10-25% in normal font underlined; >0.5-10% in normal font; brackets indicate absence).

Taxa	Score
(Siphlonuridae) Heptageniidae Leptophlebiidae Ephemerellidae (Potamanthidae) Ephemeridae Taeniopterygidae Leuctridae (Capniidae) Perlodidae (Perlidae) (Chloroperlidae) (Aphelocheiridae) Phryganeidae Molannidae (Beraeidae) (Odontoceridae) **Leptoceridae** Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	10
Astacidae (Lestidae) Agriidae (Gomphidae) (Cordulegasteridae) Aeshnidae (Corduliidae) Libellulidae Psychomyiidae+Ecnomidae (Philopotamidae)	8
Caenidae Nemouridae Rhyacophilidae+Glossosomatidae Polycentropodidae **Limnephilidae**	7
Neritidae Viviparidae Ancylidae+Acroloxidae Hydroptilidae **Unionidae** Corophiidae **Gammaridae+Crangonyctidae** Platycnemididae **Coenagriidae**	6
Mesoveliidae Hydrometridae Gerridae Nepidae Naucoridae **Notonectidae** Pleidae **Corixidae** **Haliplidae** Hygrobiidae **Dytiscidae+Noteridae** Gyrinidae Hydrophilidae+Hydraenidae (Clambidae) Scirtidae (Dryopidae) Elmidae. Hydropsychidae Tipulidae Simuliidae **Planariidae+Dugesiidae** Dendrocoelidae	5
Baetidae **Sialidae** **Piscicolidae**	4
Valvatidae Hydrobiidae+Bithyniidae Lymnaeidae Physidae Planorbidae Sphaeriidae **Glossiphoniidae** Hirudinidae **Erpobdellidae** **Asellidae**	3
Chironomidae	2
Oligochaeta	1

Fig. 5.1 shows the frequency distribution of BMWP scores in three single seasons (spring, summer and autumn), in spring and autumn combined and also with three seasons combined. The number of sites (n) included in each histogram varies for the individual seasons since some of the 174 sites were only sampled once or twice during the 1990 GQA Survey. The histograms based on the combined seasons (i.e. two seasons and three seasons) only include the 86 sites that were sampled on all three occasions. Thus, more reliable comparisons are possible between the last two histograms. Figures 5.2 and 5.3 show similar frequency histograms for the Number of taxa and Average Score Per Taxon (ASPT).

Single-season BMWP scores varied from 2 –169, indicating the wide range of canal types and biological qualities encompassed in the survey. When samples from spring and autumn were combined, then BMWP scores ranged from 14-193, and with all three seasons combined the range of scores was 18-252. The highest BMWP scores for each of the individual seasons and also for the combined season options were all from a single site on the Kennet and Avon Canal. The reason why the three season combined score of 252 was so much higher than the spring and autumn score (193) was because the summer sample included eight BMWP taxa (including three with a BMWP score of 10) which were not found in either spring or autumn.

When comparing the BMWP score histograms for the single seasons, it is apparent that the modal value and also the highest individual site scores occurred in summer. Both the modal value and highest site score increased when two and then three seasons were combined, as would be expected. Nevertheless, the differences between the two and three season histograms were modest, when compared to the single season histograms. Generally, most sites showed only moderate increases in BMWP score when the third season was added, although the Kennet and Avon site was a notable exception. Several sites showed no increase in score. Note that the majority of the sites with single season BMWP scores below 10 were only sampled in a single season, and are therefore absent from the combined seasons histograms.

Frequency histograms based on the Number of Taxa (Fig. 5.2) were broadly similar to the results for BMWP score, as would be expected. The range in the Number of Taxa for single season sampling was 1-32, for two seasons combined it was 4-36 and for three seasons combined it was 5-44. The modal number of taxa was highest in summer and lowest in autumn, as for BMWP score. The other combined seasons histograms were distinctly different in shape from the single season histograms, again broadly reflecting the BMWP score with an increase in the modal value from two to three seasons combined.

Fig. 5.3 presents the equivalent ASPT histograms. ASPT values for single seasons varied from 1.5 to 5.41, with relatively minor differences between seasons. However, the effect on ASPT of combining seasons was to greatly decrease the range of values at the lower end of the scale, while maintaining the same modal value as the single seasons. The range of values for two seasons combined was 3.0 to 5.36, and for three seasons combined it was 3.0 to 5.73.

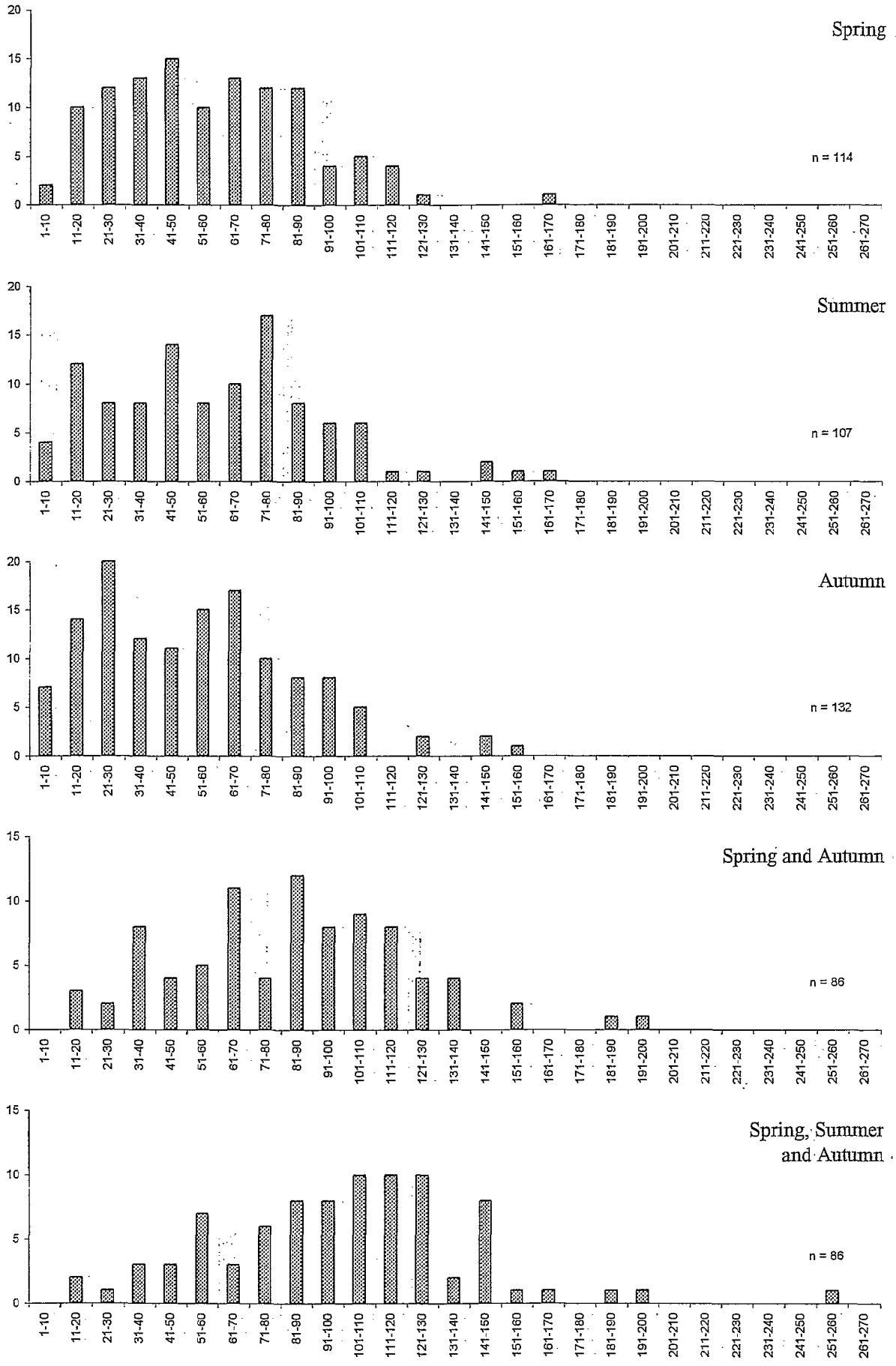


Fig. 5.1 Frequency distribution of BMWP score in three single seasons, in spring and autumn combined and in three seasons combined.

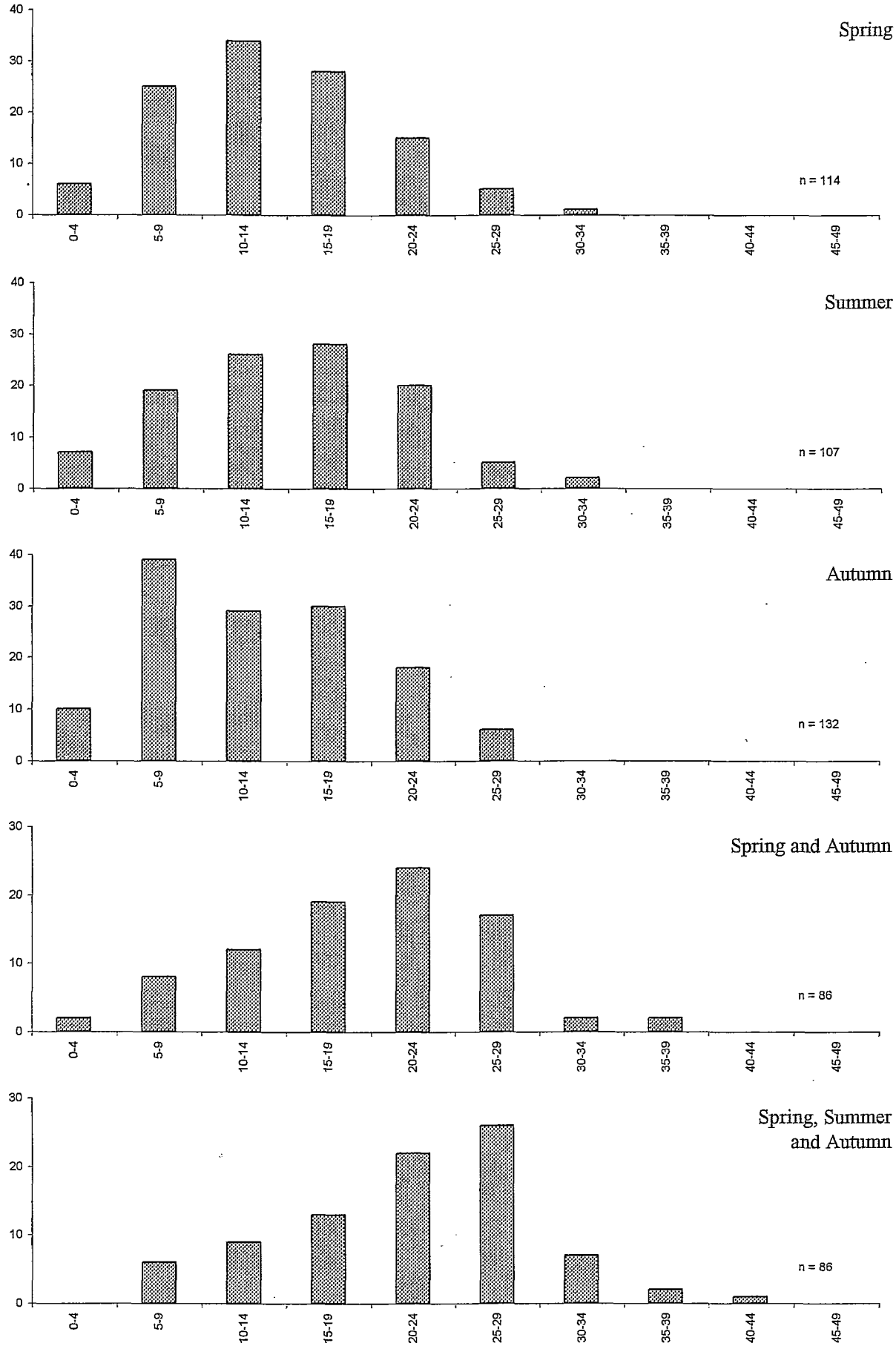


Fig. 5.2 Frequency distribution of the number of taxa in three single seasons, in spring and autumn combined and in three seasons combined.

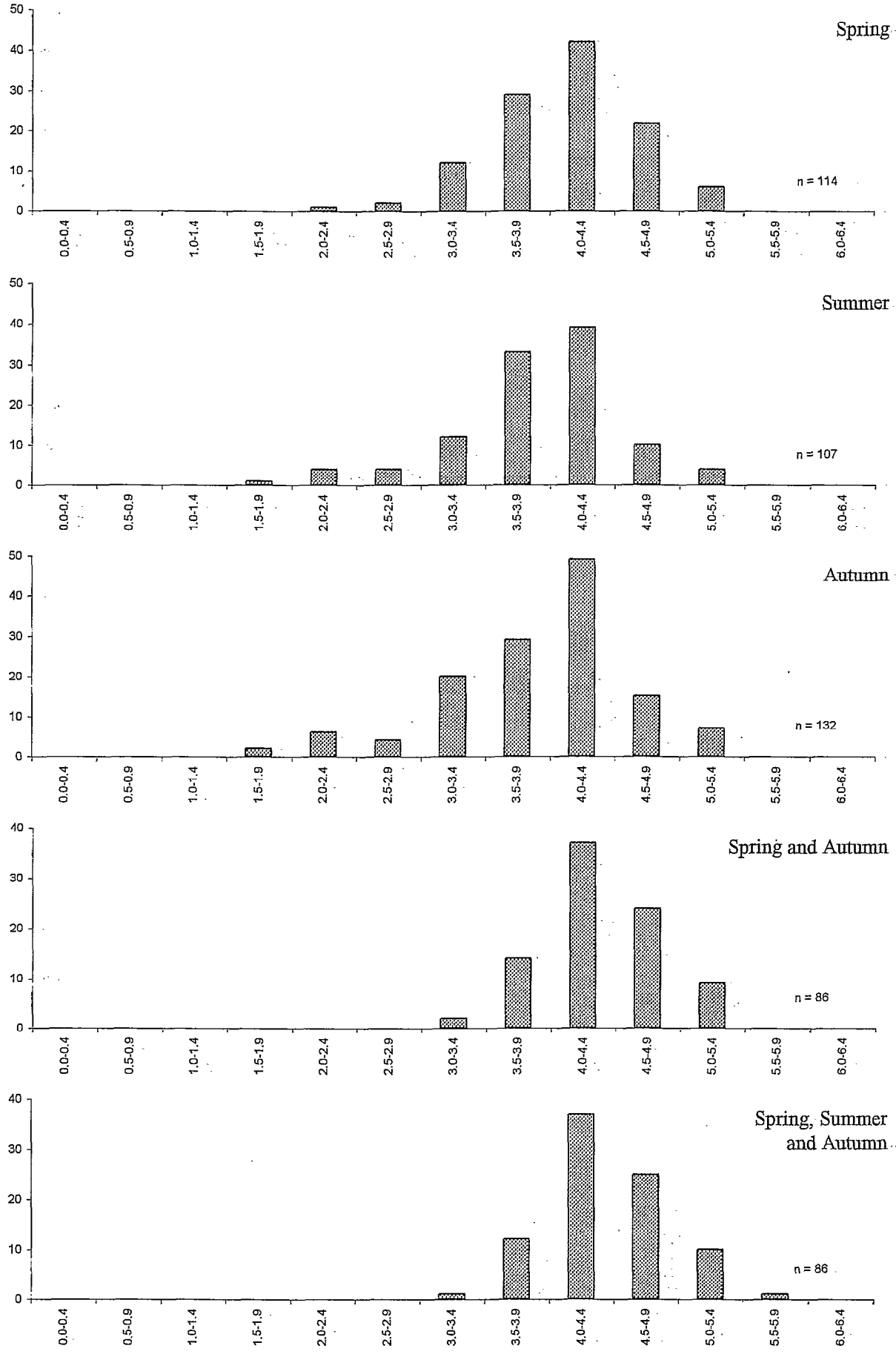


Fig. 5.3 Frequency distribution of ASPT in three single seasons, in spring and autumn combined and in three seasons combined.

5.4 Current Environment Agency procedures for canals

This section of the report presents the results obtained from the Environment Agency in response to Questions 7 to 10 of the Questionnaire on sampling for macroinvertebrates in deep rivers and canals (Appendix 4). Additional information provided by SEPA in Scotland and IRTU in Northern Ireland is also given where appropriate. The responses to Question 11 are given in Section 5.5

5.4.1 Occurrence of canals in each Environment Agency Region

Question 7 - Occurrence and type of canals

The purpose of this question was to establish which Environment Agency Regions and Areas had canals, and then to determine the type of canal(s) present, based on a number of broad categories.

These categories were:

- Navigable canals - mainly commercial traffic/mainly leisure traffic/disused
- Unnavigable canals
- Canals scheduled as Sites of Special Scientific Interest (SSSIs)
- Other – as specified by the respondent

The results are given in Table 5.6. It is apparent from the replies that there are now very few canals which are primarily used by commercial traffic. Only three areas contain canals in this category, Lower Trent in the Midlands Region, Ridings in North East Region and the southern area of North West Region. This reflects the great decline in waterborne freight from the early part of this century onwards. In contrast, the expansion of leisure traffic over the past few decades has occurred throughout the entire canal network and new restorations continue to add to the total navigable length in a number of areas.

All Regions contain some disused and unnavigable canal sections and with the exception of Anglian Region, all have one or more sites designated as SSSIs.

Table 5.6 Categories of canals within each area of the Environment Agency as reported in response to the Questionnaire (Question 7). Some further information for Scotland and Northern Ireland is also given.

Region	Area	Navigable canals			Un-navigable	SSSI	Other
		Commercial	Leisure	Disused			
Anglian	Eastern		+				
	Central		+				
	Northern		+	+	+		
Midland	Upper Severn		+	+		+	
	Lower Severn		+		+		
	Upper Trent		+	+	+	+	+ (1)
	Lower Trent	+	+	+	+	+	
North East	Dales		+	+		+	
	Ridings	+	+	+	+	+	
	Northumbria						
North West	Northern		+	+	+		
	Central		+				+ (2)
	Southern	+	+	+	+	+	
Southern	Kent		+	+		+	
	Sussex						+ (3)
	Hants & IOW		+		+		
South West	Cornwall		+	+	+		
	Devon		+				
	North Wessex		+	+	+	+	+ (4)
	South Wessex		+				
Thames	North East		+				+ (5)
	South East		+			+	
	West		+	+	+		
Welsh	North		+				
	South East		+	+			
	South West		+	+		+	
SEPA	North						+ (6)
	Dumfries						
	East Kilbride		+	+	+	+	
N. Ireland			+	+			

Footnotes to Table 5.6 :
(1) Proposed new extensions or redevelopment of unnavigable sections
(2) CBHS – County Biological Heritage Site
(3) In process of being opened up for leisure traffic
(4) Drains, ditches and rhynes. Penned rivers which stop flowing or reverse direction in summer.
(5) Navigable rivers. Trapezoidal/canalized watercourses/flood channels etc. (artificial conduits)
(6) For drainage purposes.

5.5.2 Sampling programme in each EA Region

Question 8 – Current sampling programme for canals

The purpose of this question was to establish which Areas within the Environment Agency are currently undertaking a sampling programme for macroinvertebrates on their canals and secondly, to attempt to acquire a list of National and Regional GQA Monitoring sites on canals. Table 5.7 indicates that just 15 of the 26 Agency areas have a monitoring programme. This situation is not unexpected in view of the fact that RIVPACS is currently inappropriate for use on canals and therefore there was no biological assessment of quality undertaken on canals in the 1995 GQA. The number of sites sampled (presented at Regional level only) is also given in Table 5.6 and a full listing of the sites is presented in Appendix 7.

Table 5.7 Listing of the Environment Agency areas which sample canals and the number of sites sampled per region, as reported in the Questionnaire (Question 8)

Region	Area	Canals Sampled?	Number of sites sampled
Anglian	Eastern	NO	17
	Central	YES	
	Northern	YES	
Midland	Upper Severn	YES	99
	Lower Severn	NO	
	Upper Trent	YES	
	Lower Trent	YES	
North East	Dales	YES	9
	Ridings	YES	
	Northumbria	NO (No canals)	
North West	Northern	NO	1
	Central	NO	
	Southern	YES	
Southern	Kent	YES	7
	Sussex	YES	
	Hants & Isle of Wight	NO	
South West	Cornwall	YES	7
	Devon	YES	
	North Wessex	YES	
	South Wessex	NO	
Thames	North East	YES	37
	South East	NO	
	West	YES	
Welsh	North	NO	0
	South East	NO	
	South West	NO	

5.4.3 Sampling procedures used in canals

Question 9 – Sampling Methods

In this section of the questionnaire, information was requested on the habitats sampled (marginal and benthic) and the techniques used to sample macroinvertebrates in canals. Agency biologists were asked whether they sampled canal margins, and if so, whether they sampled:

- hard margins – defined as concrete and/or steel piling
- soft margins – defined as marginal vegetation
- backwaters or other areas not in the main channel

They were also requested to supply information on the methods used to sample the substratum of the canal in order to document the benthic fauna. The sampling options included:

- Active disturbance of substratum with a long-handled pond-net
- Use of a dredge
- Use of an Air-lift
- Use of a grab
- Other – to be specified

Finally, information was requested on whether the sampling techniques involved the use of a boat or bridge, and the total number of personnel involved in field sampling.

The Agency results are given in Table 5.8 and additional responses from three areas of SEPA and from IRTU in Northern Ireland are also included. All 15 Environment Agency areas which currently sample canals (plus the three Welsh areas which have not sampled canals since 1990/1991), indicated that soft margins were sampled. Hard margins were sampled in 7 Agency areas (one area qualifying this with "only if unavoidable"). The bottom substratum was sampled in 17 Environment Agency areas but in two of these (shown in brackets) only where access to shallow marginal areas for kick/sweeping was possible. Backwaters were normally sampled by two Agency areas and one other area sampled backwaters within SSSIs.

Active disturbance of the substratum with a long-handled pond-net was the method most frequently used for sampling the bottom substratum (12 Agency areas) with five areas using a dredge and one area (Ridings, North East) using an Air-lift. Kick sampling was carried out where possible in shallow areas by four areas, and one area searched boulders or solid retrievable objects for attached invertebrates. Several areas employed more than one method depending upon the nature of each site.

Sampling was carried out from the bank in all areas, only one area utilising a boat or bridge (for operating the Air-lift). The manpower used was not always specified but was mainly two (10 areas) or just one biologist(five areas) but three people were required to operate the Air-lift in Ridings area of North East Region when used from a boat.

Table 5.8 The habitats sampled and the sampling methods used for canals in each Environment Agency area, as reported in the Questionnaire (Question 9). Some further information for Scotland and Northern Ireland is also given. (PN = pond-net; D = dredge; A = Air-lift. See footnote for explanation of numbers)

Region	Area	Habitats sampled				Sampling Method
		Hard margins	Soft margins	Substratum	Backwaters	
Anglian	Eastern	Not sampled				
	Central	+	+			
	Northern	+	+	+		PN
Midland	Upper Severn		+	+		PN
	Lower Severn	Not sampled				
	Upper Trent	+	+	+	Only SSSIs	PN & 1
	Lower Trent	+	+	+	+	PN
North East	Dales		+	+		PN
	Ridings		+	+		PN & A
	Northumbria	No Canals				
North West	Northern	Not sampled				
	Central	Not sampled				
	Southern		+	(+)		2
Southern	Kent		+	+		PN
	Sussex		+	(+)		3
	Hants & IOW	Not sampled				
South West	Cornwall	+	+	+		D
	Devon		+	+		D
	North Wessex		+	+		PN & D
	South Wessex	Not sampled				
Thames	North East	+	+	+		PN, D & 4
	South East	Not sampled				
	West	+	+	+	+	PN
Welsh	North		(+)	(+)		(PN)
	South East		(+)	(+)		(D) & 5
	South West		(+)	(+)		(PN)
SEPA	North		+	+		PN
	Dumfries	No canals				
	East Kilbride	+	+	+		PN
N. Ireland		+	+	+		PN & (D)

Other methods (1) 3 min. kick if access to margins is possible
(2) Kick/sweep in shallow margins
(3) Kick sampling of accessible areas + net sweep
(4) Search of boulders/solid retrievable objects
(5) Kick sampling in shallow canals

5.4.4 Field protocols used in canals

Question 10 – Field protocol

In this question, respondents were asked for specific information on the sampling protocol employed for each sampling method listed in response to question 9. That is, for marginal samples, information was requested on the sampling procedures employed for 'hard margins' and for 'soft margins'. Details of the sampling method and field protocol used for collecting

samples of the benthic fauna from the substratum were also requested. Finally, details of whether the marginal samples were examined separately or combined with substratum samples was requested.

Marginal samples – soft margins

Soft margins were always sampled with a pond-net but the exact protocol varied between Environment Agency areas and within the same area, depending on site conditions. Sampling time was not specified by all areas, but where stated, was normally three minutes with an additional one minute search specified by two areas. In three areas, where the marginal sample supplemented a deep-water dredge sample, one minute was specified for the duration of marginal sweeps.

As previously stated, four areas sampled the marginal substratum, with additional sweeps of the marginal vegetation, where access was possible.

When airlift sampling was carried out from a boat, the supplementary marginal sweep may also have been taken from the boat on occasions, presumably where access from the bank was difficult or prohibited.

Marginal samples - hard margins

Where hard margins were sampled, the protocol was usually the same as for soft margins, but one area did specify hand-searching as a method.

Deep-water samples

Method or sampling-time was not always specified when a long-handled pond-net was used. The only comments supplementing 'active disturbance of substratum' were 'net dragged over bottom', and 'net drawn in from distance using smooth raking movement'. A combined total sampling time of three minutes was specified by one area for marginal and deep water samples (but it is likely that this was the case in other areas where the long-handled pond-net was the only method used).

Areas using the dredge referred to question 3 of the deep-rivers section of the questionnaire to describe the sampling protocol. A number of slightly different methods were used to obtain a substratum sample of manageable size. Up to five throws or hauls of the dredge were performed depending upon the nature of the substratum and two areas specified volumes of material (3-5 litres) gathered prior to sieving. The weight and aperture dimensions of dredges varied slightly between regions but the mesh size was always 1mm.

The protocol for the airlift sampling was 'as laid out in BT001 Agency Manual'.

Later treatment of marginal and substratum data

In all cases where benthic samples were taken, they were combined with the marginal samples for analysis. However, one area did state that for some sites and on some occasions the samples were examined separately.

5.5 Appraisal of future options

5.5.1 Some basic considerations

The primary objective is the development of a procedure for the biological assessment of the quality of canals. Biological assessment is also the primary application for RIVPACS, but this system was developed for running waters and there was never any intention that the running-water version should be applied in man-made waterways such as canals.

Because of the fundamental differences between rivers and canals it will be necessary to develop a separate system with distinct differences from RIVPACS. For example, locations along canals, cannot be defined in a meaningful way as 'x km from source', as is done in rivers, when predicting faunal composition. In addition, features such as width, depth and substratum do not vary in a predictable manner along the length of a canal, as they do along a river system. Being man-made, canals do not possess natural geomorphological features that change downstream. Instead, their basic characteristics have been defined by man during construction, and subsequently altered to a greater or lesser degree by past and present uses and current the management procedures.

The reference sites within RIVPACS offer a basis for predicting a 'target' community of macroinvertebrates to be expected at a given running-water site with defined environmental characteristics in the absence of environmental stress. However, it would not be possible to set a single 'target' fauna for a canal at a given geographical location and supplied with a given water source. This is because one canal might have 'hard' vertical sides whereas another might have a thick fringe of marginal vegetation. Clearly, the potential of these two canal-types to support a diverse assemblage of macroinvertebrates would differ, and hence different 'target' assemblages would be required before a realistic appraisal could be made of the observed fauna in each canal. Similarly, given that canals were designed for boat traffic, should adverse effects on macrophytic vegetation with potential consequences for their macroinvertebrate assemblages be viewed as a form of stress (resulting in lowered O/E ratios), or should different 'target' assemblages be specified, depending on the level of boat traffic? These and similar questions would need to be faced when designing a suitable framework for predicting the fauna in canals.

The specification for this project proposes that existing RIVPACS methodologies be used if possible, unless they are likely to be ineffective in canals. However, canals have some of the characteristics of deep rivers and the discussion of sampling methodologies in Chapter 4 of this report is relevant. Method development undertaken in the Environment Agency project on Biological Techniques of Still Water Quality Assessment (Williams *et al.* 1998) is also relevant. For this reason, an account is given in section 5.5.2 of this report.

The Environment Agency, the Scottish Environment Protection Agency, and the Department of the Environment (NI) have all used the RIVPACS protocols for the biological appraisal of river quality. Therefore they are likely to favour a uniform approach to the appraisal of the quality of canals.

English Nature recognise the importance of canals for biodiversity and in particular for a number of macrophytes and the water vole. A small proportion of canals, often at the end of the network, have become disused and are now high quality refuges for wildlife (English

Nature 1997). However, as pressure on canals increases due to recreational boating, English Nature has some concerns over the condition of some of the canal SSSIs and has commissioned Liverpool University to undertake an audit of canal SSSIs in order to determine whether there is evidence of change over time (Mary Gibson, pers. comm).

British Waterways have expressed an interest in the development of a RIVPACS module specifically for canals. They take the view, quite correctly, that the current version of RIVPACS is inappropriate for monitoring the biological quality of canals (Grahame Newman, pers. comm.). British Waterways are responsible for canal management, including dredging, bank protection and control of navigation. These activities may influence biological quality and given that BW have a statutory duty to consider the environmental impacts of their work, they recognise that an appropriate survey methodology would be of value to them. The assumption is that the Environment Agency would undertake any survey work under their water quality remit and then make the data available to BW.

British Waterways have been consulted by Pond Action in connection with their R & D project on Biological Assessment of Still Waters. At present BW have some concerns that insufficient weight is being given to macrophytes, in view of their importance in providing basic habitat structure and as a measure of the impact of boat traffic etc.

Any new system for the biological appraisal of canals will require the collection of both biological and environmental data. The next two sections present a synopsis of the sampling protocols for canals recently proposed by Pond Action (Williams *et al.* 1998) and a consideration of the environmental variables which may be required for a prediction system.

5.5.2 Sampling protocols used by Williams *et al.* (1998). (Pond Action Report)

Selection of sampling sites

Initially, a total of 83 sites were chosen to reflect the range of physical, chemical and biotic factors likely to influence the invertebrate communities in canals.

The pilot survey area encompassed the majority of the canal network and therefore included the lowland Midland region of England and eastern Wales. The more isolated canals of the extreme south-west and south-east as well as those north of the Humber were excluded (as were canals in Scotland). The survey area covered an altitudinal range of approximately 50m – 150m above sea level and included a varied range of geological strata.

Information collected from 70 sites in spring 1997 was used in the analysis. Thirty of the sites were 'minimally impaired', defined as having 'good water quality (GQA chemical Class A or B) and low or moderate boat traffic. These were used as reference sites. The remaining sites were 'degraded' to a lesser or greater extent and varied in chemical quality and the degree of impairment by boat traffic, run off, sewage discharge etc.

The survey excluded sites on any of the major river navigations (e.g. Lee and Stort) on the basis that they contain many sections which are essentially riverine in nature.

Sampling methods and protocol

The sampling method had some features in common with the shallow and deep water protocols used for RIVPACS (Murray-Bligh *et. al.* 1997), but differed in that habitats were not sampled in proportion to their occurrence, more sampling time being devoted to the marginal areas. A sample comprised: 1minute search with a hand-net; 2 minutes of active hand-net sampling in the shallow margins and emergent vegetation (typically along 5m –15m bank length); 4 hauls of a pond-net (in wadeable areas) each approximately 3 m perpendicular to the bank or 4 hauls of a dredge (where too deep to wade) with a hand-net sub-sample taken from the dredged material.

Replicate invertebrate samples were taken at approximately 20% of the sites concentrating on well vegetated vs bare banks. The majority of the samples were taken from nearside (i.e. towpath) but a small number of replicates were from the opposite bank to provide data from contrasting bank types in close proximity.

Data collection

Environmental data were recorded on site and included attributes of the channel vegetation, bank type, degree of shading etc. Other physical data were provided by the relevant authorities and related to water flow, boat movements and dredging records. Water samples were collected from all the invertebrate survey sites to provide chemical data. Additional data were obtained from the Environment Agency routine water chemistry samples and British Waterways sediment chemistry data.

Invertebrate samples were sorted live and identification was generally to species level with the exception of Oligochaeta (class), Diptera (family) and *Pisidium* (genus). These groups were retained separately for further identification, if necessary, at a later stage.

5.5.3 Environmental variables for prediction

Variables used in Williams et al. (1998) in the Pond Action Report

Site classification and the techniques for relating the biological groupings to environmental factors followed those used in RIVPACS (Wright 1995). TWINSPAN analysis of the invertebrate data from the 30 minimally impaired reference sites produced 4 end-groups, each comprising between 4 and 10 reference sites.

The physical variables used to predict the end-groups were associated with location, turbidity, bank structure, depth and vegetation. When 9 variables were used, all of the sites were correctly assigned to the 4 end groups. These variables were:

Location – Northing; Easting; Altitude
Turbidity – Secchi depth
Bank - % earth; bank angle; % grass in bank top zone
Depth – sediment depth
Vegetation – Number of submerged plant species

A variety of invertebrate metrics were used to assess the degree of environmental degradation of the remaining impaired sites. Significant correlations were found between many of the metrics considered and the physical and chemical attributes of the degraded sites. Bank structure and vegetation were strongly correlated with many of the metrics including invertebrate species and family richness. ASPT was strongly correlated with water quality measures, but not with bank degradation measures. BMWP score, however, was correlated with both water quality and bank structure.

Responses to question 11 in the IFE Questionnaire

Question 11 asked the Environment Agency biologists to indicate which environmental factors they regarded as important predictors of the macroinvertebrate fauna (independent of water quality). A list of factors was provided and the biologists were asked to score them as very important, fairly important or not important. Space was provided for the addition of other factors which they considered to be potentially important predictors. The results, based on 16 replies are summarised in Table 5.9.

Additional factors – several additional factors were regarded as very important or fairly important. They included flow of water, dredging regime, salinity, altitude, distance from water feed, type of boat traffic, development of marginal vegetation, shading and length of canal.

Table 5.9 Response by Environment Agency biologists to Question 11 in the Questionnaire.

Factor	Very Important	Fairly Important	Not Important
Alkalinity	5	5	6
Geographical location	4	6	6
Substratum type	11	5	0
Water width	0	3	13
Water depth	1	9	6
Proximity of/connection to a free-flowing river	4	8	4
Character of marginal vegetation	11	5	0
Development of submerged macrophytes	15	1	0
Density of boat traffic	8	5	3
Turbidity of the water	6	8	2
Proximity of locks	4	4	8

Further points and conclusions

It is evident from the results of the Pond Action study and from the replies to the questionnaire that the most important factors for predicting the invertebrate fauna at minimally impaired sites (and for determining the faunal composition of degraded canal sites) are those associated with bank structure and the development of vegetation. In the absence of pollution, habitat variability is the key determinand of faunal richness and factors which affect habitat diversity in canals, whether directly or indirectly, will be strongly correlated

with the metrics which are a measure invertebrate faunal richness. Many of the environmental factors are closely interrelated. Boat traffic, for example, strongly affects turbidity and the development of submerged and emergent macrophytes. Studies have demonstrated that high densities of boat traffic can greatly reduce the diversity of macrophytes in canals. Quantitative surveys of plant growth in British Cruising and Remainder canals by Murphy and Eaton (1983) show significant associations between community composition, abundance of aquatic macrophytes and pleasure boat traffic. Cluster analysis revealed four principle groupings of sites which had significantly different mean boat traffic densities and markedly different macrophyte community compositions and abundances.

Further research by Eaton *et al.* (1989) placed over 40 species of aquatic macrophytes into one of four groups depending upon the sensitivity of each to boat traffic density (measured as number of boat movements per year – standardised for a canal 10 m wide and 1 m deep). By recording the presence or absence of some or all of the species it may be possible to quickly assess the impact of boat traffic at a particular site and classify the site into one of the above four principle groupings. These groupings could form the basis for a categorisation of sites according to the degree of degradation due to boat traffic apart from other factors affecting invertebrate faunal composition.

Other factors may also influence the invertebrate fauna of canals. For example, the presence of trees along a canal bank may have a number of direct and indirect effects on the invertebrate fauna. Even isolated trees may provide shelter or focal points for mating swarms of the adult stages of some orders of insects which have aquatic larval stages. Deciduous trees supply the canal ecosystem with an annual input of allochthonous detritus in the form of leaves. In canals there may be very little or no movement of detritus from trees compared to rivers. Leafy detritus forms an important food source for many aquatic invertebrates and therefore distribution and abundance could be influenced by the proximity of trees. Trees may also have negative effects on faunal richness. By partial shading of the water they may suppress macrophyte growth and richness, thereby reducing the habitat diversity.

Although river navigations were excluded from the Pond Action study they may have more in common, in terms of invertebrate communities, with canals than with rivers. There may also be some true canals included in the Pond Action survey with characteristics more akin to rivers (e.g. some sections of the Kennet and Avon Canal). It may therefore be more appropriate to include river navigations in an initial classification. They may subsequently form a discrete subset of 'riverine canals' that could be characterized by a number of physical attributes related to flow, bank structure, substrate etc.

5.6 Proposals for future sampling in canals

5.6.1 The current position

For some time, the Environment Agency has recognised the need for an assessment system specific to canals. Discussions between the Agency and the IFE on this topic started as early as 1995 but the wide range of issues to be addressed in the current RIVPACS project, of which a RIVPACS-type methodology for canals was just one of ten separate packages, contributed to delays in formalising the final programme, which commenced in January 1998.

In a separate project funded by the Environment Agency and undertaken by Pond Action (Biological Techniques of Still Water Quality Assessment), a Phase 1 desk study in 1995-96 offered proposals for a rationale and methodology for the biological monitoring of still water bodies in England and Wales (Williams *et al.* 1996). Phase 2 of this project (1997-98) included the development of the Phase 1 approach through some preliminary field trials (Williams *et al.* 1998). The still water bodies chosen for the trials included ponds and canals. The Pond Action field programme for canals commenced in April 1997, well before the IFE project was underway and therefore the Pond Action team, in the absence of a prescribed methodology, devised a standard canal survey technique, as described in Section 5.5.2 of this report. The Pond Action report (Williams *et al.* 1998) describes the technique as a 'hybrid' between the shallow and deep-water RIVPACS procedures in use at that time.

The original specification for package 3 of the IFE project, that is, a scoping study leading to the development of a RIVPACS methodology for canals, has therefore been partially overtaken by events. Nevertheless, it is important for the IFE to draw together relevant findings from the present scoping study, comment on the results in the Pond Action report (Williams *et al.* 1998) and offer the Environment Agency a way forward so that a full methodology is available for use on canals as soon as possible.

Within the specification of the IFE scoping study, there is a request that existing RIVPACS methodologies should be used unless they are likely to be ineffective in canals. There is a further request that the potential relevance of any developments in deep water sampling protocols (Package 10) should be considered. Sections 5.4.2-5.4.4 of this report, which describe the Environment Agency sampling protocols in current use, demonstrate some variation in approach between Regions. Whereas pond-net sampling is the favoured technique, a number of Regions employ a dredge where this is considered necessary. Pond Action (Williams *et al.* 1998) also developed a protocol in which pond-net sampling of the margins and the deeper bottom sediments was undertaken where feasible, but the option of collecting bottom sediments with a Naturalist's dredge was available where canals were too deep for pond-netting.

Are the deep water protocols discussed in Section 4 of this report relevant to canals? Clearly, an important proposal for deep water sites is the concept of distinguishing the margins from the benthos, undertaking separate sampling protocols and keeping these two components separate. In practice, deep rivers exhibit much greater variety than canals, in that they can be much wider than canals, fast flowing, of very variable substratum and with banks subject to great variation of form. As a consequence, the sampling protocol for the benthos may need to vary with the type of river and the margins warrant separate consideration. Because canals are more uniform than deep rivers in terms of cross section, width, substratum and bank slope, then it is more likely that a simple protocol, undertaken from the bank will provide an adequate sample for the appraisal of biological quality. Hence, we take the view that the more complex proposals for deep rivers are not required for canals.

This leads to the question of whether the methodology employed in the pilot survey of canals conducted by Pond Action in April 1997 offers an appropriate field protocol on which to build a comprehensive system for assessing the biological quality of canals. The Pond Action team is familiar with the RIVPACS protocols and the importance of a standard field procedure not only when collecting the reference dataset for system development but when using the system for the routine appraisal of site quality. The pilot survey protocol devised by

Pond Action was developed after a consideration of the RIVPACS protocols for shallow and also deep rivers in use at that time and appears to offer a level of sampling effort similar to or greater than that in current use by most Environment Agency staff who sample canals. In addition, it takes account of the margins and the benthos. In view of the experience gained by the Pond Action team in detailed discussion with British Waterways and in sampling a total of 70 canals sites in England and Wales, the team are now well placed to judge whether the pilot survey field protocol can be applied in a standard manner to a wide range of canals or whether it needs modification before being adopted as a standard protocol.

Of the 70 canal sites examined in April 1997, just 30 minimally impaired sites were used to develop a basic classification and prediction system using standard RIVPACS techniques. That is, development of a site classification based on mainly 'species level' data using TWINSPAN, followed by Multiple Discriminant Analysis to predict end-groups, using a small sub-set of physical variables. The project also included investigations to determine the potential value of biological attributes (metrics) for recognising anthropogenic degradation. However, this topic is not within the remit of the IFE scoping study and will not be considered further in this report.

For the preliminary analyses undertaken by Pond Action, the biological data for the margins and deep water components of the sample at each site were merged. The 30 canal sites were then classified into just four groups (4-10 sites per group) and the use of nine environmental variables allowed all 30 sites to be predicted to the 'correct' classification group. Williams *et al.* (1998) concluded from this pilot sampling exercise that predictive multivariate techniques, as used in RIVPACS, could be applied successfully to canals and other still water-bodies. We would agree with this viewpoint. However, as Williams *et al.* (1998) point out, further development work is required in a number of areas in order to develop a fully operational methodology. They list a number of important areas including extending the geographical and seasonal aspects of the scheme, conducting variability studies relating to data collection and analysis, field testing the method and also the development of appropriate software.

5.6.2 Future Action required

Here we offer a list of the factors to be considered during the further development of an operational system for canals, including the points already flagged by Williams *et al.*(1998).

Field Protocols

Sampling method – The protocol recently used by Pond Action (Williams *et al.* 1998) would appear to be capable of accumulating the characteristic elements of the fauna at each site. We assume that the marginal and benthic components of the sample will be kept separate. There would also be merit in taking replicate samples at canal sites where contrasting bank types (well vegetated vs bare/reinforced banks) occur in close proximity because Williams *et al.*(1998) have demonstrated that replicate samples do not always classify into the same end-groups.

Number of sites – The 30 canal sites used by Pond Action during the trial classification and prediction exercise were acknowledged as barely adequate to demonstrate the technique. Clearly, a larger number of sites, classification groups and sites per group would be required

for an operational system. Given that the total length of canals in England and Wales has been estimated at 2474 km, then one site per 25 km would result in the need for 100 sites in a reference system. If 100 sites formed the basis for a system throughout Great Britain or the United Kingdom, then the density would drop well below one site per 25 km.

Type of sites – RIVPACS and also the pilot version of the classification and prediction system for canals have been based on minimally impacted reference sites. Given that canals are man-made and that when used for their intended purpose of transport there may be impacts on the biota, it is possible to argue for the inclusion of some impacted sites within the reference database. A choice may have to be made between a severely limited reference dataset of sites that may not be capable of representing the full range of canals in the country, versus a wider range of sites which include some sites subject to a level of boat traffic which undoubtedly does affect the biota.

When developing RIVPACS, our focus was on the selection of the highest quality reference sites in order to offer predictions of the fauna to be expected in the absence of major environmental stress. Test sites would then be measured against these 'target' predictions. If this stance is maintained for canals, then sites with substantial boat traffic would fail to register Observed/Expected ratios near unity and there would be a need to set lower O/E ratios as acceptable targets. The concern is that the reference dataset may be inadequate for some areas.

The alternative is a more comprehensive reference dataset, inclusive of some modestly impacted sites. If this option were to be chosen, then it would be important to be fully aware of those classification groups which represented impacted sites and the fact that predictions based on these groups would set lower targets. In the case of a canal with substantial boat traffic (and the same observed fauna as in the first example) the O/E ratio might be near unity and therefore acceptable (just as a lower O/E ratio in the first example was acceptable, given the level of boat traffic). The use of this second approach would introduce complications but canals, being man-made, have a fauna heavily influenced by man's activities, past and present, and variations to the methods used in rivers may be worth investigating. A further option would be to include the full range of sites from high to low biological quality and use both classification and ordination techniques to seek and interpret the various gradients within the dataset, as undertaken in watercourses in the Netherlands (Verdonschot 1990).

Geographical location of sites – A comprehensive system for monitoring the biological quality of canals in Great Britain (or the United Kingdom) should, if feasible, include sites on all the major types of canals in each geographical region. In view of the limited canal network in Northern Ireland, it would be simplest to include all sites (in Great Britain and Northern Ireland) within one scheme, despite the fact that separate RIVPACS modules were developed for Great Britain and Northern Ireland in RIVPACS III. We suggest that river navigations should also be included in the canal prediction system.

Number of sampling seasons – For full compatibility with RIVPACS III, samples should be taken in three seasons. This maximises the options for making predictions based on one, two or all three seasons combined. However, in view of the fact that in 1995 GQA samples were restricted to two seasons, the Environment Agency may conclude that a two-season prediction system is adequate for their purposes. This same question arises in the case of the new protocol for deep water sampling in RIVPACS.

Laboratory Protocols

Live versus dead sorting – In Williams *et al.*(1998) the invertebrate samples collected at canal sites were sorted 'live' in the laboratory. Sorting was exhaustive and typically took five to six hours per sample (range 3-16 hours). Abundant taxa were subsampled where appropriate. If the same field protocols developed by Pond Action are used at all future reference sites in each season, then a decision is required on whether the standard laboratory protocol is to be live or dead sorting. Ideally, the procedure used to sort samples during the development of a prediction system should be the same as the procedure used later when assessing the biological quality of test sites. All RIVPACS reference site data was sorted dead and most RIVPACS sampled collected by Environment Agency biologists are sorted dead after being preserved.

Level of identification – Williams *et al.*(1998) identified most groups to species, but *Pisidium* spp. (Bivalvia) were not identified and neither were Oligochaeta. The Diptera were identified to family only. Nevertheless, the specimens from all three groups were retained for identification at a later stage, if necessary. In view of the importance of Pisidia, Oligochaeta and Diptera in canals in terms of their taxonomic richness, numerical abundance, and their role in the functioning of the system, there are good arguments for further identification. This would also provide the Environment Agency with a broader basis on which to assess the conservation interest of canals. However, this task is time consuming and may not be regarded as critical for the appraisal of the biological quality of sites, given that many appraisals are based on BMWP family level assessments.

Use of abundance data – Williams *et al.* (1998) made an attempt to record the approximate abundance of each taxon in each sample, rather than restrict estimates to log category abundance at family level, as in RIVPACS. Again, the exact protocol will need to be clarified and once incorporated into a standard protocol, the same procedures will be required if abundance data are required at test sites. Incorporation of abundance data could be useful, but in view of the qualitative nature of the field sampling techniques coupled with the cost in time of accumulating the information, there may be a need to seek a simplified procedure.

Analyses

Standardisation of faunal lists – Once all identifications have been confirmed and listings of taxa for each site have been transferred to computer and validated, it is important to ensure that identifications have been taken to a standard level throughout the dataset prior to the commencement of analyses.

Procedure for marginal/benthic components of the sample – The initial classification of 30 canal sites in Williams *et al.* (1998) was based on a single listing of mainly species –level taxa derived by combining information from the marginal and benthic components of the sample from each site in a single season. The future option of undertaking separate classification exercises based on the marginal and benthic components of the sample remains, as they were sorted and identified separately. At present, is difficult to judge whether this approach would be useful. Initially, the focus should be on the acquisition of a more comprehensive reference dataset sampled in two or three seasons to ensure that reasonably comprehensive taxon lists are available for a wide range of sites prior to classification. Classification exercises undertaken on margin + benthic taxon listings, followed by margin

only and benthic only, may then help to clarify whether margin only or benthic only systems are worth considering. (Alternatively, because a margin + benthic classification should be more robust, it might still be possible to predict separate probabilities of occurrence for marginal and benthic components of a sample from a test site if required).

Analyses at species/family/species + family level – A further consideration is whether the classification should be developed using species level (presence/absence only or using abundance data), family level (presence/absence only or using abundance data), or a combination of the two (species presence/absence plus family log. categories) as used in RIVPACS III. In general, species-level (presence/absence) data was favoured for development of early versions of RIVPACS, although it was also necessary to include family log. category data in RIVPACS III to obtain an acceptable classification (Wright *et al.*1997).

Site classification – TWINSPAN (Hill 1979), the classification technique used by Williams *et al.* (1998) for development of the pilot classification for canals, has proved to be the most appropriate technique for successive versions of RIVPACS. However, a number of alternative approaches have been investigated (Wright *et al.* 1995) and some of these have been favoured by scientists working on RIVPACS-type schemes in Canada (Reynoldson *et al.*1995) and Australia (Norris 1996).

Variables for prediction – Williams *et al.* (1998) had c.150 possible environmental variables available to them for development of their prediction system, although they pointed out that a high proportion were omitted in order to optimise the prediction methodology at degraded sites. There will be a need to retain a flexible approach to the selection of variables for prediction, because the best variables for a one-season classification may differ from those required for a three or two season-based classification system. Williams *et al.* (1998) point out that two of the nine variables used for prediction (turbidity and number of submerged plant species) were not regarded as ideal predictors since both can vary significantly with anthropogenic factors such as boat usage. However, these variables were retained in the analyses because they considerably increased predictive power. These practical difficulties may be difficult to overcome, particularly if it becomes necessary for the reference database to take in some partially degraded sites in order to be comprehensive. As previously noted, it will be important to recognise any partially-degraded classification groups and their consequences for target-setting.

Prediction to group/prediction of taxa – Once a full reference dataset is in place, an acceptable classification is available and decisions have been made on the best subset of environmental variables for prediction (based on prediction to group), then it is necessary to generate computer files holding the information on the frequency of taxa in each classification group as a prelude to prediction of taxa. If the system is to offer predictions for individual seasons, paired seasons and three seasons combined, then separate files are required for each seasonal option. If predictions are required at different taxonomic levels (and also if predicted abundances are required), then further blocks of data must be available for use in the prediction system.

Variation in O/E values – Once a full prediction system is in place, with the facility to predict taxon occurrence, it is useful to calculate O/E values for BMWP score, number of taxa and ASPT for all reference sites in order to determine the distribution of O/E values around unity. In addition, a chi-square test provides more detailed information on the

goodness of fit between the number and type of taxa predicted and those observed at each reference site. For further details see Wright *et al.* (1995). Ideally, it is also helpful to have an independent dataset of high quality sites on which to test any new prediction system.

Banding of O/E ratios – This operation requires input from Environment Agency staff to ensure that it meets their requirements. The task will be complicated if a decision has been made to include some 'reference' sites that are acknowledged to be impacted to some degree.

Software development

As indicated in Williams *et al.* (1998), in order to make a biological assessment system for canals fully operational, there will be a need to develop appropriate data entry routines and specify appropriate outputs. The latter will include the facility to classify sites, predict to group, predict taxon occurrence at the level specified and generate indices from the observed and expected taxon data.

5.6.3 Conclusions

Pond Action has made a useful start in the development of a classification-prediction system for canals. It has also championed the use of multimetrics for diagnosing the causes of degradation. (Note that this topic was not within the specification of the IFE scoping study). As indicated above, there is still much work to be done before an operational methodology for assessing the biological quality of canals is in place.

However, we now understand that Phase 3 of the Pond Action project is underway and that within the specification, there is an opportunity to increase the number of reference sites from 30 to approximately 60 reference sites The field protocols adopted for the pilot sampling programme described in Williams *et al.* (1998) will also be used in the new sampling programme. (J.Biggs. pers. comm.).

In view of these developments within the Pond Action project 'Biological Techniques of Still Water Quality Assessment', and the fact that they were not anticipated within the specification of the current RIVPACS contract, discussions are needed within the Environment Agency regarding the next steps to be taken in order to develop an operational system for assessing the biological quality of canals.

It is now apparent that a fully-fledged system cannot be in place prior to the GQA Survey in 2000. However, the field protocols developed by Pond Action could be formalised and used as the basis of a sampling programme to be undertaken on canals during the GQA Survey in 2000. Such a survey would include a wide geographical range of sites encompassing both high quality and impacted sites. If there is a need to supplement the existing reference dataset in terms of additional sites or seasons, then selected samples collected during the GQA Survey could be passed on to a contractor for processing at species level. Once the full dataset was assembled, the classification and prediction exercises could commence, and on completion of an operational system, it should still be possible to make an appraisal of the full range of canal sites sampled during the GQA Survey in 2000.

6. REFERENCES

Benjamin J.(1998). *A comparative study of methods for sampling macroinvertebrates in Sussex Rifes.* Unpublished report to Environment Agency, Southern Region. 103pp.

Briggs, J. (1988). (Ed.) *Montgomery Canal Ecological Survey: Survey Report.* Report to British Waterways and the Nature Conservancy Council.

Burrow, K. (1975). *An assessment of the diversity and distribution of the invertebrate fauna of the Lancaster canal with notes on water quality.* B.Sc. Project Report, Polytechnic of Central London.

Clarke, R.T., Cox, R., Furse, M.T., Wright, J.F. and Moss, D. (1997) *RIVPACS III+ River Invertebrate Prediction and Classification System. With Error Assessments. User Manual.* Environment Agency R & D Technical Report E26.

Cooke, J. (1989). A study of Mollusca found in the Gayton Arm of the Grand Union Canal 1983/84. *Journal of the Northamptonshire Natural History Society and Field Club,* **40**, 25-34.

Cox, R., Wright, J.F., Furse, M.T. and Moss, D.(1995) *RIVPACS III (River Invertebrate Prediction and Classification System). User Manual.* NRA R & D Note 454.

Downing, J. A. and Rigler, F. H. (eds.) (1984). A manual on methods for the assessment of secondary productivity in fresh waters. IBP Handbook No. **17**. Blackwell, Oxford. 358pp.

Drake, C, M, and Elliott J M (1982). A comparative study of three air-lift samplers used for sampling benthic macro-invertebrates in rivers. *Freshwater Biology,* **12**, 511-533

Drake, C. M. and Elliott, J. M. (1983). A new quantitative air-lift sampler for collecting macroinvertebrates on stony bottoms in deep rivers. *Freshwater Biol*ogy, **13**, 545-559

Eaton, J.W., O'Hara, K, Pygott, J.R. and Staples, J.A. (1989). The effects of boat traffic on the ecology and fisheries of canal. Progress report on Research for the British Waterways Board, University of Liverpool.

Elliott, J. M. and Drake, C. M. (1981a). A comparative study of seven grabs used for sampling benthic macroinvertebrates in rivers. *Freshwater. Biol*ogy, **11**, 99-120

Elliott, J. M. and Drake, C. M. (1981b). A comparative study of four dredges used for sampling benthic macroinvertebrates in rivers. *Freshwater Biol*ogy, **11**, 245-261

Elliott, J. M., Drake, C. M. and Tullett, P. A. (1980). The choice of a suitable sampler for benthic macroinvertebrates in deep rivers. *Pollution Report, Department of the Environment, U.K.* No. **8**, 36-44.

Elliott, J. M., Tullett, P. A. and Elliott, J. A.(1993). A new bibliography of samplers for freshwater benthic invertebrates. FBA Occasional Publication 30. 92pp.

English Nature (1995). *Canal SSSIs – management and planning issues*. English Nature Freshwater Series No.2. English Nature, Peterborough.

English Nature (1997). *Wildlife and Fresh Water. An Agenda for Sustainable Management.* English Nature, Peterborough.

Flannagan, J. F. (1970). Efficiencies of various grabs and corers in sampling freshwater benthos. *Journal of the Fisheries Reearch. Board of Canada*, **27**, 1691-1700

Furse, M. T., (1978). An Ecological Survey of the Middle Reaches of the River Thames. Volume 1 –Main Report, Volume 2 – Appendices. A report by the Freshwater Biological Association to Thames Water Authority.

Furse, M.T., Clarke, R.T., Winder, J.M., Symes, K.L., Blackburn, J.H., Grieve, N.J. and Gunn, R.J.M. (1995). *Biological Assessment Methods: Controlling the quality of Biological Data. Package 1. The variability of data used for assessing the biological condition of rivers.* NRA R & D Note 412

Hill, M.O. (1979). TWINSPAN – *A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and the attributes*. Cornell Unviersity, Ithaca, NY.

HMSO (1984). *Methods of biological sampling: Sampling of benthic macroinvertebrates in deep rivers 1983.* Methods for the examination of waters and associated materials. HMSO, London. 16pp.

Humpesch, U. H. and Elliott, J. M. (eds.) (1990). Methods of biological sampling in a large, deep river – the Danube in Austria. *Wasser Abwasser (Suppl.)* **2/90**, 83pp.

Humphries, P., Growns, J. E., Serafini, L. G., Hawking, J. H., Chick, A. J. and Lake, P. S. (1998). Macroinvertebrate sampling methods for lowland Australian rivers. *Hydrobiologia* **364** (2), 209-218.

Ingle, R.W. and Clark, P.F. (1989). Turkish crayfishes thrive in a London canal. *London Naturalist*, **68**, 73-75.

Kelcey, J. G. (1979). Ecological studies in Milton Keynes No. 50 – An assessment of the proposed marina development on the Grand Union Canal. MKDC

Mackey, A. P. (1972). An air-lift sampler for sampling freshwater benthos. *Oikos*, **23**, 413-415.

Mackey, A. P., Cooling, D. A. and Berrie, A. D. (1984). An evaluation of sampling strategies for qualitative surveys of macro-invertebrates in rivers, using pond nets. *Journal of Applied Ecology*, **21**, 515-534

Morgan, J.B. (1887-91). The land and freshwater shells of Montgomeryshire, parts I-III. *Montgomeryshire Collections* XXI-XXV.

Morphy, M.J. and Clarkson, N. (1978). The gastropod fauna of the Huddersfield Broad Canal. *Naturalist*, **103**; 151-153.

Morphy, M.J.; Haigh, M., Thorburn, I. and Watkin, J.R. (1977). The gastropod fauna of the Huddersfield Narrow Canal. *Naturalist*, **102**; 137-139.

Murphy, K. J. and Eaton, J. W. (1983). Effects of pleasure boat traffic on macrophyte growth in canals. *Journal of Applied Ecol*ogy, **20**; 713-729

Murray-Bligh, J. A. D., Furse, M. T., Jones, F. H., Gunn, R. J. M., Dines, R. A. and Wright, J. F. (1997). *Procedure for collecting and analysing macroinvertebrate samples for RIVPACS.* Institute of Freshwater Ecology & Environment Agency, 155pp.

National Rivers Authority (1991). *The Quality of Rivers, Canals and Estuaries in England and Wales. Report of the 1990 survey.* National Rivers Authority, Water Quality Series No. 4.

Norris, A. (1982). Notes on Yorkshire Mollusca –5 *Ferrisia wautieri* (Mirolli) a freshwater limpet, new to Yorkshire. *Naturalist*, **107**; 59-60.

Norris, R.H. (1996). Predicting water quality using reference conditions and associated communities. *In: Study Design and data analysis in benthic macroinvertebrate assessments of freshwater ecosystems using a reference site approach* (Eds. Bailey, R.C., Norris, R.C. and Reynoldson, T.B.). Technical Information Workshop. North American Benthological Society, 44th Annual Meeting, Kalispell, Montana.

Odum, H. T. (1967). Biological circuits and the marine systems of Texas.*In: Pollution and Marine Ecology* (Eds. Olson T A & Burgess F J). 99-157. Wiley, New York

Pearson, R. G., Litterick, M. R. and Jones, N. V. (1973). An air-lift for quantitative sampling of the benthos. *Freshwater Biology*, **3**, 309-315

Pygott, J. and Douglas, S., (1989). Current distribution of *Corophium curvispinum* in Britain with notes on its ecology in the Shropshire Union Canal. *Naturalist* **114**, 15-17

Reynoldson, T.B., Bailey, R.C., Day, K.E. and Norris, R.H. (1995). Biological guidelines for freshwater sediment based on Benthic Assessment of SedimenT (the BEAST) using a multivariate approachbfor predicting biological state. *Australian Journal of Ecology*, 20, 198-219.

Sanders, H .L. (1968). Marine benthic diversity: a comparative study. *American Naturalist*, **102**, 243-282

Verdonschot, P.F.M., (1990) *Ecological Characterization of surface waters in the Province of Overijssel (The Netherlands).* Research Institute for Nature Management.

Watkin, J.R. and Morphy, M.J. (1976). The Sphaeriidae fauna of the Huddersfield Narrow Canal. *Naturalist*, No.936, 19-25.

Williams, P., Biggs, J., Dodds, L., Whitfield, M., Corfield, A. and Fox, G.(1996). *Biological techniques of still water quality assessment. Phase 1 Scoping Study.* Environment Agency, R & D Technical Report E7. Environment Agency, Bristol.

Williams, P., Biggs, J., Whitfield, M., Corfield, A., Fox, G. and Adare, K. (1998). *Biological techniques of still water quality assessment. 2. Method development.* Environment Agency, R & D Technical Report E56.

Wright, J.F.(1987). Colonisation of rivers and canals in Great Britaiin by *Dugesia tigrina* (Girard) (Platyhelminthes: Tricladida). *Freshwater Biology*, **17**, 69-78.

Wright, J.F., (1995). Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology*, **20**, 181- 197.

Wright, J.F., Furse, M.T., Clarke, R.T., Moss, D., Gunn, R.J.M, Blackburn, J.H., Symes, K.L., Winder, J.M., Grieve, N.J. and Bass, J. A.B. (1995). Testing and further development of RIVPACS. NRA R&D Note 453

Wright, J.F., Moss, D., Clarke, R.T., and Furse, M.T., (1997). Biological assessment of river quality using the new version of RIVPACS (RIVPACS III). In Boon, P.J. and Howell, D.L. (Eds). *Freshwater Quality: defining the Indefinable*?, HMSO, Edinburgh, 102-108.

Wright, J.F.,Winder, J.M., Gunn, R.J.M., Blackburn, J.H., Symes, K.L. & Clarke, R.T. (submitted). The macroinvertebrate fauna of the R.Thames in the vicinity of Didcot Power Station. *Regulated Rivers.*

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Appendix 2. RIVPACS International Workshop Programme

Jesus College, Oxford, 16-18 September 1997

Tuesday 16 September

Session 1	**Chairman: Peter Davies**	
1030-1040	Chairman's introductory remarks	Peter Davies
1040-1100	Introduction to the workshop	Roger Sweeting
1100-1130	An Introduction to RIVPACS	John Wright
1130-1200	Evolution of Methods	Dorian Moss
1200-1230	Variability, errors and biases	Ralph Clarke
1245-1400	**LUNCH**	
Session 2	**Chairman: Trefor Reynoldson**	
1400-14230	Classification of the biological quality of rivers in England and Wales	Brian Hemsley-Flint
1430-1500	Quality Assurance	Bob Dines & John Murray-Bligh
1500-1530	Practical applications of RIVPACS	Mike Furse
1530-1600	The potential of RIVPACS for predicting the effects of environmental change	Patrick Armitage
1600-1630	**TEA**	
Session 3	**Chairman: Alasdair Berrie**	
1630-1700	Stream monitoring in Sweden	Richard Johnson
1700-1735	Running water biomonitoring in Spain- Opportunities for a predictive approach	Javier Alba-Tercedor and Ana Pujante
1735-1800	Discussion 2	
1830-19-30	**BUFFET SUPPER**	

Posters and software demonstrations

1930-1940	Introduction; Nick Schofield
1940-2100	Demonstrations

Authors of posters and demonstrators of software will be available for discussion during the evening.

Wednesday 17 September 1997

Session 4	**Chairman: Vince Resh**	
0900-0930	Australia's National River Health Programme	Peter Davies
0930-1000	AusRivAs –development of models and outputs	Richard Norris
1000-1030	AusRivAs – operator sample processing errors And temporal variability: implications for model Sensitivity	Chris Humphrey, Andrew Storey, Lisa Thurtell
1030—1100	**COFFEE**	
Session 5	**Chairman: Peter Hale**	
1100-1130	Great Lakes, the development of the BEAST,a Predictive approach to assessing sediment quality	Trefor Reynoldson
1130-1200	Establishing reference conditions in the Fraser River catchment basin, British Columbia, Canada Using the BEAST	David Rosenberg T.B.Reynoldson V.H.Resh
1200-1230	A multimetric approach to water quality assessment of the Fraser River, British Columbia	Vincent Resh, David Rosenberg Trefor Reynoldson
1230-1245	Discussion 3	
1245-1400	**LUNCH**	
Session 6	**Chairman: Niels de Pauw**	
1400-1430	Alternative approaches to RIVPACS based on artificial intelligence	Bill Walley V.N.Fontana
1430-1500	Water management tools – developments in the Netherlands	Piet Verdonschot
1500-1530	Application of the RIVPACS approach in assessing the biological condition of miontane streams in California: a comparison with Australian models	Chuck Hawkins Richard Norris
1530-1545	Discussion 4	
1545-1600	Workshop Introductions – John Hilton	
1600-1615	**TEA**	

Session 7 (1615-1830)	**Workshops**
Workshop 1	The reference condition – problems and solutions
	Chairman: Trefor Reynolson
Workshop 2	Summarising, presenting and interpreting RIVPACS outputs
	Chairman: Richard Norris
Workshop 3	using RIVPACS as a modelling tool to predict the impact of Environmental changes
	Chairman: Niels De Pauw
Workshop 4	Use of RIVPACS for conservation and biodiversity studies and application Of the approach to other systems and biota
	Chairman: Phil Boon
Workshop 5	RIVPACS and alternative statistical modelling techniques – accuracy and soundness of principles
	Chairman: Richard Johnson
1930	**RECEPTION**
2000	**BANQUET**

Thursday 18 September 1997

Session 7 continued

900-1045	Workshops continued
1045-1100	**COFFEE**
Session 8	
1100-1200	Presentation and discussion of Workshops 1 and 2 Chairman: Roger Sweeting
1200-1300	**LUNCH**
Session 9	
1300-1430	Presentation and discussion of Workshops 4-6 Chairman: John Hiilton
1430-1500	Concluding remarks; Roger Sweeting
1500-1515	**TEA**
1600-2000	Boat trip on the River Thames to see the sites around Oxford.

Appendix 3 ASCII Text documentation file explaining how to use program EXCLRIVP

Program EXCLRIVP : written by Ralph Clarke (IFE) : Last Updated 15/10/98

This program reads either RIVPACS Biological or Environmental data
saved in a comma-separated format (CSV format) file
and makes an output file in either :
(i) RIVPACS Biological data file format
or (ii) RIVPACS Environmental data file format;
ready for use in RIVPACS III, RIVPACS III+ or RIVPACS III++

Microsoft EXCEL, LOTUS 123, Microsoft ACCESS and many other packages
can save their spreadsheets or tables in CSV format.

CSV format files are ASCII files which can viewed by any ASCII text file editor
See documentation/help for each package for how to save data in CSV format.

This program was compiled using 32-bit DIGITAL Visual Fortran
using the command: DF EXCLRIVP.FOR

Thus this program will only run on Windows 95.

Program EXCLRIVP can be started by either of the following two methods

(1) To run the program EXCLRIVP from MS-Windows, just double-click on
the file EXCLRIVP.EXE in Windows Explorer.
This opens an MS-DOS window, which you can maximise in the usual
Windows way. The directory holding EXCLRIVP.EXE is your initial current
directory when the program is running.

(2) To run the program EXCLRIVP from an MSDOS Window from within MS-Windows,
- select MSDOS from within Windows (as an icon or off the program list)
- Type CD C:\RIVPAC3Q (or wherever EXCLRIVP IS stored)
- Type EXCLRIVP

The layout of the BIOLOGICAL data is assumed to be one of the following three formats :

All three layouts are easily available for EXCEL or LOTUS spreadsheets.
Layout type 3 (list form) is perhaps most useful for biological data extracted from databases using Microsoft ACCESS (e.g. IFE's National Invertebrate database system)

LAYOUT TYPE 1 (Spreadsheet matrix with rows = Taxa , columns = Samples) :

	A	B	C	D	...
1	TITLE				
2		SAMPLE1	SAMPLE2	SAMPLE3	...
3	TAXON1	N11	N12	N13	...
4	TAXON2	N21	N22	N23	...
5	TAXON3	N31	N32	N33	...
6	....	...	...	...	...

LAYOUT TYPE 2 (rows = Samples , columns = Taxa:

	A	B	C	D	...
1	TITLE				
2		TAXON1	TAXON2	TAXON3	...
3	SAMPLE1	N11	N21	N31	...
4	SAMPLE2	N12	N22	N32	...
5	SAMPLE3	N13	N32	N33	...
6	....	...	...	...	...

LAYOUT TYPE 3 ('list format' option for biological data only) :

	A	B	C
1	SAMPLE1	TAXON i	Ni1
2	SAMPLE1	TAXON j	Nj1
3	SAMPLE1	TAXON k	Nk1
4	....	...	...
	SAMPLE2	TAXON i	Ni2
	SAMPLE2	TAXON j	Nj2

where TITLE = compulsory non-blank title or spreadsheet description
SAMPLE1 = Name for Sample 1 , etc. (commas not allowed)
TAXON1 = Name for Taxon 1 , etc. (commas not allowed)
(Taxa could be species, families or BMWP families)

and for example

N23 = Integer representing either Presence/Absence (1/0), the abundance, or the RIVPACS Log abundance category [0,1=1-9, 2=10-99, etc] for taxon 2 in sample 3 , etc.

NOTE:

1. You must provide a non-blank name for each Site/Sample and Taxa.
2. RIVPACS will use only the first 20 characters of the SITE or SAMPLE name, so the first 20 characters should be unique within the dataset. As usual in RIVPACS, the name for each site/sample must be exactly the same in the biological and environmental data files.
3. RIVPACS will use only the first 8 characters of the taxa name and these should be RIVPACS taxonomic codes.
4. This program will truncate names which are longer than required.
5. Commas are not allowed within site or taxa names.
6. The spreadsheet must only contain the cells as defined above for EXCLRIVP. If you have other used cells, they must be deleted before you save in CSV format.
7. You can either fill up the spreadsheet area for the actual data with zeroes before you start and then overwrite the non-zero values, or the program should cope with you just leaving the cells with zero values blank.

The layout of the EXCEL spreadsheet for ENVIRONMENTAL data is assumed to be in the following format :

	A	B	C	D	...
1	TITLE				
2		VAR1	VAR2	VAR3	...
3	SAMPLE1	X11	X21	X31	...
4	SAMPLE2	X12	X22	X32	...
5	SAMPLE3	X13	X32	X33	...
6	....	...	...	...	...

where TITLE = compulsory non-blank title or spreadsheet description

VAR1, VAR2, etc are optional environmental variable names

and X23 = value of variable 2 in sample 3, etc

NOTE

1. The environmental variables MUST be in the correct standard RIVPACS order for environmental variables, as given in Section 5.4.1 of the RIVPACS III User Manual or in Section 6.4.1 of the RIVPACS III+ User Manual. The order is:

   National Grid Reference letters, NGR easting, NGR northing,
   Altitude, Slope, Discharge category, Velocity category,
   Distance from source, Mean width, Mean depth, Alkalinity,
   Total hardness, Calcium, Conductivity, %cover of boulders & cobbles.

%cover of pebbles and gravel, %cover of sand, %cover of silt & clay

2. All columns must be present, but cells in the spreadsheet with missing values can be left blank.
3. You must provide a non-blank name for each Site/Sample.
4. RIVPACS will use only the first 20 characters of the SITE or SAMPLE name, so the first 20 characters should be unique within the dataset. This program will truncate names which are longer than required.
5. Remember : commas are not allowed within site or variable names.
6. The spreadsheet must only contain cells as defined above for EXCLRIVP If you have other used cells, they must be temporarily deleted before you save in CSV format.
7. RIVPACS does not use either the TITLE or optional variable names, but these are included in the standard format to aid clarity.

Current input Dataset Limits :

The limits are set by the maximum number of data rows and columns you can have in a spreadsheet.

The maximum number of columns allowed in any single EXCEL spreadsheet is 256, so the maximum number of data COLUMNS is 255

for LAYOUT 1, maximum no. of SAMPLES = 255
maximum no. of TAXA = 1000

for LAYOUT 2, maximum no. of SAMPLES = unlimited
maximum no. of TAXA = 255

for LAYOUT 3, maximum no. of SAMPLES = unlimited
maximum no. of TAXA = unlimited

EXCLRIVP : seeing the current cell's sample and taxa names in EXCEL

When inputting your data into EXCEL in the format required by program EXCLRIVP, you can easily tell which sample and taxon cell you are pointing at by using the EXCEL facility to scroll underneath a fixed set of rows and columns.

This can be set up so that when you scroll down, the rows pass up and underneath a fixed copy of the first 2 rows (row 2 would hold the sample names (layout type 1) or taxa names (layout type 2).

Similar, when you scroll right, the columns pass underneath the first column which holds the taxa names (layout type 1) or sample names (layout type 2). Thus you can always see the name of the sample and taxon whose value you are about to enter/edit.

This is done by clicking on the little black rectangle at the right hand end

of <-- --> horizontal slide for the spreadsheet and then dragging it to the left so it lies between the first and second columns. Then click on the little black rectangle and top end of <-- --> vertical slide for the spreadsheet and then dragging it down so it lies between the third and fourth rows.

If this is unclear, then ask someone who is familiar with EXCEL.

Appendix 4. Questionnaire on Sampling for macroinvertebrates in deep rivers and canals (Plus accompanying explanatory letter)

SAMPLING FOR MACROINVERTEBRATES IN DEEP RIVERS AND CANALS

E.A.Region:..... Area:.....

Questionaire answered by:..... Phone No: .....

Address:.....
.....
.....

A). DEEP RIVER SITES

Question 1 – Definition.

How would you define the term 'deep water site' as applied to rivers?

Site too deep to take a reliable kick/sweep sample? Yes / No
Site too deep to sample full width with a pond-net? Yes / No
Site with main channel deeper than .....cm
Site with entire width deeper than .....cm
Other definition – as specified below
.....
.....

Question 2 – Sampling method

Do you use kick sampling with a pond-net at all your sampling sites? Yes / No

If no, please tick methods used for deep water sampling. Also indicate if these involve the use of a boat or bridge and the total number of personnel involved in field sampling.

	Yes?	Boat	Bridge	No.People
Marginal sweep with pond-net	.....	.....	.....	.....
Active disturbance of substratum with a long-handled pond-net	.....	.....	.....	.....
Use of a Dredge	.....	.....	.....	.....
Use of an Airlift	.....	.....	.....	.....
Use of a Grab	.....	.....	.....	.....
Other (please specify)	.....	.....	.....	.....

Question 3 – Field Protocol

For each deep water sampling method identified in question 2, please provide details of the field sampling protocol. It would also be helpful if you can specify the particular model/make of dredge/ airlift/grab etc used for deep water sampling.

(For example: Light-weight version of Medium Naturalist's Dredge used. Total weight 5kg with a 46 x 20 cm aperture and fitted with a 1mm mesh collecting net. Dredge towed for 5m along substratum before being lifted. Five dredge samples per site.)

Sampling Method	**Field Protocol**

Question 4 – Criteria used for selection of sampling method

Can you define the conditions under which you select a given procedure for sampling in deep water?

(Example: Dredge employed in rivers where width exceeds 10m, depth exceeds 1m and substratum ranges from soft sediments to coarse gravel (but not large stones).

Sampling Method	**Width**	**Depth**	**Substratum**
Marginal sweep with pond-net	.....	.....	.....
Active disturbance of substratum with a long-handled pond-net	.....	.....	.....
Use of a dredge	.....	.....	.....
Use of an Airlift	.....	.....	.....
Use of a Grab	.....	.....	.....
Other	.....	.....	.....

Question 5 – Practical experience of sampling in deep water

Please comment on the advantages and disadvantages of the methods used for deep water sampling in your area. We would be particularly interested in your views on:

Ease of use of equipment in the field	(simple/moderate/complex)
Your views on the efficiency of the sampling device	(poor/moderate/good)
Time required for field operation	(short/moderate/long)
Time required for subsequent laboratory processing	(short/moderate/long)

Sampling Method	Ease of Use	Efficiency	Time in field/lab

We would welcome more detailed comments on a separate sheet if the broad categories offered above on ease of use, efficiency and time in field/lab are too restrictive.

Question 6 – Availability of data from a replicated sampling programme

Do you have *replicate sampling units* from a site (or sites) taken with one or more deep water sampling devices which offer insights into the reliability of a sampling procedure?

YES /NO

If so, we would be interested to have access to the data/reports/scientific papers.

With this questionaire you will find a listing of ***potential*** deep water sites for your Region, taken from the 1995 GQA database. Please tick those within your Area, and provide the data requested for those sites sampled ***by deep water sampling procedures – i.e. methods other than kick/sweep with a pond net.*** Please add any other sites in your area that you also sample with deep water sampling procedures.

B). CANAL SITES

Question 7 - Occurrence and type of canals

Are there any canals in your area? YES / NO

If YES, please categorise them (tick as many as appropriate).

Navigable - mainly commercial traffic .....

- mainly leisure traffic .....

- disused .....

Unnavigable .....

With SSSI status .....

Other (please specify) .....

Question 8 – Current sampling programme for canals

Do you sample for macroinvertebrates in the canals in you area? YES / NO

Note: The IFE contract with the Environment Agency requires us to obtain a list of National and Regional GQA Monitoring sites on canals.

Please indicate whether:

a). You are requesting the Regional Biologist to supply this listing for the entire Region
(Name of Regional Biologist contacted .....)

or

b). You are supplying the list of National and regional GQA sites for your Area.

Question 9 – Sampling Methods

Which methods do you use for sampling macroinvertebrates in canals?

Do you sample the margins? YES / NO

Do you sample 'hard' margins? (ie concrete and/or steel piling) YES / NO

Do you sample 'soft' margins? (ie marginal vegetation) YES / NO

Do you sample 'backwaters' or other areas not in main channel YES / NO

Please tick the deep water methods used to sample the substratum and indicate whether these involve the use of a boat or bridge and the total number of personnel involved in field sampling.

	Yes?	Boat	Bridge	No.People
Active disturbance of substratum with a long-handled pond-net	.....	.....	.....	.....
Use of a Dredge	.....	.....	.....	.....
Use of an Airlift	.....	.....	.....	.....
Use of a Grab	.....	.....	.....	.....
Other (please specify)	.....	.....	.....	.....

Question 10 – Field protocol

For each sampling method listed in question 9, please provide details of the field sampling protocol.

Marginal samples

Please describe your sampling procedure (e.g. long-handled pond- net, 3 mins):

Hard Margins -

Soft Margins -

Are marginal samples examined separately YES / NO

Combined with substratum samples YES / NO

Substratum samples

Please specify the particular model/make of dredge/ airlift/grab etc used for deep water sampling unless the field protocol is as used for deep water sites. In this case simply indicate ' as in Q.3' against the field protocol.

Sampling Method	**Field Protocol**

Question 11 – Environmental factors which may be important predictors of the invertebrate fauna in a canal

Based on your local experience, please indicate the range of factors which you regard as potential predictors of the macroinvertebrate fauna (independent of water quality). Score the factors below as Very (V), Fairly (F) or Not (N) Important.

..... Alkalinity
..... Geographical location
..... Substratum type
..... Water width
..... Water depth

..... Proximity of /connection to a free-flowing river (if present)
..... Character of marginal areas (hard vs soft margins)
..... Development of submerged macrophytes
..... Density of boat traffic
..... Turbidity of the water
..... Proximity of locks

....
....
....

Question 12 – Additional Points

The topics considered under questions 4-6 in the Deep Rivers section of this questionaire are also relevant to canals. They include criteria for selection of sampling method (4), practical experience of sampling in deep water (5), and data from replicated sampling programmes (6).

Please refer back to these questions for further details and if you have additional information on canals which is relevant to these topics, then we would be pleased to receive it.

Letter to accompany the Questionnaire.

Dear xxxxxxxxxxxx

SAMPLING FOR MACROINVERTEBRATES IN DEEP RIVERS AND CANALS

The Environment Agency has placed a new contract with the Institute of Freshwater Ecology for the further development of RIVPACS (Phase 3. Development of new RIVPACS methodologies). The new contract is for a period of three years and includes ten separate elements, all geared to enhance the use of biological data within the Environment Agency. Two elements in the study are concerned with deep rivers and canals. They are:

1). the production of a scoping report on the standardisation of sampling methods for deep rivers so that the cost of further work can be estimated and a separate project can be specified and

2). the production of a scoping study on the work needed to incorporate canals into RIVPACS so that the cost can be estimated and a separate project can be specified.

You will be aware that it has been possible to standardise the protocol for RIVPACS sampling with a pond-net in shallow streams and rivers. This is essential for the effective comparison of the observed and expected fauna using RIVPACS. However, the standardisation of sampling in deep rivers is a more formidable problem which requires further consideration. In addition, the current version of RIVPACS is inappropriate for use in canals and hence it was not possible to include a RIVPACS-type assessment for canals in the 1995 GQA survey.

Each of these scoping studies is to be completed within the first year of the contract. If the conclusion from one or more of these scoping studies is that further field testing of sampling methods is required, then this can be undertaken in 1999. In this way standard protocols will be in place for the GQA survey in 2000.

One of our first tasks is to draw on your own experience of sampling in deep rivers and canals and to be aware of the pitfalls and problems that you have encountered. To this end we have developed a questionnaire which incorporates questions on both deep rivers and canals. We do realise that questionnaires rarely engender enthusiasm from the recipient, but would urge you to devote a small amount of your valuable time to this one, to ensure that your voice is heard and your views and experiences are brought to our attention.

We are also very aware that there are no easy solutions to sampling these difficult systems and that scientific, practical and time considerations all have to be taken into account if acceptable protocols are to be devised for use within the Environment Agency.

Please note that Rick Gunn will be taking the lead role in the production of the scoping report on deep river sampling and John Blackburn will be taking on similar responsibilities in relation to the scoping report on canals.

Finally, we would be most grateful if you would return the completed questionnaire to us as soon as possible and no later than 30 June. Thankyou.

Appendix 5 Publications and reports on sampling for macroinvertebrates in deep rivers (1993-1998)

Benjamin, J. (1998). *A comparative study of methods for sampling macroinvertebrates in Sussex Rifes.* Unpublished report to Environment Agency, Southern Region.

De Pauw, N, Lambert. V, Van Kenhove, A. & Bij de Vaate, A. (1994). Performance of two artificial substrate samplers for macroinvertebrates in biological monitoring of large and deep rivers and canals in Belgium and the Netherlands. Environmental Monitoring and Assessment, **30**, 25-47.

Evrard, M. (1996). The use of pupal exuviae of Chironomidae (Diptera) as biological indicators of the water quality of walloon rivers. Namur Belgium Facultes Uniuversitaires Notre Dame de la Paix, 260pp.

Fesl, C. and Weilguni, H. (1996). Vertical distribution of the macrozoobenthos and sediment structure in the main channel of a large deep river, the Danube at river-kilometre 1889.9. *Archiv. fur Hydrobiologie Suppl.* **113**, 411-416.

Humpesch, U. H. and Niederreiter, R. (1993). Freeze-core method for sampling the vertical distribution of the macrozoobenthos in the main channel of a large deep river the River Danube at kilometre 1889. *Archiv fur Hydrobiologie Suppl* ,**101**,87-90.

Humphries, P., Growns, J. E., Serafini, L. G., Hawking, J. H., Chick, A. J. and Lake, P. S. (1998). Macroinvertebrate sampling methods for lowland Australian rivers. *Hydrobiologia* **364**, 209-218.

Kirk, E. J. and Perry, S. A. (1994). A comparison of three artificial substrate samplers: Macroinvertebrate densities, taxa richness and ease of use. *Water Environment Research*, **66**, 193-198.

Major, W., Grassley, J., Grue, C. and Gardner, S. (1998). A vacuum pump/filtration sampler for the collection of aquatic invertebrates. *Journal of Freshwater Ecology*, **13**, 361-363.

Miller, A. C. and Payne, B. S. (1993). Qualitative versus quantitative sampling to evaluate population and community characteristics at a large-river mussel bed. *American Midland Naturalist*, **130**, 133-145.

Murray-Bligh, J. A. D., Furse, M. T., Jones, F. H., Gunn, R. J. M., Dines, R. A. and Wright, J.F. (1997). *Procedure for collecting and analysing macroinvertebrate samples for RIVPACS.* Institute of Freshwater Ecology & Environment Agency, 155pp.

Pinel-Alloul, B., Methot, G., Lapierre, L. and Willsie, A. (1996). Macroinvertebrate community as a biological indicator of ecological and toxicological factors in Lake Saint-Francois (Quebec). *Environmental Pollution*, **91** (1), 65-87.

Resh, V. H., Norris, R. H. and Barbour, M. T. (1995). Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates. *Australian Journal of Ecology*, **20**, 108-121.

Turner, A. M. and Trexler, J. C (1997). Sampling aquatic invertebrates from marshes: evaluating the options. *Journal of the North American Benthological Societ,y* **16**, 694-709.

Williams, P., Biggs, J., Whitfield, M., Corfield, A., Fox, G. and Adare, K. (1998*). Biological techniques of still water quality assessment. 2. Method development.* Report to the Environment Agency, R & D Technical Report E56.

Wright, J.F.,Winder, J.M., Gunn, R.J.M., Blackburn, J.H., Symes, K.L. & Clarke, R.T. (submitted). The macroinvertebrate fauna of the R.Thames in the vicinity of Didcot Power Station. *Regulated Rivers*.

Appendix 6. Listing of 24 sites in RIVPACS III at which dredge or airlift samples were taken. RIVPACS groups, sampling methods and selected environmental characteristics are also given. Values are means of three samples in one year (* indicates a method only used in one season only).

River	Site	RIVPACS group	Sampling method	Mean width	Mean Depth	Boulders & Cobbles	Pebbles & Gravel	Sand	Silt & Clay
Bure	Corpusty	GB08	KS/Dredge*	5.67	58.2	0.0	15.0	26.7	58.3
Urr Water	Haugh of Urr	GB16	KS/Airlift*	15.33	24.7	67.5	29.7	3.0	0.0
Teith	Blackdub	GB20	Dredge	30.00	100	26.7	31.7	8.3	33.3
Derwent	Norton	GB26	Airlift	20.00	172.2	0.0	6.7	53.3	40.0
Derwent	Stamford Bridge	GB26	Airlift	21.67	150	0.0	60.0	3.3	36.7
Derwent	Thorganby	GB26	Airlift	21.67	183.2	0.0	13.3	10.0	76.7
Wye	Redbrook	GB26	Dredge	50.00	129.1	68.3	24.0	4.3	3.3
Exe	Flowerpot	GB27	Dredge	66.67	143.9	33.3	53.3	6.0	7.3
Derwent	Yedingham	GB30	Airlift	5.00	82.8	0.7	2.7	48.3	48.3
Bure	Buxton Mill	GB33	Dredge	17.33	133.4	0.3	2.0	2.3	95.3
Hull/West Beck	Corpslanding	GB33	Dredge	11.33	122.2	0.0	0.0	0.0	100.0
Stour	Longham	GB33	Dredge	26.67	139	7.3	36.7	11.7	44.3
Great Ouse	Sharnbrook	GB34	Dredge	28.67	100	0.0	3.0	2.0	95.0
Great Ouse	Roxton Lock	GB35	Dredge	35.00	100	2.0	79.7	18.0	0.3
Ouse/Ure	Aldwark Toll Bridge	GB35	Airlift	50.00	177.8	0.0	60.0	3.3	36.7
Ouse/Ure	Nether Poppleton	GB35	Airlift	50.00	161.1	0.0	0.0	33.3	66.7
Ouse/Ure	Acaster Malbis	GB35	Airlift	80.00	200	0.0	16.7	41.7	41.7
Severn	Stourport	GB35	Dredge	63.33	177.8	21.3	19.3	1.0	58.3
Thames/Isis	Malthouse	GB35	Dredge	26.67	161.1	20.0	51.7	11.7	16.7
Thames/Isis	Bablock Hythe	GB35	Dredge	33.33	183.2	2.3	58.3	6.7	32.7
Thames/Isis	Shillingford	GB35	Dredge	50.00	183.2	0.0	1.7	35.0	63.3
Thames/Isis	Reading	GB35	Dredge	51.67	205.6	9.7	73.3	10.0	7.0
Thames/Isis	Spade Oak	GB35	Dredge	70.00	155.6	2.0	88.7	6.3	3.0
Thames/Isis	Runnymede	GB35	Dredge	56.67	238.8	10.0	25.0	2.3	62.7

Appendix 7. List of 174 canal sites sampled in the 1990 River Quality Survey together with the BMWP score, No.of Taxa and ASPT in each season.

Region	Canal Name	Site Name	NGR	Sample ID	Season	BMWP	# Taxa	ASPT
Ang	ALDRETH CANAL	U/S CONFLUENCE OLD WEST RIVER	TL439932	019000619	1	34	10	3.40
Ang	ALDRETH CANAL	U/S CONFLUENCE OLD WEST RIVER	TL439932	019000618	2	39	11	3.55
Ang	ALDRETH CANAL	U/S CONFLUENCE OLD WEST RIVER	TL439932	019003067	3	51	14	3.64
Ang	FOSSDYKE CANAL	DRINSEY NOOK	SK872743	019001243	1	43	10	4.30
Ang	FOSSDYKE CANAL	DRINSEY NOOK	SK872743	019001244	2	40	10	4.00
Ang	FOSSDYKE CANAL	DRINSEY NOOK	SK872743	019001245	3	51	11	4.64
Ang	FOSSDYKE CANAL	PYEWIPE	SK949723	019001259	1	50	10	5.00
Ang	FOSSDYKE CANAL	PYEWIPE	SK949723	019001260	2	53	13	4.08
Ang	FOSSDYKE CANAL	PYEWIPE	SK949723	019001261	3	67	15	4.47
Ang	FOSSDYKE CANAL	SAXILBY	SK900751	019001249	1	39	10	3.90
Ang	FOSSDYKE CANAL	SAXILBY	SK900751	019001250	2	62	15	4.13
Ang	FOSSDYKE CANAL	SAXILBY	SK900751	019001251	3	45	11	4.09
Ang	GRAND UNION CANAL (01)	A43 BRIDGE BLISWORTH	SP724534	019001897	1	35	9	3.89
Ang	GRAND UNION CANAL (01)	A43 BRIDGE BLISWORTH	SP724534	019001898	2	60	15	4.00
Ang	GRAND UNION CANAL (01)	A43 BRIDGE BLISWORTH	SP724534	019000633	3	86	20	4.30
Ang	GRAND UNION CANAL (01)	B4036 RD BRIDGE WELTON	SP579651	019000904	1	34	9	3.78
Ang	GRAND UNION CANAL (01)	B4036 RD BRIDGE WELTON	SP579651	019001903	2	57	14	4.07
Ang	GRAND UNION CANAL (01)	B4036 RD BRIDGE WELTON	SP579651	019001904	3	49	13	3.77
Ang	GRAND UNION CANAL (01)	BR DEBDALE WHARF	SP695916	019000906	1	30	8	3.75
Ang	GRAND UNION CANAL (01)	BR DEBDALE WHARF	SP695916	019001909	2	83	19	4.37
Ang	GRAND UNION CANAL (01)	BR DEBDALE WHARF	SP695916	019001910	3	125	26	4.81
Ang	GRAND UNION CANAL (01)	GRAFTON RD BROOK ASHTON	SP763480	019000261	1	101	22	4.59
Ang	GRAND UNION CANAL (01)	GRAFTON RD BROOK ASHTON	SP763480	019000400	2	46	12	3.83
Ang	GRAND UNION CANAL (01)	GRAFTON RD BROOK ASHTON	SP763480	019002634	3	56	13	4.31
Ang	GRAND UNION CANAL (01)	GREAT BOWDEN ROAD BR	SP732892	019000916	1	109	23	4.74
Ang	GRAND UNION CANAL (01)	GREAT BOWDEN ROAD BR	SP732892	019001907	2	85	20	4.25
Ang	GRAND UNION CANAL (01)	GREAT BOWDEN ROAD BR	SP732892	019001908	3	81	18	4.50
Ang	GRAND UNION CANAL (01)	HUNSBURY HILL	SP725581	019000903	1	113	25	4.52
Ang	GRAND UNION CANAL (01)	HUNSBURY HILL	SP725581	019001899	2	96	23	4.17
Ang	GRAND UNION CANAL (01)	HUNSBURY HILL	SP725581	019001900	3	109	23	4.74
Ang	GRAND UNION CANAL (01)	NETHER HEYFORD	SP651590	019001901	2	25	7	3.57
Ang	GRAND UNION CANAL (01)	NETHER HEYFORD	SP651590	019001902	3	45	12	3.75
Ang	GRAND UNION CANAL (01)	ROAD BR LAUGHTON HILLS	SP663876	019003075	2	72	18	4.00
Ang	GRAND UNION CANAL (01)	WEST OF A5	SP597694	019001905	1	56	13	4.31

Region	Canal Name	Site Name	NGR	Sample ID	Seas.	BMWP	# Taxa	ASPT
Ang	GRAND UNION CANAL (01)	WEST OF A5	SP597694	019001906	2	79	18	4.39
Ang	GRAND UNION CANAL (01)	WEST OF A5	SP597694	019000632	3	66	15	4.40
Ang	HORNCASTLE CANAL	DALDERBY	TF247660	019000547	1	70	17	4.12
Ang	HORNCASTLE CANAL	DALDERBY	TF247660	019001492	2	142	30	4.73
Ang	HORNCASTLE CANAL	DALDERBY	TF247660	019001493	3	99	22	4.50
Ang	HORNCASTLE CANAL	WHARF LANE	TF228587	019000881	1	105	23	4.57
Ang	HORNCASTLE CANAL	WHARF LANE	TF228587	019001494	2	71	19	3.74
Ang	HORNCASTLE CANAL	WHARF LANE	TF228587	019001495	3	82	20	4.10
Ang	LOUTH CANAL	ALVINGHAM	TF365908	019001108	1	43	13	3.31
Ang	LOUTH CANAL	ALVINGHAM	TF365908	019001109	2	59	17	3.47
Ang	LOUTH CANAL	ALVINGHAM	TF365908	019001110	3	42	13	3.23
Ang	LOUTH CANAL	AUSTEN FEN	TF368946	019001113	1	68	17	4.00
Ang	LOUTH CANAL	AUSTEN FEN	TF368946	019001114	2	71	19	3.74
Ang	LOUTH CANAL	AUSTEN FEN	TF368946	019001115	3	51	13	3.92
Ang	LOUTH CANAL	FIREBEACON	TF353970	019001116	1	64	17	3.76
Ang	LOUTH CANAL	FIREBEACON	TF353970	019001117	2	73	19	3.84
Ang	LOUTH CANAL	FIREBEACON	TF353970	019001118	3	78	20	3.90
Ang	LOUTH CANAL	HIGH BRIDGE HOUSE	TF375922	019001111	1	75	18	4.17
Ang	LOUTH CANAL	HIGH BRIDGE HOUSE	TF375922	019001289	2	81	21	3.86
Ang	LOUTH CANAL	HIGH BRIDGE HOUSE	TF375922	019001112	3	49	15	3.27
Ang	LOUTH CANAL	TETNEY LOCK	TA342021	019001125	1	83	19	4.37
Ang	LOUTH CANAL	TETNEY LOCK	TA342021	019001290	2	88	22	4.00
Ang	LOUTH CANAL	TETNEY LOCK	TA342021	019001126	3	107	25	4.28
Ang	LOUTH CANAL	THORESBY BRIDGE	TF336997	019001122	1	87	21	4.14
Ang	LOUTH CANAL	THORESBY BRIDGE	TF336997	019001123	2	110	26	4.23
Ang	LOUTH CANAL	THORESBY BRIDGE	TF336997	019001124	3	91	22	4.14
Ang	LOUTH CANAL	TICKLEPENNY LOCK	TF350889	019001105	1	65	16	4.06
Ang	LOUTH CANAL	TICKLEPENNY LOCK	TF350889	019001106	2	98	24	4.08
Ang	LOUTH CANAL	TICKLEPENNY LOCK	TF350889	019001107	3	49	13	3.77
Ang	LOUTH CANAL	U/S TETNEY HAVEN LOCK	TA347028	019001127	1	45	11	4.09
Ang	LOUTH CANAL	U/S TETNEY HAVEN LOCK	TA347028	019001128	2	27	7	3.86
Ang	LOUTH CANAL	U/S TETNEY HAVEN LOCK	TA347028	019001129	3	23	6	3.83
Ang	LUD / LOUTH CANAL	RIVERHEAD (ENGINE GATE WALK)	TF340882	019001102	1	71	15	4.73
Ang	LUD / LOUTH CANAL	RIVERHEAD (ENGINE GATE WALK)	TF340882	019001103	2	102	19	5.37
Ang	LUD / LOUTH CANAL	RIVERHEAD (ENGINE GATE WALK)	TF340882	019001104	3	44	11	4.00
Ang	NETTLETON BK/CAISTOR CANAL	NORTH END	TF043989	019001039	1	20	7	2.86
Ang	NETTLETON BK/CAISTOR CANAL	NORTH END	TF043989	019001040	2	66	17	3.88

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Ang	NETTLETON BK/CAISTOR CANAL	NORTH END	TF043989	019001041	3	75	18	4.17
Mid	ASHBY CANAL	BURTON HASTINGS	SP402892	049002389	3	66	15	4.40
Mid	ASHBY CANAL	MARKET BOSWORTH	SK392032	049002292	3	58	14	4.14
Mid	B'HAM AND FAZELEY CANAL	FAZELEY	SK203019	049002390	1	14	5	2.80
Mid	B'HAM AND FAZELEY CANAL	GRAVELLEY PARK	SP103900	049002295	1	12	4	3.00
Mid	B'HAM AND FAZELEY CANAL	MINWORTH LOCK	SK152923	049002391	1	21	6	3.50
Mid	B'HAM AND WOLV'S CANAL	BRASSHOUSE BRIDGE, HIGH LEVEL	SO019889	049002393	1	21	6	3.50
Mid	B'HAM AND WOLV'S CANAL	CABLE ST.	SO927977	049002392	1	10	3	3.33
Mid	B'HAM AND WOLV'S CANAL	JAMES MILL	SO927977	049002394	1	22	7	3.14
Mid	BEESTON/NOTTINGHAM CANAL	NOTTINGHAM	SK582385	049002413	1	39	10	3.90
Mid	CALDON CANAL	LEEK BRANCH, DENTON	SJ956536	049002395	3	56	13	4.31
Mid	CHESTERFIELD CANAL	RETFORD	SK721820	049001663	1	75	17	4.41
Mid	CHESTERFIELD CANAL	RETFORD	SK721820	049002902	3	90	21	4.29
Mid	CHESTERFIELD CANAL	WALKERINGHAM	SK794929	049001664	1	49	13	3.77
Mid	CHESTERFIELD CANAL	WALKERINGHAM	SK794929	049002903	3	78	19	4.11
Mid	CHESTERFIELD CANAL	WORKSOP	SK595791	049001662	1	83	18	4.61
Mid	CHESTERFIELD CANAL	WORKSOP	SK595791	049002901	3	102	23	4.43
Mid	COVENTRY CANAL	COALPITS LANE	SP364862	049002926	3	61	15	4.07
Mid	COVENTRY CANAL	FOXFORD	SP351839	049002927	3	57	13	4.38
Mid	COVENTRY/OXFORD CANAL	BEDWORTH	SP372858	049002286	3	16	5	3.20
Mid	COVENTRY/OXFORD CANAL	POLESWORTH	SK261021	049002287	1	16	5	3.20
Mid	DAW END BRANCH (WYR AND ESS)	CLAYHANGER BRIDGE	SK047047	049002404	1	77	16	4.81
Mid	DUDLEY CANAL	DARBY END	SO958878	049001380	1	30	7	4.29
Mid	DUDLEY CANAL	DARBY END	SO958878	049001381	2	75	17	4.41
Mid	DUDLEY CANAL	DARBY END	SO958878	049002607	3	58	14	4.14
Mid	EREWASH CANAL	SHIPLEY GATE	SK463453	049001667	2	47	13	3.62
Mid	EREWASH CANAL	SHIPLEY GATE	SK463453	049002095	3	49	13	3.77
Mid	EREWASH CANAL	TRENT LOCK	SK490313	049001666	2	82	18	4.56
Mid	EREWASH CANAL	TRENT LOCK	SK490313	049002096	3	66	17	3.88
Mid	FOSS DYKE NAVIGATION (04)	TORKSEY LOCK	SK837781	049000052	1	23	7	3.29
Mid	FOSS DYKE NAVIGATION (04)	TORKSEY LOCK	SK837781	049001270	2	24	6	4.00
Mid	FOSS DYKE NAVIGATION (04)	TORKSEY LOCK	SK837781	049001942	3	23	6	3.83
Mid	GLOUCESTER AND SHARPNESS CANAL	PURTON	SO693044	049002917	3	25	7	3.57
Mid	GRAND UNION CANAL (04)	CATHERINE DE BARNES	SP180803	049002398	3	13	5	2.60
Mid	GRAND UNION CANAL (04)	CRICK	SP595725	049002920	3	35	9	3.89
Mid	GRAND UNION CANAL (04)	FOSSE WAY	SP365643	049002922	3	69	17	4.06
Mid	GRAND UNION CANAL (04)	LAPWORTH	SP194723	049002399	3	19	5	3.80

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Mid	GRAND UNION CANAL (04)	LOUGHBOROUGH	SK528210	049002414	1	55	13	4.23
Mid	GRAND UNION CANAL (04)	SMALL HEATH	SP096848	049002397	3	23	6	3.83
Mid	GRAND UNION CANAL (04)	SOUTH KILWORTH	SP617807	049002919	3	70	15	4.67
Mid	GRAND UNION CANAL (04)	WARWICK	SP265655	049002921	3	24	6	4.00
Mid	GRAND UNION CANAL (04)	WISTOW	SP650961	049002409	1	80	19	4.21
Mid	GRANTHAM CANAL (04)	HICKLING BASIN	SK691295	049002411	1	54	14	3.86
Mid	GRANTHAM CANAL (04)	TOLLERTON BRIDGE	SK609369	049002412	1	68	16	4.25
Mid	GRANTHAM CANAL (04)	WOOLSTHORPE	SK842351	049002410	1	115	25	4.60
Mid	OXFORD CANAL	HILLMORTON	SP542740	049002923	3	9	3	3.00
Mid	OXFORD CANAL	LOWER SHUCKBURGH	SP491628	049002925	3	34	10	3.40
Mid	OXFORD CANAL	SOWE COMMON	SP375831	049002924	3	38	9	4.22
Mid	RIDGEACRE BRANCH (WALSALL)	PHOENIX ST WEST BROMWICH	SO986917	049002401	1	10	3	3.33
Mid	RUSHALL CANAL	ALDRIDGE ROAD	SP040993	049002299	1	46	12	3.83
Mid	SHROPSHIRE UNION CANAL (04)	ABERBECHAIN BRIDGE	SO143933	049001859	1	65	14	4.64
Mid	SHROPSHIRE UNION CANAL (04)	ABERBECHAIN BRIDGE	SO143933	049001790	2	60	14	4.29
Mid	SHROPSHIRE UNION CANAL (04)	ABERBECHAIN BRIDGE	SO143933	049001757	3	66	14	4.71
Mid	SHROPSHIRE UNION CANAL (04)	BREWOOD BRIDGE	SJ880088	049002396	3	21	7	3.00
Mid	SHROPSHIRE UNION CANAL (04)	BREWOOD PARK FARM	SJ891066	049002388	3	22	6	3.67
Mid	SHROPSHIRE UNION CANAL (04)	DOBSONS BRIDGE	SJ492343	049001376	1	38	10	3.80
Mid	SHROPSHIRE UNION CANAL (04)	DOBSONS BRIDGE	SJ492343	049001377	2	71	16	4.44
Mid	SHROPSHIRE UNION CANAL (04)	DOBSONS BRIDGE	SJ492343	049001756	3	51	12	4.25
Mid	SHROPSHIRE UNION CANAL (04)	FOUR CROSSES	SO263171	049001378	1	91	18	5.06
Mid	SHROPSHIRE UNION CANAL (04)	FOUR CROSSES	SO263171	049001379	2	64	13	4.92
Mid	SHROPSHIRE UNION CANAL (04)	FOUR CROSSES	SO263171	049002606	3	67	15	4.47
Mid	SHROPSHIRE UNION CANAL (04)	NORBURY JUNCTION	SJ792230	049001372	1	35	9	3.89
Mid	SHROPSHIRE UNION CANAL (04)	NORBURY JUNCTION	SJ792230	049001373	2	9	3	3.00
Mid	SHROPSHIRE UNION CANAL (04)	NORBURY JUNCTION	SJ792230	049002245	3	8	3	2.67
Mid	SHROPSHIRE UNION CANAL (04)	PENDEFORD BRIDGE	SJ888034	049002290	3	24	8	3.00
Mid	SHROPSHIRE UNION CANAL (04)	WELSH FRANKTON	SJ354325	049001374	1	43	10	4.30
Mid	SHROPSHIRE UNION CANAL (04)	WELSH FRANKTON	SJ354325	049001375	2	55	13	4.23
Mid	SHROPSHIRE UNION CANAL (04)	WELSH FRANKTON	SJ354325	049001755	3	40	9	4.44
Mid	STAFFS AND WORCS CANAL	AWBRIDGE	SO860949	049001362	1	17	5	3.40
Mid	STAFFS AND WORCS CANAL	AWBRIDGE	SO860949	049001363	2	18	5	3.60
Mid	STAFFS AND WORCS CANAL	AWBRIDGE	SO860949	049001753	3	30	7	4.29
Mid	STAFFS AND WORCS CANAL	COVEN HEATH	SJ914054	049002288	3	12	5	2.40
Mid	STAFFS AND WORCS CANAL	OXLEY RAIL BRIDGE	SJ902017	049002298	3	12	5	2.40
Mid	STAFFS AND WORCS CANAL	SLADE HEATH	SJ919066	049002289	3	34	9	3.78

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Mid	STAFFS AND WORCS CANAL	STEWPONNEY	SO861848	049001364	1	34	7	4.86
Mid	STAFFS AND WORCS CANAL	STEWPONNEY	SO861848	049001365	2	25	7	3.57
Mid	STAFFS AND WORCS CANAL	STEWPONNEY	SO861848	049001754	3	31	6	5.17
Mid	STAFFS AND WORCS CANAL	TETTENHALL	SJ896004	049001298	1	25	7	3.57
Mid	STAFFS AND WORCS CANAL	TETTENHALL	SJ896004	049001361	2	34	10	3.40
Mid	STAFFS AND WORCS CANAL	TETTENHALL	SJ896004	049002231	3	27	7	3.86
Mid	STAINFORTH / KEADBY CANAL (04)	AT KEADBY	SE825115	049001665	1	48	11	4.36
Mid	STAINFORTH / KEADBY CANAL (04)	AT KEADBY	SE825115	049002473	3	67	17	3.94
Mid	STOURBRIDGE CANAL	BROMLEY	SO902881	049001383	1	83	19	4.37
Mid	STOURBRIDGE CANAL	BROMLEY	SO902881	049001382	2	98	20	4.90
Mid	STOURBRIDGE CANAL	BROMLEY	SO902881	049002609	3	76	19	4.00
Mid	STRATFORD ON AVON CANAL	HOCKLEY HEATH	SP152725	049002296	3	4	2	2.00
Mid	STRATFORD ON AVON CANAL	LAPWORTH	SP159719	049002916	3	24	7	3.43
Mid	STRATFORD ON AVON CANAL	SILLBORNE RISE	SP162617	049002918	3	50	10	5.00
Mid	STRATFORD ON AVON CANAL	STIRCHLEY	SP059796	049002297	3	20	5	4.00
Mid	TAME VALLEY CANAL	SALFORD BRIDGE	SP096901	049002400	3	13	5	2.60
Mid	TITFORD CANAL	WOLVERHAMPTON ROAD OLDBURY	SO988878	049002402	1	15	5	3.00
Mid	TRENT / MERSEY CANAL	ASTON	SJ915321	049002294	1	21	6	3.50
Mid	TRENT / MERSEY CANAL	FRADLEY JUNCTION	SK137137	049002383	3	47	11	4.27
Mid	TRENT / MERSEY CANAL	GREAT HAYWOOD	SJ995230	049002293	1	55	13	4.23
Mid	TRENT / MERSEY CANAL	HARECASTLE TUNNEL	SJ849517	049002291	3	17	5	3.40
Mid	TRENT / MERSEY CANAL	SHARDLOW	SK455307	049002415	1	66	15	4.40
Mid	WALSALL CANAL	BULL LANE MOXLEY	SO969955	049002386	1	29	7	4.14
Mid	WORCESTER & BIRMINGHAM CANAL	ALVECHURCH	SO022722	049001366	1	28	8	3.50
Mid	WORCESTER & BIRMINGHAM CANAL	ALVECHURCH	SO022722	049001367	2	40	9	4.44
Mid	WORCESTER & BIRMINGHAM CANAL	ALVECHURCH	SO022722	049002232	3	58	13	4.46
Mid	WORCESTER & BIRMINGHAM CANAL	BLACKPOLE	SO867576	049001370	1	72	15	4.80
Mid	WORCESTER & BIRMINGHAM CANAL	BLACKPOLE	SO867576	049001371	2	97	21	4.62
Mid	WORCESTER & BIRMINGHAM CANAL	BLACKPOLE	SO867576	049002244	3	60	15	4.00
Mid	WORCESTER & BIRMINGHAM CANAL	KINGS NORTON	SP055797	049002387	3	25	6	4.17
Mid	WORCESTER & BIRMINGHAM CANAL	SOMERSET BRIDGE, EDGBASTON	SP050844	049002385	3	16	5	3.20
Mid	WORCESTER & BIRMINGHAM CANAL	WHITFORD BRIDGE	SO959674	049001368	1	56	13	4.31
Mid	WORCESTER & BIRMINGHAM CANAL	WHITFORD BRIDGE	SO959674	049001369	2	61	15	4.07
Mid	WORCESTER & BIRMINGHAM CANAL	WHITFORD BRIDGE	SO959674	049002608	3	72	16	4.50
Mid	WYRLEY AND ESSINGTON CANAL	NEWTOWN, BROWNHILLS	SK057060	049002285	3	28	8	3.50
Mid	WYRLEY AND ESSINGTON CANAL	SLACKEY LANE GOSCOTE	SK016020	049002403	1	61	12	5.08
Mid	WYRLEY AND ESSINGTON CANAL	WILLENHALL LN BLOXWICH	SJ986013	049002384	1	41	11	3.73

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NE	AIRE & CALDER CANAL	KNOTTINGLEY	SE530230	109000770	2	12	5	2.40
NE	AIRE & CALDER CANAL	POLLINGTON	SE612194	109000769	2	15	6	2.50
NE	AIRE & CALDER CANAL	RAWCLIFFE BRIDGE	SE700211	109000768	2	9	4	2.25
NE	AIRE & CALDER CANAL	SWILLINGTON POTTERY LANE	SE367296	109000771	2	13	4	3.25
NE	CALDER & HEBBLE CANAL	ALTOFTS	SE376246	109000773	2	23	8	2.88
NE	CALDER & HEBBLE CANAL	ELLAND	SE127224	109000551	2	50	12	4.17
NE	CALDER & HEBBLE CANAL	HORBURY BRIDGE	SE280179	109000418	2	9	4	2.25
NE	DRIFFIELD CANAL	AT CANAL HEAD	TA029573	109000129	1	52	13	4.00
NE	DRIFFIELD CANAL	AT CANAL HEAD	TA029573	109000449	2	49	12	4.08
NE	DRIFFIELD CANAL	AT CANAL HEAD	TA029573	109000875	3	31	9	3.44
NE	DRIFFIELD CANAL	D/S SNAKEHOLM LOCK	TA068554	109000216	1	50	13	3.85
NE	DRIFFIELD CANAL	D/S SNAKEHOLM LOCK	TA068554	109000456	2	72	17	4.24
NE	DRIFFIELD CANAL	D/S SNAKEHOLM LOCK	TA068554	109000862	3	71	19	3.74
NE	DRIFFIELD CANAL	WANSFORD	TA065561	109000145	1	72	18	4.00
NE	DRIFFIELD CANAL	WANSFORD	TA065561	109000450	2	104	23	4.52
NE	DRIFFIELD CANAL	WANSFORD	TA065561	109000863	3	67	18	3.72
NE	LEEDS & LIVERPOOL CANAL	BINGLEY	SE118384	109000558	2	15	5	3.00
NE	LEEDS & LIVERPOOL CANAL	CANAL ROAD LEEDS	SE277340	109000779	2	80	17	4.71
NE	LEEDS & LIVERPOOL CANAL	GARGRAVE	SD935545	109000420	2	50	14	3.57
NE	LEVEN CANAL	LEVEN	TA100450	109000374	2	142	28	5.07
NE	MARKET WEIGHTON CANAL	BROOMFLEET	SE869272	109000185	1	48	12	4.00
NE	MARKET WEIGHTON CANAL	BROOMFLEET	SE869272	109000448	2	60	14	4.29
NE	MARKET WEIGHTON CANAL	BROOMFLEET	SE869272	109000848	3	53	12	4.42
NE	MARKET WEIGHTON CANAL	NORTH CLIFFE	SE843375	109000810	2	40	10	4.00
NE	NEW JUNCTION CANAL	KIRK BRAMWITH	SE619120	109001120	3	18	6	3.00
NE	NEW JUNCTION CANAL	SKYEHOUSE	SE645173	109001121	3	22	7	3.14
NE	POCKLINGTON CANAL	HAGG BRIDGE	SE717451	109000979	2	82	19	4.32
NE	RIPON CANAL	LITTLETHORPE	SE327694	109000803	2	70	17	4.12
NE	SELBY CANAL	BRAYTON	SE610303	109000785	2	32	10	3.20
NE	SELBY CANAL	WEST HADDLESEY	SE572265	109000784	2	3	2	1.50
NE	SHEFF & S YORKS CANAL	BACON LANE	SK377884	109001302	3	21	7	3.00
NE	SHEFF & S YORKS CANAL	TINSLEY	SK399909	109001122	3	30	10	3.00
NE	STAINFORTH / KEADBY CANAL (10)	U/S THORNE LOCK	SE681131	109001312	3	33	10	3.30
NW	NAVIGATION COURSE	SALTERSFORD LOCK	SJ627750	039001975	3	12	4	3.00
Sou	CHICHESTER CANAL	U/S CUTFIELD BRIDGE	SU842013	059000335	1	75	18	4.17
Sou	CHICHESTER CANAL	U/S CUTFIELD BRIDGE	SU842013	059000570	2	68	18	3.78
Sou	CHICHESTER CANAL	U/S CUTFIELD BRIDGE	SU842013	059000839	3	67	18	3.72

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Sou	ROYAL MILITARY CANAL	GIGGERS GREEN	TR070342	059000257	1	63	15	4.20
Sou	ROYAL MILITARY CANAL	GIGGERS GREEN	TR070342	059000536	2	102	23	4.43
Sou	ROYAL MILITARY CANAL	GIGGERS GREEN	TR070342	059001169	3	98	23	4.26
Sou	ROYAL MILITARY CANAL	HAMSTREET	TR004324	059000042	1	83	20	4.15
Sou	ROYAL MILITARY CANAL	HAMSTREET	TR004324	059000481	2	101	24	4.21
Sou	ROYAL MILITARY CANAL	HAMSTREET	TR004324	059000984	3	105	25	4.20
Sou	ROYAL MILITARY CANAL	HYTHE	TR152347	059000258	1	90	22	4.09
Sou	ROYAL MILITARY CANAL	HYTHE	TR152347	059000646	2	117	27	4.33
Sou	ROYAL MILITARY CANAL	HYTHE	TR152347	059001170	3	98	23	4.26
Sou	ROYAL MILITARY CANAL	STONE BRIDGE	TQ946264	059000426	1	52	14	3.71
Sou	ROYAL MILITARY CANAL	STONE BRIDGE	TQ946264	059000645	2	100	24	4.17
Sou	ROYAL MILITARY CANAL	STONE BRIDGE	TQ946264	059000983	3	71	18	3.94
SW	BRIDGWATER AND TAUNTON CANAL	NORTH NEWTON	ST304307	099000394	1	58	14	4.14
SW	BRIDGWATER AND TAUNTON CANAL	NORTH NEWTON	ST304307	099000749	2	61	16	3.81
SW	BRIDGWATER AND TAUNTON CANAL	NORTH NEWTON	ST304307	099001124	3	36	9	4.00
SW	BUDE CANAL	FALCON BRIDGE	SS207060	069000432	1	55	13	4.23
SW	BUDE CANAL	FALCON BRIDGE	SS207060	069001033	2	46	12	3.83
SW	BUDE CANAL	FALCON BRIDGE	SS207060	069001398	3	36	8	4.50
SW	EXETER CANAL	30M U/S A379 BR COUNTESS WEAR	SX939894	069000438	1	69	16	4.31
SW	EXETER CANAL	30M U/S A379 BR COUNTESS WEAR	SX939894	069000875	2	62	15	4.13
SW	EXETER CANAL	30M U/S A379 BR COUNTESS WEAR	SX939894	069001159	3	122	24	5.08
SW	GRAND WESTERN CANAL	30M U/S FENACRE BRIDGE	ST070177	069000372	1	97	20	4.85
SW	GRAND WESTERN CANAL	30M U/S FENACRE BRIDGE	ST070177	069000812	2	68	18	3.78
SW	GRAND WESTERN CANAL	30M U/S FENACRE BRIDGE	ST070177	069001184	3	80	19	4.21
SW	TIVERTON CANAL	THE BASIN TIVERTON	SS963123	069000336	1	2	1	2.00
SW	TIVERTON CANAL	THE BASIN TIVERTON	SS963123	069000793	2	22	6	3.67
SW	TIVERTON CANAL	THE BASIN TIVERTON	SS963123	069001196	3	16	4	4.00
SW	WESTPORT CANAL	HAMBRIDGE	ST402216	099000386	1	43	11	3.91
SW	WESTPORT CANAL	HAMBRIDGE	ST402216	099000741	2	75	20	3.75
SW	WESTPORT CANAL	HAMBRIDGE	ST402216	099001116	3	10	4	2.50
Tha	BASINGSTOKE CANAL	AT EELMOOR BRIDGE	SU843528	079000214	1	124	25	4.96
Tha	BASINGSTOKE CANAL	AT EELMOOR BRIDGE	SU843528	079000518	2	151	29	5.21
Tha	BASINGSTOKE CANAL	AT EELMOOR BRIDGE	SU843528	079000739	3	149	29	5.14
Tha	BODDINGTON CANAL FEEDER	CLAYDON - BODDINGTON RD	SP461516	079000278	1	115	25	4.60
Tha	GUC (ABOVE BERKHAMSTED)	AT TRING	SP948121	079000230	1	39	9	4.33
Tha	GUC (ABOVE BERKHAMSTED)	AT TRING	SP948121	079000530	2	15	4	3.75
Tha	GUC (ABOVE BERKHAMSTED)	AT TRING	SP948121	079000896	3	25	7	3.57

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Tha	GUC (AYLESBURY ARM)	COLLEGE BRIDGE, ASTON CLINTON	SP872140	079000182	1	81	17	4.76
Tha	GUC (AYLESBURY ARM)	COLLEGE BRIDGE, ASTON CLINTON	SP872140	079000483	2	83	20	4.15
Tha	GUC (AYLESBURY ARM)	COLLEGE BRIDGE, ASTON CLINTON	SP872140	079000703	3	84	19	4.42
Tha	GUC (BLACK JACKS REACH)	AT COPPERMILL LANE, HAREFIELD	TQ040911	079000231	1	32	9	3.56
Tha	GUC (BLACK JACKS REACH)	AT COPPERMILL LANE, HAREFIELD	TQ040911	079000617	2	12	5	2.40
Tha	GUC (BLACK JACKS REACH)	AT COPPERMILL LANE, HAREFIELD	TQ040911	079000855	3	3	2	1.50
Tha	GUC (CASSIOBURY REACH)	AT GADE BANK CRESCENT	TQ088964	079000228	1	73	14	5.21
Tha	GUC (CASSIOBURY REACH)	AT GADE BANK CRESCENT	TQ088964	079000507	2	43	11	3.91
Tha	GUC (CASSIOBURY REACH)	AT GADE BANK CRESCENT	TQ088964	079000899	3	29	9	3.22
Tha	GUC (COWLEY REACH)	ABOVE LOCK 97	TQ149796	079000217	1	24	6	4.00
Tha	GUC (COWLEY REACH)	ABOVE LOCK 97	TQ149796	079000616	2	16	6	2.67
Tha	GUC (COWLEY REACH)	ABOVE LOCK 97	TQ149796	079000666	3	42	10	4.20
Tha	GUC (COWLEY REACH)	AT HORTON ROAD BRIDGE	TQ066800	079000220	1	78	17	4.59
Tha	GUC (COWLEY REACH)	AT HORTON ROAD BRIDGE	TQ066800	079000615	2	42	11	3.82
Tha	GUC (COWLEY REACH)	AT HORTON ROAD BRIDGE	TQ066800	079000668	3	96	21	4.57
Tha	GUC (CROXLEY REACH)	AT DURANTS HILL ROAD	TL058056	079000232	1	44	13	3.38
Tha	GUC (CROXLEY REACH)	AT DURANTS HILL ROAD	TL058056	079000533	2	44	12	3.67
Tha	GUC (CROXLEY REACH)	AT DURANTS HILL ROAD	TL058056	079000898	3	34	11	3.09
Tha	GUC (DENHAM REACH)	AT A40, DENHAM	TQ053857	079000221	1	32	8	4.00
Tha	GUC (DENHAM REACH)	AT A40, DENHAM	TQ053857	079000619	2	37	8	4.63
Tha	GUC (DENHAM REACH)	AT A40, DENHAM	TQ053857	079000854	3	37	7	5.29
Tha	GUC (PADDINGTON ARM)	HAMPSTEAD ROAD, CAMDEN TOWN	TQ286840	079000255	1	12	4	3.00
Tha	GUC (PADDINGTON ARM)	HAMPSTEAD ROAD, CAMDEN TOWN	TQ286840	079000368	2	12	5	2.40
Tha	GUC (PADDINGTON ARM)	HAMPSTEAD ROAD, CAMDEN TOWN	TQ286840	079000904	3	9	4	2.25
Tha	GUC (PADDINGTON ARM)	SOLBAY STREET, MILE END	TQ363822	079000218	1	74	17	4.35
Tha	GUC (PADDINGTON ARM)	SOLBAY STREET, MILE END	TQ363822	079000626	2	73	19	3.84
Tha	GUC (PADDINGTON ARM)	SOLBAY STREET, MILE END	TQ363822	079000923	3	60	16	3.75
Tha	GUC (PIX FARM REACH)	1500M D/S BERKHAMPSTED STW	TL027063	079000219	1	35	10	3.50
Tha	GUC (PIX FARM REACH)	1500M D/S BERKHAMPSTED STW	TL027063	079000540	2	27	8	3.38
Tha	GUC (PIX FARM REACH)	1500M D/S BERKHAMPSTED STW	TL027063	079000679	3	12	5	2.40
Tha	GUC (PIX FARM REACH)	ABOVE BERKHAMSTED STW	TL007071	079000911	1	35	10	3.50
Tha	GUC (PIX FARM REACH)	ABOVE BERKHAMSTED STW	TL007071	079000912	2	27	8	3.38
Tha	GUC (PIX FARM REACH)	ABOVE BERKHAMSTED STW	TL007071	079000897	3	17	5	3.40
Tha	GUC (WENDOVER ARM)	AT ROADBRIDGE, TRING	SP924132	079000181	1	70	15	4.67
Tha	GUC (WENDOVER ARM)	AT ROADBRIDGE, TRING	SP924132	079000482	2	70	17	4.12
Tha	GUC (WENDOVER ARM)	AT ROADBRIDGE, TRING	SP924132	079000702	3	70	17	4.12
Tha	KENNET & AVON CANAL (07)	AT MIDGHAM BRIDGE	SU551662	079000562	2	73	19	3.84

Region	Canal Name	Site Name	NGR	Sample ID	Seas.	BMWP	# Taxa	ASPT
Tha	KENNET & AVON CANAL (SUMMIT)	AT FROXFIELD BRIDGE	SU306678	079000237	1	102	21	4.86
Tha	KENNET & AVON CANAL (SUMMIT)	AT FROXFIELD BRIDGE	SU306678	079000579	2	103	22	4.68
Tha	KENNET & AVON CANAL (SUMMIT)	AT FROXFIELD BRIDGE	SU306678	079000759	3	95	22	4.32
Tha	KENNET & AVON CANAL (WOOLHAMP)	AT UFTON BRIDGE	SU618687	079000086	1	167	32	5.22
Tha	KENNET & AVON CANAL (WOOLHAMP)	AT UFTON BRIDGE	SU618687	079000408	2	169	32	5.28
Tha	KENNET & AVON CANAL (WOOLHAMP)	AT UFTON BRIDGE	SU618687	079000694	3	157	29	5.41
Tha	LEE NAVIGATION (SUB B)	AT SUB B, KEIDES WEIR	TQ363953	079000226	1	58	16	3.63
Tha	LEE NAVIGATION (SUB B)	AT SUB B, KEIDES WEIR	TQ363953	079000371	2	33	10	3.30
Tha	LEE NAVIGATION (SUB B)	AT SUB B, KEIDES WEIR	TQ363953	079000922	3	88	21	4.19
Tha	OXFORD CANAL LOWER SECTION	1.2KM BELOW KIDLINGTON STW	SP488112	079000247	1	90	21	4.29
Tha	OXFORD CANAL LOWER SECTIO	1.2KM BELOW KIDLINGTON STW	SP488112	079000456	2	55	15	3.67
Tha	OXFORD CANAL LOWER SECTION)	1.2KM BELOW KIDLINGTON STW	SP488112	079000789	3	64	17	3.76
Tha	OXFORD CANAL MIDDLE SECTION	AT HEYFORD BRIDGE	SP483247	079000246	1	92	20	4.60
Tha	OXFORD CANAL MIDDLE SECTION	AT HEYFORD BRIDGE	SP483247	079000455	2	77	20	3.85
Tha	OXFORD CANAL MIDDLE SECTION	AT HEYFORD BRIDGE	SP483247	079000790	3	85	20	4.25
Tha	OXFORD CANAL UPPER SECTION	AT CROPREDY BRIDGE	SP469465	079000245	1	48	11	4.36
Tha	OXFORD CANAL UPPER SECTION	AT CROPREDY BRIDGE	SP469465	079000454	2	87	21	4.14
Tha	OXFORD CANAL UPPER SECTION	AT CROPREDY BRIDGE	SP469465	079000791	3	70	18	3.89
Tha	STORT NAVIGATION	ABOVE TWYFORD MILL LOCK	TL493192	079000274	1	89	21	4.24
Tha	STORT NAVIGATION	ABOVE TWYFORD MILL LOCK	TL493192	079000375	2	77	20	3.85
Tha	STORT NAVIGATION	ABOVE TWYFORD MILL LOCK	TL493192	079000917	3	80	19	4.21
Tha	STORT NAVIGATION	AT ROYDON	TL417113	079000072	1	120	25	4.80
Tha	STORT NAVIGATION	AT ROYDON	TL417113	079000374	2	125	27	4.63
Tha	STORT NAVIGATION	AT ROYDON	TL417113	079000724	3	142	29	4.90
Tha	STORT NAVIGATION	AT SAWBRIDGEWORTH	TL486152	079000263	1	88	21	4.19
Tha	STORT NAVIGATION	AT SAWBRIDGEWORTH	TL486152	079000621	2	42	11	3.82
Tha	STORT NAVIGATION	AT SAWBRIDGEWORTH	TL486152	079000918	3	90	20	4.50
Wel	MONMOUTH-BRECON CANAL	AT CROES Y PANT	SO313040	089000564	1	87	21	4.14
Wel	MONMOUTH-BRECON CANAL	AT CROES Y PANT	SO313040	089000952	2	78	20	3.90
Wel	MONMOUTH-BRECON CANAL	AT CROES Y PANT	SO313040	089001523	3	72	17	4.24
Wel	MONMOUTH-BRECON CANAL	AT PONTYPOOL	SO295004	089000568	1	61	16	3.81
Wel	MONMOUTH-BRECON CANAL	AT PONTYPOOL	SO295004	089000956	2	47	14	3.36
Wel	MONMOUTH-BRECON CANAL	AT PONTYPOOL	SO295004	089001527	3	49	14	3.50
Wel	MONMOUTH-BRECON CANAL	AT PONTYWAUN	ST220926	089000566	1	76	17	4.47
Wel	MONMOUTH-BRECON CANAL	AT PONTYWAUN	ST220926	089000954	2	41	11	3.73
Wel	MONMOUTH-BRECON CANAL	AT PONTYWAUN	ST220926	089001525	3	92	18	5.11
Wel	MONMOUTH-BRECON CANAL	AT TALYBONT ON USK	SO115225	089000565	1	64	14	4.57

Region	Canal Name	Site Name	NGR	Sample ID	Seas.	BMWP	# Taxa	ASPT
Wel	MONMOUTH-BRECON CANAL	AT TALYBONT ON USK	SO115225	089000953	2	45	12	3.75
Wel	MONMOUTH-BRECON CANAL	AT TALYBONT ON USK	SO115225	089001524	3	56	12	4.67
Wel	MONMOUTH-BRECON CANAL	U/S NEWPORT	ST305895	089000567	1	81	21	3.86
Wel	MONMOUTH-BRECON CANAL	U/S NEWPORT	ST305895	089000955	2	79	20	3.95
Wel	MONMOUTH-BRECON CANAL	U/S NEWPORT	ST305895	089001526	3	65	18	3.61
Wel	NEATH CANAL	ABERDULAIS	SS774993	089000244	1	92	19	4.84
Wel	NEATH CANAL	ABERDULAIS	SS774993	089001090	2	72	17	4.24
Wel	NEATH CANAL	ABERDULAIS	SS774993	089001260	3	95	21	4.52
Wel	PORT TENNANT CANAL	JERSEY MARINE	SS712939	089000243	1	101	20	5.05
Wel	PORT TENNANT CANAL	JERSEY MARINE	SS712939	089001089	2	94	21	4.48
Wel	PORT TENNANT CANAL	JERSEY MARINE	SS712939	089001259	3	110	24	4.58
Wel	SHROPSHIRE UNION CANAL (08)	AT CHRISTLETON	SJ444651	089000743	1	20	6	3.33
Wel	SHROPSHIRE UNION CANAL (08)	AT CHRISTLETON	SJ444651	089001990	2	20	5	4.00
Wel	SHROPSHIRE UNION CANAL (08)	AT CHRISTLETON	SJ444651	089002150	3	24	6	4.00
Wel	SHROPSHIRE UNION CANAL (08)	AT PONTCYSYLLTE	SJ272423	089000789	1	11	3	3.67
Wel	SHROPSHIRE UNION CANAL (08)	AT PONTCYSYLLTE	SJ272423	089002035	2	10	3	3.33
Wel	SHROPSHIRE UNION CANAL (08)	AT PONTCYSYLLTE	SJ272423	089002188	3	4	2	2.00
Wel	SHROPSHIRE UNION CANAL (08)	GRINDLEY BROOK	SJ523429	089000767	1	22	6	3.67
Wel	SHROPSHIRE UNION CANAL (08)	GRINDLEY BROOK	SJ523429	089002014	2	19	6	3.17
Wel	SHROPSHIRE UNION CANAL (08)	GRINDLEY BROOK	SJ523429	089002166	3	3	2	1.50
Wel	SWANSEA CANAL	CLYDACH PARK	SN703017	089000245	1	41	10	4.10
Wel	SWANSEA CANAL	CLYDACH PARK	SN703017	089001091	2	45	11	4.09
Wel	SWANSEA CANAL	CLYDACH PARK	SN703017	089001261	3	61	14	4.36

Appendix 8: List of National and Regional GQA monitoring sites on canals.

Region	Canal Name	Site Name	NGR
Ang	FOSSDYKE CANAL	PYEWIPE	SK949723
Ang.	FOSSDYKE CANAL	SAXILBY	SK900751
Ang	GRAND UNION CANAL (01)	A43 BRIDGE BLISWORTH	SP724534
Ang	GRAND UNION CANAL (01)	B4036 RD BRIDGE WELTON	SP579651
Ang	GRAND UNION CANAL (01)	BOWLERS BRIDGE SIMPSON	SP880363
Ang	GRAND UNION CANAL (01)	BR DEBDALE WHARF	SP695916
Ang	GRAND UNION CANAL (01)	COOKS WHARF	SP928162
Ang	GRAND UNION CANAL (01)	GRAFTON RD BROOK ASHTON	SP763480
Ang	GRAND UNION CANAL (01)	MARSWORTH RD BR	SP919147
Ang	HORNCASTLE CANAL	WHARF LANE	TF228587
Ang	LOUTH CANAL	ALVINGHAM	TF365908
Ang	LOUTH CANAL	AUSTEN FEN	TF368946
Ang	LOUTH CANAL	FIREBEACON	TF353970
Ang	LOUTH CANAL	HIGH BRIDGE HOUSE	TF375922
Ang	LOUTH CANAL	TETNEY LOCK	TA342021
Ang	LOUTH CANAL	TICKLEPENNY LOCK	TF350889
Ang	CAISTOR CANAL	WESTFIELD FARM	TF020990
Mid	ASHBY CANAL	BURTON HASTINGS	SP402892
Mid	ASHBY CANAL	MARKET BOSWORTH	SK392032
Mid	CHESTERFIELD CANAL	FOOTBRIDGE TURNERWOOD	SK543813
Mid	CHESTERFIELD CANAL	PUDDING DYKE BRIDGE	SK528814
Mid	CHESTERFIELD CANAL	RETFORD	SK721820
Mid	CHESTERFIELD CANAL	WALKERINGHAM	SK794929
Mid	CHESTERFIELD CANAL	WORKSOP	SK595791
Mid	DUDLEY CANAL	CHERRY ORCHARD	SO963861
Mid	DUDLEY CANAL	DUDLEY MIXED CONCRETE	SO934888
Mid	DUDLEY CANAL	QUEENS HEAD MINOR ROAD BRIDGE	SJ339268
Mid	EREWASH CANAL	SHIPLEY GATE	SK463453
Mid	EREWASH CANAL	STANTON LOCK	SK481390
Mid	EREWASH CANAL	TRENT LOCK	SK490313
Mid	FOSS DYKE NAVIGATION (04)	TORKSEY LOCK	SK837781
Mid	GRAND UNION CANAL (04)	MILL LANE	SK582038
Mid	GRAND UNION CANAL (04)	SWANS NEST BRIDGE	SK590660
Mid	MONTGOMERY CANAL	LLANDYSILIO A483 BR	SJ264173
Mid	MONTGOMERY CANAL	WELSHPOOL BUTTINGTON CROSS	SJ241089
Mid	SHROPSHIRE UNION CANAL (04)	ABERBECHAIN BRIDGE	SO143933
Mid	SHROPSHIRE UNION CANAL (04)	DOBSONS BRIDGE	SJ492343
Mid	SHROPSHIRE UNION CANAL (04)	MAES TERMYN A495 BRIDGE	SJ353326
Mid	SHROPSHIRE UNION CANAL (04)	PLATT LANE BRIDGE	SJ511365
Mid	STAFFS/WORCESTER CANAL	COMPTON BRIDGE	SO883988
Mid	STAFFS/WORCESTER CANAL	JUNCTION WITH BHAM CANAL	SJ902011
Mid	STAFFS/WORCESTER CANAL	WORCESTER ROAD KIDDERMINSTER	SO828758
Mid	STAINFORTH / KEADBY CANAL (04)	AT KEADBY	SE825115
Mid	STAINFORTH / KEADBY CANAL (04)	THORNE	SE681132
Mid	STOURBRIDGE CANAL	ROMAN ROAD (BIO SP PT)	SO874856
Mid	WORCESTER & BIRMINGHAM CANAL	TIBBERTON WORCESTER	SO907583
Mid	CALDON CANAL	FROGHALL	SK026477

Region	Canal Name	Site Name	NGR
Mid	CALDON CANAL	CHEDDLETON	SJ981521
Mid	CALDON CANAL	LEEK BRANCH DENFORD	SJ956536
Mid	CALDON CANAL	ENDON	SJ933536
Mid	CALDON CANAL	MILTON	SJ902501
Mid	CALDON CANAL	IVY HOUSE BRIDGE HANLEY	SJ893472
Mid	TRENT & MERSEY CANAL	HARECASTLE TUNNEL	SJ849517
Mid	TRENT & MERSEY CANAL	TRUBSHAW CROSS	SJ857498
Mid	TRENT & MERSEY CANAL	HEM HEATH	SJ880410
Mid	TRENT & MERSEY CANAL	ASTON	SJ915321
Mid	TRENT & MERSEY CANAL	LITTLE HAYWOOD	SK004212
Mid	TRENT & MERSEY CANAL	FRADLEY JUNCTION	SK137137
Mid	TRENT & MERSEY CANAL	WYCHNOR	SK185161
Mid	TRENT & MERSEY CANAL	STRETTON	SK259260
Mid	COVENTRY CANAL	BEDWORTH	SP371869
Mid	COVENTRY CANAL	TUTTLEHILL JUDKINS QUARRY	SP353924
Mid	COVENTRY CANAL	MANCETTER, TILCON QUARRY BRIDGE	SP315963
Mid	COVENTRY CANAL	POLESWORTH	SK261021
Mid	COVENTRY CANAL	FRADLEY AIRFIELD	SK146137
Mid	BIRMINGHAM & FAZELEY CANAL	SALFORD BRIDGE	SP097901
Mid	BIRMINGHAM & FAZELEY CANAL	MINWORTH LOCK	SP152923
Mid	BIRMINGHAM & FAZELEY CANAL	FAZELEY	SP203019
Mid	GRAND UNION CANAL	CATHERINE-DE-BARNES	SP180803
Mid	GRAND UNION CANAL	LAPWORTH	SP194723
Mid	GRAND UNION CANAL	NECHELLS	SP095877
Mid	STRATFORD UPON AVON CANAL	HOCKLEY HEATH	SP152725
Mid	STRATFORD UPON AVON CANAL	STIRCHLEY	SP059796
Mid	SHROPS UNION	GNOSSALL BRIDGE	SJ819203
Mid	SHROPS UNION	WHEATON ASTON	SJ858127
Mid	SHROPS UNION	BREWOOD	SJ880088
Mid	SHROPS UNION	PENDEFORD BRIDGE	SJ888034
Mid	BIRMINGHAM & WORCESTER CANAL	BATH ROW BRIDGE	SP061860
Mid	BIRMINGHAM & WORCESTER CANAL	PERSHORE ROAD	SP054803
Mid	STAFFS & WORCS	OXLEY BRIDGE	SJ902017
Mid	STAFFS & WORCS	COVEN HEATH	SJ914054
Mid	STAFFS & WORCS	SLADE HEATH	SJ919066
Mid	STAFFS & WORCS	GAILEY LOCK	SJ920104
Mid	STAFFS & WORCS	PENKRIDGE	SJ928140
Mid	STAFFS & WORCS	TEDDLESEY, PARK GATE	SJ937158
Mid	STAFFS & WORCS	ACTON TRUSSEL	SJ935184
Mid	STAFFS & WORCS	RADFORD BRIDGE	SJ939216
Mid	STAFFS & WORCS	TIXALL BRIDGE	SJ975216
Mid	HATHERTON BRANCH	FOUR CROSSES	SJ951091
Mid	WYRLEY & ESSINGTON	WILLENHALL LANE, BLOXWICH	SJ986013
Mid	WYRLEY & ESSINGTON	SLACKY LANE, GOSCOTE	SK016020
Mid	WYRLEY & ESSINGTON	CLAYHANGER BRIDGE, DAW END BRANCH	SK047047
Mid	WYRLEY & ESSINGTON	BCN ANGELSEY BRANCH, NEWTOWN, B.HILLS	SK057060
Mid	WYRLEY & ESSINGTON	CANNOCK EXTENSION, WYRLEY GROVE BRDG.	SJ986013
Mid	WALSALL CANAL	RAYBOULDS BRIDGE	SP004997
Mid	WALSALL CANAL	ANSON BRIDGE	SO988983
Mid	WALSALL CANAL	BULL LANE, MOXLEY	SO969955
Mid	WALSALL CANAL	MOORS MILL LANE	SO977932
Mid	WALSALL CANAL	RYDERS GREEN	SO983917

Region	Canal Name	Site Name	NGR
Mid	WALSALL CANAL	PHOENIX STREET, RIDGACRE BRANCH	SO986917
Mid	WALSALL CANAL	ALDRIDGE ROAD, ALDRIDGE	SP040993
Mid	TITFORD CANAL	WOLVERHAMTON ROAD, OLDBURY	SO988878
Mid	TAME VALLEY CANAL	SALFORD BRIDGE	SP096901
Mid	TAME VALLEY CANAL	HOLLOWAY BANK	SO990939
Mid	TAME VALLEY CANAL	NEWTON ROAD	SP036940
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	CABLE ST. (JAMES MILL)	SO927977
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	PARK LANE EAST	SO966919
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	GOWER BRANCH	SO978903
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	BRADES ROAD	SO982900
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	BROMFORD LANE	SO995903
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	BRASSHOUSE BRIDGE, HIGH LEVEL	SP019889
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	OFF BAKER STREET, TIPTON	SO954917
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	OOZELLS ST. LOOP, SHEEPCOTE STREET	SP058866
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	SOHO LOOP, WESTERN ROAD BRIDGE	SP051880
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	KING EDWARD'S ROAD	SP060869
Mid	BIRMINGHAM & WOLVERHAMPTON CAN.	BRASSHOUSE BRIDGE, LOW LEVEL	SP019889
NE	DRIFFIELD CANAL	AT CANAL HEAD	TA029573
NE	DRIFFIELD CANAL	C100M D/S WANSFORD NEW TF DISCHARGE	TA069552
NE	DRIFFIELD CANAL	NEAR WHINHILL FISH FARM	TA051569
NE	DRIFFIELD CANAL	U/S NAFFERTON BECK	TA061565
NE	DRIFFIELD CANAL	WANSFORD	TA065561
NE	MARKET WEIGHTON CANAL	NEWPORT	SE856304
NE	POCKLINGTON CANAL	CHURCH BRIDGE	SE785452
NE	POCKLINGTON CANAL	HAGG BRIDGE	SE717451
NE	SELBY CANAL	BRAYTON	SE610303
NW	NAVIGATION COURSE	SALTERSFORD LOCK	SJ627750
Sou	CHICHESTER CANAL	A27 BY-PASS BRIDGE	SU859036
Sou	CHICHESTER CANAL	U/S CUTFIELD BRIDGE	SU842013
Sou	ROYAL MILITARY CANAL	APPLEDORE	TQ957291
Sou	ROYAL MILITARY CANAL	BILSINGTON	TR040339
Sou	ROYAL MILITARY CANAL	HAMSTREET	TR004324
Sou	ROYAL MILITARY CANAL	HYTHE	TR152347
Sou	ROYAL MILITARY CANAL	IDEN LOCK	TQ937245
SW	BRIDGWATER AND TAUNTON CANAL	ALBERT STREET, BRIDGWATER	ST295366
SW	BRIDGWATER AND TAUNTON CANAL	NORTH NEWTON (40M D/S SWING BRIDGE)	ST303311
SW	EXETER CANAL	30m u/s A379 Br Countess Wear	SX939894
SW	GRAND WESTERN CANAL	30m u/s Fenacre Bridge	ST070177
SW	GRAND WESTERN CANAL	Tiverton Basin 150m from Tearooms	SS966123
SW	KENNET & AVON CANAL (09)	AVONCLIFF	ST803600
SW	BUDE CANAL	FALCON BRIDGE	SS207060
Tha	BRENT/GUC	AT LOCK 100 BOSTON MANOR PARK	TQ167778
Tha	COLNE/GUC	ABOVE BATCHWORTH LOCK	TQ064940
Tha	LEE NAVIGATION	AT SPRINGHILL	TQ348876
Tha	LEE NAVIGATION (SUB B)	AT SUB B, KEIDES WEIR	TQ363953
Tha	LEE NAVIGATION (SUB F)	BELOW STANSTEAD LOCK	TL381120
Tha	LEE NAVIGATION (SUB H)	ABOVE MARSHGATE LANE, HERTFORD	TL331132
Tha	STORT NAVIGATION	ABOVE HARLOW LOCK	TL474129
Tha	STORT NAVIGATION	ABOVE TWYFORD MILL LOCK	TL493192
Tha	STORT NAVIGATION	AT ROYDON	TL417113
Tha	STORT NAVIGATION	AT SAWBRIDGEWORTH	TL486152
Tha	STORT NAVIGATION	NAVIGATION ABOVE SPELLBROOK LOCK	TL490178

Region	Canal Name	Site Name	NGR
Tha	GUC, AYLESBURY ARM	COLLEGE BRIDGE, ASTON CLINT	SP872140
Tha	GUC, WENDOVER ARM	ROADBRIDGE, TRING	SP924132
Tha	KENNET AND AVON CANAL	FROXFIELD BRIDGE	SU306678
Tha	KENNET AND AVON CANAL	MIDGHAM BRIDGE	SU551662
Tha	KENNET AND AVON CANAL	UFTON BRIDGE	SU618687
Tha	OXFORD CANAL (LOWER)	1.2KM BELOW KIDLINGTON STW	SP488112
Tha	OXFORD CANAL (MIDDLE)	HEYFORD BRIDGE	SP483247
Tha	OXFORD BRIDGE (UPPER)	CROPREDY BRIDGE	SP469465
Tha	BASINGSTOKE CANAL	EELMOOR BRIDGE	SU843528
Tha	GUC (ABOVE BERKHAMSTED)	TRING, ABOVE BERKHAMSTED	SP948121
Tha	GUC (BATCHWORTH REACH)	ABOVE SPRINGWELL LOCK	TQ043929
Tha	GUC (BLACK JACKS REACH)	COPPERMILL LANE, HAREFIELD	TQ040911
Tha	GUC (BOXMOOR REACH)	FISHERIES LANE, CHAULDEN (B)	TL038061
Tha	GUC (CASSIOBURY REACH)	GADE BANK CRESCENT, CASSIOBURY	TQ088964
Tha	GUC (COWLEY REACH)	HORTON ROAD BRIDGE, COWLEY REACH	TQ066800
Tha	GUC (COWLEY REACH)	ABOVE LOCK 97, COWLEY REACH	TQ149796
Tha	GUC (CROXLEY REACH)	LOTMEAD LOCK, CROXLEY REACH	TQ073944
Tha	GUC (DENHAM REACH)	A40 DENHAM	TQ053857
Tha	GUC (HAREFIELD REACH)	ABOVE MAPLE LODGE STW	TQ042922
Tha	GUC (KINGS LANGLEY REACH)	200M BELOW STATION FOOTPATH, K	TL077018
Tha	GUC (LADY CAPELS REACH)	HUNTON BRIDGE	TL082005
Tha	GUC (PADDINGTON ARM)	HAMPSTEAD ROAD, CAMDEN	TQ286840
Tha	GUC (PIX FARM REACH)	U/S BERKHAMSTED STW, PIX FARM	TL007071
Tha	GUC (PIX FARM REACH)	1500M DS BERKHAMSTED STW	TL027063
Tha	GUC (REGENT'S CANAL)	SOLEBAY ST MILE END	TQ363882
Tha	GUC (SLOUGH ARM)	BELOW THORNEY LANE NORTH	TQ044806