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North South Shared Aquatic Resource (NS SHARE)

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Review of methods for sampling invertebrates in deep rivers

Final Report

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DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT

INTERREG IIIA

North **S**outh **Sh**ared **A**quatic **Re**source (NS Share)

Water Framework Directive

A Directive establishing a new framework for Community action in the field of water policy (2000/60/EC) came into force in December 2000. This Water Framework Directive (WFD) rationalises and updates existing legislation and provides for water management on the basis of River Basin Districts (RBDs). The WFD was transposed into national law in Northern Ireland by the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2003 and in the Republic of Ireland by the European Communities (Water Policy) Regulations 2003. The primary objective of the WFD is to maintain the "high status" of waters where it exists, prevent deterioration in existing status of waters and to achieve at least ***"good status"*** in relation to all waters by 2015.

NS Share Study Area

NS Share is a cross border project and incorporates three River Basin Districts as set out in the joint North/South Consultation paper *Managing our Shared Waters*:

1. North Western International River Basin District (NWIRBD);
2. Neagh Bann International river Basin District (NBIRBD);
3. North Eastern River Basin District (NERBD).

The NW and NB are International River Basin Districts as they share their waters between Northern Ireland (NI) and Republic of Ireland (ROI). The NERBD is contained wholly within NI.

NS Share Project

The overall objective of the project is to strengthen inter-regional capacity for environmental monitoring and management at the river basin district level, to improve public awareness and participation in water management issues, and to protect and enhance the aquatic environment and dependent ecosystems.

The NS Share project aims to facilitate delivery of the objectives of the WFD within the project area between August 2004 and March 2008.

The NS Share project is funded by the EU INTERREG IIIA Programme for Ireland / Northern Ireland. The Department of the Environment (NI) and the Department of the Environment, Heritage and Local Government (ROI) are implementing agents for the project. Donegal County Council is the project promoter. Technical support is proivded by the Environment and Heritage Service an agency within the Department of the Environment (NI), and the Environmental Protection Agency (ROI). RPS Consulting Engineers in association with Jennings O'Donovan are the principal consultants.

Assistance was also provided by the Marine Institute, Central Fisheries Board, Geological survey Ireland, Geological survey Northern Ireland, Loughs Agency, North West Regional Fisheries Board, and Cavan, Leitrim, Longford, Louth, Meath, Monaghan, and Sligo County Councils.

Project publications are available at www.nsshare.com/publications

PREFACE

The work presented in this paper was carried out as part of the NS SHARE project, which is funded by the European Union INTERREG IIIA programme for Ireland/Northern Ireland. The implementing agents for the NS SHARE project are the Department of Environment (DOE), Northern Ireland, and the Department of Environment Heritage and Local Government (DEHLG), Republic of Ireland. Donegal County Council (DCC) is the project promoter.

REVIEW OF METHODS FOR SAMPLING INVERTEBRATES IN DEEP RIVERS

DRAFT INTERIM REPORT

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1. Introduction

1.1 Background

This review forms the first stage of the NS-Share Deep Rivers Sampling Project. This project was commissioned as the result of a shared requirement to identify appropriate method(s) for collecting representative macroinvertebrate samples from deep river sites in both the United Kingdom and the Republic of Ireland. This review builds on those performed by Wright *et al*. (1999) and Bass *et al.* (2000) by extending their scope to include the Republic of Ireland and by reviewing additional deep river sampling methods that are currently in use in the rest of Europe.

The sampling methodology developed for use at shallow river sites (timed pond-net collections) is comparatively simple with the result that a high degree of standardisation is possible (Murray-Bligh *et al*. 1997; McGarrigle *et al.* 1992). In addition, much effort has been devoted in the UK to documenting and reducing sources of error from sampling variation, sorting and identification in order to improve the precision of the technique (Dines and Murray-Bligh, 2000). In contrast, sampling deep waters is inherently more difficult, hazardous and time-consuming. The biologist has much less control of the sampling device and, as a consequence, it is difficult to sample all invertebrate habitats in proportion to their occurrence.

For the Environment Agency 1995 GQA survey (England & Wales), long-handled pond net sampling from the river-bank was recommended for deep-water sites on practical and safety grounds. However, the long-handled pond-net does not allow all habitats (marginal and benthic) to be sampled in proportion to their occurrence. This is necessary if a representative sample of the species present is to be achieved; a reduced assessment of quality will be given if species are missed at a site simply because they are out of range of the technique used. Much of the main channel is out of the range of the long-handled pond-net and, as a consequence, mid-channel taxa are under-represented. A variety of other methods are in regular use for the assessment of deep-water sites across Britain and Ireland, with the methodology adopted determined at a regional level or by the individual collecting the sample.

However, more appropriate methods for sampling the benthos of deep rivers, such as dredges and airlifts, are more time-consuming than the standard pond-net technique and usually require several people, resulting in increased costs. A protocol on standard sampling effort has yet to be defined for deep river devices. Furthermore, the representation of the benthic community using such devices relative to that achieved using the standard shallow river pond-net technique, has not been assessed so that the influence of the choice of technique (deep versus shallow technique) on the assessment of a site remains unknown.

The appropriate method(s) and protocols for sampling in deep waters need to be clearly defined. There is also a need to adopt standard approaches across ecoregions to ensure that in future, bio-assessments for deep rivers are as reliable as those currently available for shallow sites and comparable with them. In the context of the current review, deep-water sites found on large rivers, impounded rivers and re-engineered channels are included but techniques used in canals, lakes and ponds are also pertinent. Nevertheless, biological monitoring strategies for some of these other water bodies are the subject of specific investigations within the NS-Share programme.

1.2 Objectives

A scoping study (Wright *et al*. 1999, EA R&D Technical Report E71) recommended a series of field investigations designed to deliver clear guidance on the sampling method(s) to be used when collecting benthic invertebrate samples at deep-water sites, and when to apply such methods in preference to shallow water techniques. The report also proposed that a protocol for the collection of separate pond-net samples in the margins be defined. Subsequent investigations were detailed in a further report (Bass *et al*. 2001, EA R&D Technical Report E134).

The overall objective of this report is to review the techniques available for use in the collection of benthic invertebrate samples from deep-water sites, with the aim of selecting methods that will be tested in the field to determine a protocol for sampling benthic invertebrates in deep rivers.

The macroinvertebrate monitoring methods chosen for use at deep-water locations need to be both scientifically defensible and practical. This requires a suitable balance between the adequacy of information obtained and the availability and cost of manpower, equipment, and time constraints. In addition, Health and Safety issues must be paramount. The (UK) National Biology Technical Group provided recommendations to Environment Agency staff on the use of invertebrate sampling equipment in deep waters (National Biology Technical Group 2000), but this may need to be reviewed.

The specific objectives of this review are:

1. To review available techniques for the collection of benthic invertebrate samples from deep-water sites and, thus, inform a field trial to examine the most appropriate technique(s) to be used when sampling (a) the deep-water benthos and (b) the watercourse margins.
2. To inform protocols that give a clear indication of when to apply such methods in preference to shallow water techniques

1.3 Glossary

The following terms are used within this report:

ASPT	Average Score Per Taxon (for a sample).
BAMS	Biological Assessment Methods
BMWP	Biological Monitoring Working Party (defined taxa and scores).
BMWP Score	BMWP total score for a sample.
CEH	Centre for Ecology and Hydrology
EA	Environment Agency (England and Wales)
EPA	Environmental Protection Agency (Ireland)
EHS	Environment and Heritage Service (Northern Ireland)
IFE	Institute of Freshwater Ecology (now CEH)
IRTU	Industrial Research and Technology Unit (now EHS)
Ntaxa	Number of BMWP scoring taxa present.
Q-Value	EPA Quality Rating System (defined taxa and scores).
RIVPACS	River Invertebrate Prediction and Classification System.
SEPA	Scottish Environment Protection Agency

2. Literature Review Of Sampling Devices And Protocols For Deep Rivers

A bibliography of devices used for sampling benthic invertebrates from the natural substrata of rivers and streams was published by the Freshwater Biological Association in 1993, Occasional Publication No. 30 '*A new bibliography of samplers for freshwater benthic invertebrates*' (Elliott *et al*. 1993), which provided the starting point for the current review of literature on new sampling devices or protocols that may be useful for sampling in deep waters. Elliott *et al*. (1993) emphasised 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.

In view of the current lack of standardised protocols for sampling macroinvertebrates in deep waters, the lack of a significant breakthrough in sampling methodology is disappointing, but not unexpected. Hence in Section 2.2 of this report, it will be necessary to focus on the merits of the various deep-water sampling devices available. Those works considered to be of particular relevance to deep-water sampling are listed below:

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

Bretschko, G. and B. Schönbauer (1998). Quantitative sampling of the benthic fauna in a large, fast flowing river (Austrian Danube). *Archiv Fur Hydrobiologie* Supplement, **115**, 195-211.

Czerniawska-Kusza, I. (2004). Use of artificial substrates for sampling benthic macroinvertebrates in the assessment of water quality of large lowland rivers. *Polish Journal of Environmental Studies,* **13**, 579-584.

Depauw, N., V. Lambert, A. Vankenhove and A. B. Devaate (1994). Performance of 2 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.

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. (1981a). 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. (1981b). 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.

Haase, P., Lohse, S., Pauls, S., Schindehuette, K., Sundermann, A., Rolauffs, P. and Hering D. (2004). Assessing streams in Germany with benthic invertebrates: development of a practical standardised protocol for macroinvertebrate sampling and sorting. *Limnologica,* **34**, 349-365.

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.

Herrig, H. (1975). Der Bodensauger – ein neuartigesGerät zur Entnahme von Sohlenproben aus großen Fließgewässern. *Dt. Gewässerkdl. Mitt*., **19**, 104-107.

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.

Humpesch, U. H. and R. Niederreiter (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 River Kilometer 1889. *Archiv Fur Hydrobiologie* Supplement, **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** (2), 209-218.

Jackson, M. J. (1997). Sampling methods for studying macroinvertebrates in the littoral vegetation of shallow lakes. Broads Authority, Norwich.

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.

McGarrigle, M. L., Lucey, J. and Clabby, K. J. (1992). Biological assessment of river water quality in Ireland. In: *River Water Quality – Ecological Assessment and Control.* 371-393, Commission of the European Communities, EUR 14606 EN-FR, Luxembourg, 751pp.

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.

Ofenböck, G. and O. Moog (2000) The Danube-Net-Basket-Sampler - a simple but effective sampling gear for sampling benthic invertebrates in deep and large stony rivers. *Archiv für Hydrobiologie* Supplement, **115**, 557-573.

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.

Pehofer, H. E. (1998). A new quantitative air-lift sampler for collecting invertebrates designed for operation in deep, fast-flowing gravelbed rivers. *Archiv Fur Hydrobiologie* Supplement, **101**, 213-232.

Petermeier, A. & Schöll, F. (1996) Das hyporheische Interstitial der Elbe – Methodenrecherche. Bundesanstalt für Gewässerkunde, Koblenz. BfG-1038.

Swift, M. C., T. J. Canfield and T. W. LaPoint (1996). Sampling benthic communities for sediment toxicity assessments using grab samplers and artificial substrates. *Journal of Great Lakes Research* **22**: 557-564.

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

Voshell, J. R., S. W. Hiner and R. J. Layton (1992). Evaluation of a benthic macroinvertebrate sampler for rock outcrops in rivers. *Journal of Freshwater Ecology* **7**: 1-6.

Wagner, F., H. Zimmermann-Timm and W. Schonborn (2003). The Bottom Sampler - a new technique for sampling bed sediments in streams and lakes. *Hydrobiologia* **505**: 73-76.

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. 158pp.

Wright, J.F., Winder, J.M., Gunn, R.J.M., Blackburn, J.H., Symes, K.L. and Clarke, R.T. (2000). Minor local effects of a River Thames power station on the macroinvertebrate fauna. *Regul. Rivers: Res. Mgmt*. **16**: 159-174.

Although there is apparently a wide array of techniques, many of the different designs are refinements to improve effectiveness when collecting quantitative samples, refinements that are unnecessary for routine bio-assessment. Current bio-assessment methods for shallow rivers rely on species occurrence or semi-quantitative samples of macroinvertebrates, with more effort put into sampling habitats in proportion to their occurrence than to produce quantitatively accurate samples from each habitat. Methodologies for routine bio-assessment of deep rivers should be consistent with those used in shallow rivers in this respect.

The methodologies available for collecting macroinvertebrate samples from deep waters can be broadly categorized into:

- Nets
- Grabs
- Dredges
- Air-lifts
- Freeze-corers
- Artificial substrates
- Light traps

Some of these and allied methodologies have been reviewed for their use in collecting invertebrate samples from amongst macrophytes by Jackson (1997) who concluded that a pond net was comparable to other more complex devices. Although macrophytes are frequently present in deep rivers, samplers specifically designed for collecting macroinvertebrates from amongst macrophytes are not considered here. Freeze-corers are not considered either, as they are designed to collect quantitative samples of the hyporheos (fauna interstitial within the sediment) and are regarded as unnecessarily complex for regular biomonitoring.

Although artificial substrates are used regularly in some countries (e.g. Austria) they are considered selective and require two site visits to collect a sample. Light traps have the same drawbacks, and do not appear to have widespread use. Hence, we will restrict our consideration to nets, grabs, dredges and air-lifts.

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. All equipment tested was suitable for use from a small boat, larger equipment requiring a winch was not tested. 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.

According to Elliot & Drake (1981a), grabs do not perform well where the substrate is coarse, particularly at sites where the water is deep (more than 1m) and the current is fast (more than 0.5m s^{-1}). Furthermore, grabs often leak around the moving parts, resulting in loss of the fine fraction during lifting, and this problem is exacerbated by stones or other debris becoming trapped in the jaws and preventing them from closing properly. These problems restrict grabs to soft sediments in sluggish rivers, and exclude them from use in regular biomonitoring. In field trials on the Danube, the Petersen Grab and Slurp Gun (Herrig 1975) consistently performed badly when compared to the FBA Air-lift and a Deep Water Freeze Corer designed for sampling hyporheos, particularly in coarse gravelly sediments (Bretschko & Schönbauer, 1998). The same result was found on the River Elbe (Petermeier & Schöll 1996). Both these studies recommend the Air-lift.

Drake & Elliott (1982) included 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 1. Note that the original Medium Naturalist's dredge referred to in Elliott and Drake (1981b) 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 Air-lift, as described in Murray-Bligh *et al.* (1997), is essentially based on the Mackey Air-lift (Mackey 1972). Hence, Table 1 offers a comparison of the two genuine deep water sampling devices in frequent use in the UK and Republic of Ireland, namely dredges and airlifts. In addition, the Mini Van-Veen grab, the Ekman grab, and the FBA Air-lift (not featured in Table 1) are used on occasions throughout Europe. 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, hence, are inappropriate for regular biomonitoring.

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, bank sweep pond-net and 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 of the whole water course. The long-handled pond-net has subsequently been found to be unwieldy to use from a boat (Bass *et al*. 2000). This suggests that the retention of a modified shallow-water protocol based solely on a long-handled pond-net should be restricted to very narrow drainage ditches and that an alternative deep-water protocol must be used in wider channels.

Table 1 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 sampling protocol.

Table 1 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 the specific design and construction can influence the effectiveness of grabs, with these factors largely dependent upon the manufacturer.

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

3. Current Procedures Employed For Sampling Deep Rivers

3.1 Introduction

In order to assess the current protocols used by the Environment Agency (England & Wales) for sampling deep rivers, Wright *et al.* (1999) sent a questionnaire to all Area Biologists working for the EA. A copy of the questionnaire may be found in Appendix 1. This questionnaire included a question to determine the biologists' perception of what is a "deep water site". There 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. Wright *et al.* (1999) had an excellent response, receiving replies 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 Environment and Heritage Service in Northern Ireland. Replies were received from 3 of the 7 SEPA laboratories and also from EHS.

To extend this work we have sent the questionnaire to workers in the EPA in the Republic of Ireland (so far receiving replies from 2 of the 3 area offices) and to other workers involved in bioassessment across Europe (so far receiving replies from Austria, Czech Republic, France, Germany and Latvia). Here we have compiled the results from all these trawls.

3.2 Definition of a deep river

<u>Question 1 – Definition.</u>

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

	EA	EHS	SEPA	EPA	Europe
Site too deep to take a reliable kick/sweep sample?	23	1	3	2	5
Site too deep to sample full width with a pond-net?	7	1		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				1
Site with main channel deeper than 80 cm	1				2
Site with main channel deeper than 100 cm	4	1	1	1	3
Site with main channel deeper than 150 cm	1			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	1	1		
Site with entire width deeper than 150 cm				1	

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 protocol used in shallow streams and rivers. Of the respondents 34 selected this response (90%).

Twenty biologists specified the main channel water depth as part of their definition. Depths ranged from 50 cm to 150 cm, the most common value being 100 cm (specified 10 times). Almost as many based their definition on the depth of the entire river width. Eighteen biologists suggested depths ranging from 40 to 150 cm. Again, the most common value was 100 cm (specified 10 times). Three 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. Eleven biologists specified Health and Safety considerations in qualifying their definitions and a further twelve commented on substratum type, in particular the difficulties of sampling soft sediments underlying otherwise shallow water.

3.3 Sampling procedures used in deep rivers

<u>Question 2 – Sampling method</u>

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

	EA	EHS	SEPA	EPA	Europe
Yes	1				
No	25	1	3	1	5

Of the 35 laboratories answering "No", there were many biologists who 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 2.

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:

	EA	EHS	SEPA	EPA	Europe
Sampling involving use of a boat	7		1	1	2
Sampling involving use of a bridge	3			1	

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.

The majority of area laboratories (33), covering 7 countries, took marginal sweep samples in deep rivers. In addition, 23 laboratories, from 5 countries, used 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, the dredge (used by 22 area laboratories and 7 countries) was the most frequently used sampling apparatus. Grabs were used (or had been used) in 7 countries, but only by 8 area laboratories, one infrequently (EA) and another discontinued (EPA). Four EA laboratories used an airlift sampler (one not routinely), with this device being used in a further 2 European countries also.

Additional minor methods listed by respondents included marginal kicks, the use of an artificial substrate, scuba divers, and an extended search of large, retrievable objects, such as boulders and traffic cones. A combination of techniques was used in some countries also.

In mainland Europe, artificial substrate (gravel in a potato sack) is used on the river Danube (Ofenböck & Moog 2000), as are more complex methods such as freeze-corers (Humpesch & Niederreiter 1993).

Seven of the 26 EA laboratories, 1 SEPA, 1 EPA (discontinued) and 4 other European countries routinely used 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 laboratories sometimes used a bridge when operating an airlift sampler and two when using a dredge.

Table 2 Sampling methods for deep river sites employed by the EA, EHS, EPA and SEPA, each by area, and Europe by country. (NR indicates not routinely, ± indicates discontinued, and brackets the number of countries using that methodology).

Region	Area	Sweep	Distur-bance	Dredge	Air -lift	Grab	Marginal Kick	Search	Artificial Substrate	Other
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	+	+	+						

Region	Area	Sweep	Distur-bance	Dredge	Air -lift	Grab	Marginal Kick	Search	Artificial Substrate	Other
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			+			
EPA	Southern	+	+	±		±				
	Dublin	+	+							
Austria		+		+	+	+			+	Freeze core Scuba
Czech Republic		+		+	+					
France				+		+			+	
Germany										
Greece		+	+			+				Sweep + grab
Latvia						+				
Totals		33 (7)	23 (5)	22 (7)	6 (3)	8 (7)	2 (2)	1 (1)	3 (3)	

4. Previous Comparisons

Comparisons between methods have been made by various workers, both in terms of the use of the equipment and its efficiency. Notable are the works of Jackson (1997), Turner & Trexler (1997), Bretschko and Schönbauer (1998), Wright *et al*. (1999), and Bass *et al*. (2000). The first two of these comparisons addressed methods of collecting macroinvertebrates from submerged vegetation and, although macrophytes are encountered frequently in deep rivers, these methods are essentially outside the remit of this review; they are included in this section for completeness and as they provide additional useful information.

4.1 Jackson (1997) and Turner & Trexler (1997).

Both these works compared the efficiency of methods suitable for collecting macroinvertebrates from waters too deep to sample by standard kick sample techniques. Jackson (1997) produced an extensive literature review of the methods available for collecting macroinvertebrates from lake littorals and conducted a desk study of their practical use and efficiency. He concluded that the pond net, used from a boat was as good as any other technique, in terms of cost, ease and speed of use, and perceived efficiency of capture of species. Turner & Trexler (1997) compared various methods experimentally in heavily vegetated sites in the field, and also concluded that the sweep net was efficient at describing the community, together with the stovepipe (a cylinder used to isolate a vertical water column combined with the use of sweep netting inside) and a funnel trap; Hester-Dendy artificial substrates, minnow trap, a benthic corer, and a plankton net were ineffective. It was noted that the number of species recorded was proportional to the number of individuals, with the techniques most effective at capturing individuals producing the best description of the community.

4.2 Bretschko & Schönbauer (1998)

Working entirely in difficult conditions in the River Danube (both deep and of high velocity), Bretschko and Schönbauer (1998) compared four quantitative methods of deep water sampling. The Petersen grab, a vacuum driven Slurp Gun (Herrig 1975), a modified FBA Air-lift (Pehofer 1998) and a Deep Water Freeze Corer designed for sampling hyporheos were compared. Three sites were sampled on three occasions. The Air-lift consistently produced the most individuals and most species, and was the preferred method. Samples from the Petersen grab and Slurp Gun were indistinguishable; both these methods consistently underestimated many taxa. The Deep Water Freeze Corer was intermediate, both in terms of numbers of individuals and species composition. The same result was found on the River

Elbe (Petermeier & Schöll 1996). Using the modified FBA Air-lift, Pehofer (1998) found significant differences in community composition between deep water samples and samples collected from an adjacent gravel bar using a Hess sampler. This suggests that samples from only the shallow or only the deep sections of rivers fail to represent community composition as a whole.

4.3 Wright *et al*. (1999)

4.3.1 Practical Use

As well as analysing data from field trials, the work of Wright *et al.* (1999) compared the relative merits of different sampling techniques as perceived by workers involved in regular monitoring by means of a questionnaire, responses of which are included in section 3 of this review. Eight techniques in use within the EA, SEPA and IRTU (marginal sweep, long-handled pondnet, dredge, airlift, modified Van Veen or Ekman grab, marginal kick sample, deep water kick sample and artificial substrates) were compared in terms of their perceived ease of use, efficiency, and the time in the field and the laboratory to process the sample. Each technique was given a "score" on a 3 point scale, with workers asked to comment on the advantages and disadvantages of the methods used in their area.

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 reproduced in Table 3.

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).

Table 3 Responses to question on some of the practical advantages and disadvantages of alternative procedures for sampling in deep water (Wright et al., 1999). 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	good	short	short
	14 + (5)	11 + (1)	12 + (3)	7
	moderate	moderate	moderate	moderate
	5	6 + (4)	5 + (2)	8 + (3)
	complex	poor	long	long
	1	2	1	4
Disturbance of substrate	simple	good	short	short
	7 + (4)	3 + (2)	6 + (3)	2
	Moderate	Moderate	Moderate	Moderate
	7	11 + (2)	7 + (1)	10 + (3)
	complex	poor	long	long
	1	1	2	3
Dredge	simple	good	short	short
	4 + (1)	4	7	1
	moderate	moderate	moderate	moderate
	8 + (1)	8	6 + (1)	5 + (1)
	complex	poor	long	long
	6	6 + (2)	5 + (1)	12
Airlift	moderate	good	moderate	long
	2	1	2	3
	complex	moderate	long	
	1	1	1	
		poor		
		1		
Grab	simple	good	moderate	moderate
	(1)	(1)	(1)	(1)
	moderate	moderate	long	long
	(2)	(1)	(2)	(1)
		poor		
		(1)		
Marginal kick	simple	good	short	short
	2	1	1	1
		moderate	moderate	moderate
		1	1	1
Deep water kick	simple	good	short	short
	1	1		

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

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

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 were listed, the number of responses was very limited and it would be unwise to attempt to draw any firm conclusions.

However, the workers were only asked to comment on the techniques that they had practical experience of using. For the EA, SEPA and IRTU workers surveyed, 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, the currently applied EA sampling manual, Murray-Bligh *et al.* (1999), recommended 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.

From the answers to the questionnaire, it was apparent that, whereas a majority of Environment Agency biologists had used long-handled pond-nets to sample the river bed in deep rivers, almost as many had used dredges. In contrast, few 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 procedures for deep water sites are poorly standardised.

4.3.2 Field Trials

A). Dredge sampling on the R. Thames

In July 1996 the IFE was commissioned to undertake a biological survey of the macroinvertebrate fauna of the R. Thames in the vicinity of Didcot Power Station (Wright *et al.* 2000). 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 than 1 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 upwards 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 wash 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 were more than two trawls required to achieve a representative sample 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 sub sample 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 sub sampling 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.* (2000). 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, where the Medium Naturalist’s dredge was found to be ineffective on mud).

B). Preliminary Field Trials, October 1998.

Members of the RIVPACS team also saw the Yorkshire pattern Air-lift in action at one or two locations where it was the preferred EA technique for routine monitoring and where dredge sampling was 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 initial 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.

Some members of the RIVPACS team also 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 bank side 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.

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 used to sweep 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 river width. Finally, the dredge was used from the bank. The weak link on the dredge (a polythene tie-wrap used as a breakable fitting on one side of the dredge to avoid wedging and loss of the apparatus) broke several times during the sampling operation but eventually, three replicates were obtained. The substratum collected by the dredge was 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 wash the dredge samples exceeded that for the air-lift samples because the air-lift samples are to some extent self-rinsing due to the flow of water through the collection net during sampling.

Table 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 substratum encountered sampling from the bridge.

Table 4 R. Calder at Methley Bridge. Raw data for each sampling method employed in a preliminary field trial on 8.10.98

	Margin sweep			Long-handled pond net			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) only the combined margin and air-lift samples combined retrieved all 12 BMWP families. Closer inspection of Table 5 reveals that only air-lift replicate 3 collected Dendrocoelidae at this site. The combined margin and long-handled pond-net samples and combined margin and dredge samples 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. In addition, it was clear that, the dredge was difficult to use at this site and generated large samples that took a long time to process.

Table 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 sweep only	Long-handled pond net + 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 protective skirt surrounding the dredge net was damaged by trawling over the hard substratum and several throws were required to obtain each sampling unit.

The raw data (Table 6) indicates that only 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 7), only the combined margin and air-lift samples generated all

13 BMWP taxa, because only the air-lift captured Sphaeriidae (Table 6). The combined margin and dredge and the combined margin and long-handled pond net captured 12 and 11 BMWP families respectively. Only the air-lift adequately represented the centre channel fauna of the Allerton Bywater site.

Table 6 R. Aire at Allerton Bywater. Raw data for each sampling method employed in a preliminary field trial on 8.10.98

	Margin sweep			Long-handled pond net			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 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 sweep only	Long-handled pond net + 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

4.4 Bass *et al*. 2000

4.4.1 Field trials

Here, Bass *et al*. (2000) compared the long-handled pond-net, Medium Naturalist's dredge, Mackey/Yorkshire pattern airlift, and marginal sweep in a series of field trials at six sites across England and Wales. To ensure a broad scope for comparisons between sampling methods, a range of representative deep-water sites known to support diverse macroinvertebrate communities were selected for the trials (Yorkshire Derwent, Yorkshire Ouse, Great Ouse/New Bedford River, South Drove Drain, River Huntspill, River Severn). A boat was used at all sites, providing a stable platform from which to take the airlift and long-handled pond net samples. The operators who collected the primary samples were experienced in the use of an extended long-handled pond-net (IFE), Medium Naturalist's dredge (IFE) and Mackey/Yorkshire pattern airlift (EA). In order to compare the selected methods in a systematic way, the sampling effort and range of habitat types sampled was consistent between each replicate sample. Six replicate samples per technique were used to provide a robust indication of sample variability, taxon accretion and for comparison of methods.

The prime objective of the study was to compare the performance and yield of the specified deep-water sampling devices. Samples were collected in the same region of riverbed, in an upstream sequence to prevent dislodgement of the fauna and downstream drift into as yet un-sampled river bed and to avoid sampling the same area more than once. The sampling staff were asked to restrict their sampling effort for each deep-water replicate sample to an area of about 1.5 m^2 so that comparable areas of riverbed were sampled by each method. However, this proved difficult, as the precise area of riverbed sampled effectively by some devices was difficult to gauge.

This comparison excluded an assessment of the performance of the full variety of deep-water sampling approaches used for regular biomonitoring. In some respects such comparisons would have been informative, but the critical aspect of gauging the effectiveness of individual sampling devices would have been compromised by the need to compare samples of different sizes and, in some cases, derived from material collected with more than one device (e.g. combined dredge and standard pond net samples).

Gauging whether a valid (representative) replicate sample has been taken needs to be unambiguous. Samples were rejected whenever a mechanical failure occurred (e.g. interruption of the air supply to the airlift, the dredge snagging or net bag becoming tangled).

Replacement samples then taken. Where a sample was excessively large (with large quantities of organic/inorganic debris), a sub-sample of 4 litres maximum (including sufficient preservative volume) was retained, after elutriating the whole sample thoroughly to reduce the bulk.

Samples were preserved and processed in the laboratory. Macroinvertebrates were identified to BMWP family level and the abundance of each BMWP family in the replicate sample was counted to maximise accuracy of between-method assessments.

Preliminary measurement of inter-operator variability

More extensive data were obtained with two of the deep-water sampling devices to test variability between individuals using the equipment. This inter-operator comparison was undertaken at single sites where the particular devices were known to work effectively.

For each device, three series of six replicate samples were taken by three different people (18 samples in total). All were experienced with the particular sampling technique and equipment. The BAMS exercise was applied to the airlift and the dredge. Such a test was not felt to be appropriate for the long-handled pond net as it had not been used previously by the individuals taking the samples.

The Yorkshire Derwent site (Stamford Bridge) was used to compare three operators using the airlift sampler. This was done by three EA staff familiar with the equipment and the site. The BAMS exercise for the dredge was undertaken in Anglian Region (South Drove Drain) by two IFE/CEH staff and one from Anglian Region (Spalding). All were experienced in using the dredge.

Margin Pond-net samples

The field trial included a programme for sampling the watercourse margins with a pond net. Margin sampling and its contribution to site quality assessments required the collection and analysis of separate data series to facilitate interpretation.

A further consideration was the comparison of the fauna from deep-water habitats with the fauna in margin habitats.

The field trial examined the potential benefits of:

- a 3-minute pond net sample from the watercourse margins in preference to a 1-minute marginal sample

- sampling the margin zone of one or both banks
- utilising results from both the watercourse margins and mid-channel habitats.

Sampling activity

Deployment and recovery of the boat, carrying sampling equipment and samples took about two hours at each site, with the rest of the day taken up with the extensive sampling activities. On this basis, the more limited sampling activities during routine monitoring will permit sampling to be completed at two or possibly three deep-water sites in a standard working day. This assumes <1 hour travelling time between sites.

Comparison of sample processing time

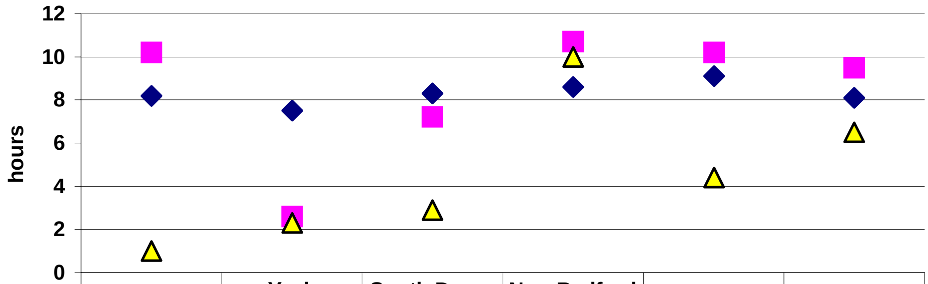
Two separate steps were involved in sample processing: (1) macroinvertebrate detection and recovery (referred to as sort time) and (2) identification and counting. The sort time for the different sampling devices and different sites was already identified as an important practical consideration in the assessment of, and subsequent recommendation of a deep river sampling method.

The time taken to sort macroinvertebrates sampled by each method was examined for inter-operator variability (Figure 1). It should be emphasised that sample size varied greatly between methods and sites, despite the attempt to obtain each replicate from a consistent area. Mean sort time was around 7 hours per replicate, with overall sort time ranging very widely from 0.3-20 hours.

The time required to recover macroinvertebrates from the deep-water samples was strongly influenced by sample debris volume (reflecting site conditions), the area sampled (as far as possible kept constant) and the characteristics of each sampling method. The sample processing time was also extended by the need to gauge sample device performance in terms of taxon abundance. Family abundance is usually only recorded in $\log_{10}$ categories in standard EA biomonitoring.

In general, the sort times for sampling devices and sites reflected sample volume. The mean sort time required for airlift samples was the most consistent between sites and reflected the consistency in the volume and type of debris obtained (Figure 1). The dredge produced small samples at one site, whilst the long-handled pond net provided samples of relatively small mean volume at 4 of the 6 sites. Compared to sample processing for standard assessments, the quantities of material collected with the dredge and the airlift were not exceptionally large, but the high proportion of fine detritus found at some of the sites studied extended the sort times

Figure 1



	York Ouse	York Derwent	South Drove Drain	New Bedford River	Huntspill	Severn
airlift	8.2	7.5	8.3	8.6	9.1	8.1
dredge	10.2	2.6	7.2	10.7	10.2	9.5
long-handled pondnet	1	2.3	2.9	10	4.4	6.5

Figure 1 Comparison of mean sample sort times between sampler types and sites

The rate at which new BMWP taxa were recovered during sample sorting and identification was compared between airlift, dredge and long-handled pond net. Mean recovery rates of BMWP taxa (Ntaxa) per hour were: airlift - 2.06; dredge - 2.14; long-handled pond net - 2.98. The airlift samples, though slower to sort, provided the most consistent return per hour.

Table 8 Mean and standard deviation (SD) of the number of BMWP taxa (Ntaxa), BMWP Total Score and Average Score Per Taxon (ASPT), by site for the four techniques tested. Additional replicates for different operators shown for the Air-lift and Dredge.

BMWP NTaxa

	Airlift		Dredge		LHP		Margin	
	mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Y. Ouse	16.8	(1.2)	8.3	(2.1)	5.8	(1.7)	12.7	(2.2)
Y. Derwent	21.2	(0.7)	16.5	(2.9)	14.5	(2.2)	21.5	(2.9)
Y. Derwent 2	25.0	(2.6)						
Y. Derwent 3	22.3	(2.0)						
South Dr.	20.0	(1.2)	18.0	(2.7)	18.2	(0.9)	24.2	(3.0)
South Dr 2			19.8	(2.4)				
South Dr 3			18.8	(1.9)				
New Bedford	19.5	(1.9)	20.8	(3.4)	20.2	(1.7)	25.3	(2.7)
Huntspill	9.2	(1.9)	9.2	(1.1)	6.3	(0.6)	13.3	(3.0)
Severn	18.8	(2.0)	13.7	(6.0)	15.3	(5.0)	10.7	(3.9)

BMWP Total Score

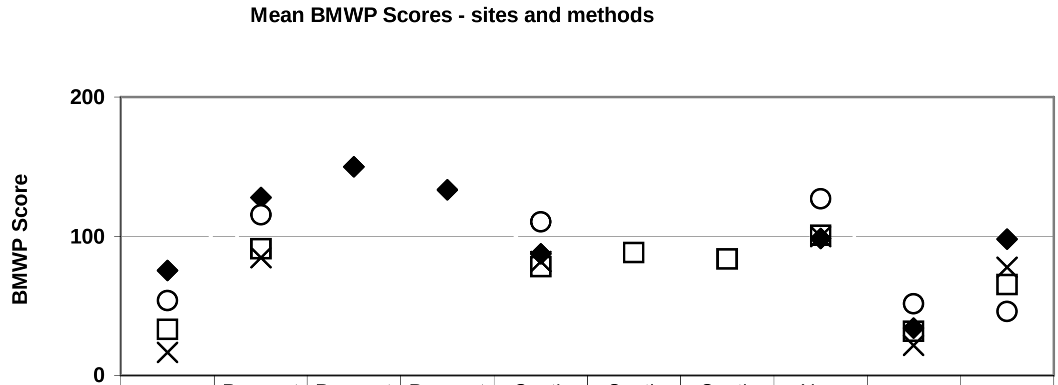
	Airlift		Dredge		LHP		Margin	
	mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Y. Ouse	75.6	(6.3)	33.3	(12.8)	16.3	(5.6)	53.7	(13.8)
Y. Derwent	128.0	(6.9)	90.8	(18.4)	84.7	(12.3)	115.5	(19.4)
Y. Derwent 2	149.7	(20.8)						
Y. Derwent 3	133.2	(8.6)						
South Dr.	87.5	(7.7)	78.3	(14.0)	81.8	(6.9)	110.3	(13.8)
South Dr 2			88.5	(10.8)				
South Dr 3			83.7	(11.5)				
New Bedford	98.5	(10.7)	100.7	(19.7)	99.8	(10.5)	126.8	(16.2)
Huntspill	34.2	(11.3)	31.8	(5.1)	21.5	(2.7)	51.7	(14.0)
Severn	97.8	(12.8)	65.5	(34.8)	77.7	(33.2)	45.8	(20.5)

ASPT

	Airlift		Dredge		LHP		Margin	
	mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Y. Ouse	4.50	(0.09)	3.84	(0.78)	2.72	(0.37)	4.19	(0.41)
Y. Derwent	6.06	(0.21)	5.49	(0.36)	5.86	(0.30)	5.36	(0.31)
Y. Derwent 2	5.97	(0.30)						
Y. Derwent 3	5.98	(0.20)						
South Dr.	4.37	(0.18)	4.33	(0.18)	4.50	(0.22)	4.55	(0.09)
South Dr 2			4.46	(0.09)				
South Dr 3			4.39	(0.21)				
New Bedford	5.02	(0.14)	4.81	(0.24)	4.94	(0.14)	5.00	(0.17)
Huntspill	3.65	(0.47)	3.44	(0.18)	3.21	(0.09)	3.83	(0.23)
Severn	5.17	(0.21)	4.38	(1.19)	4.95	(0.55)	4.19	(0.48)

BMWP Scores

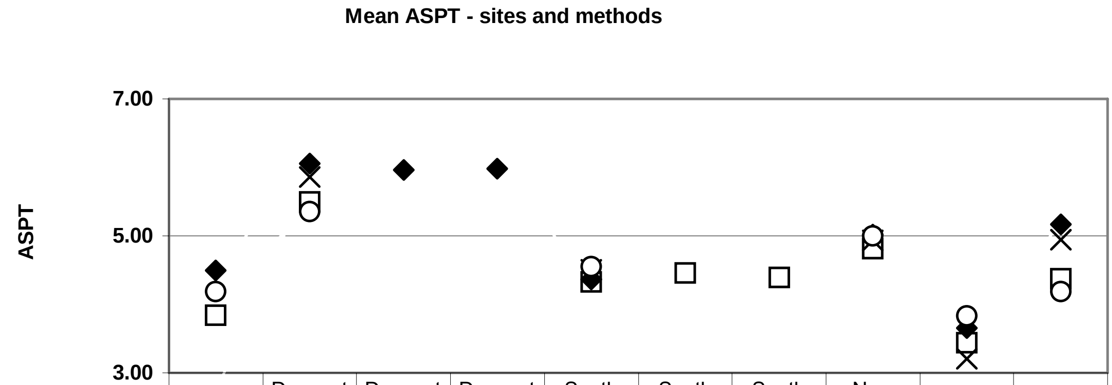
No one method yielded consistently higher BMWP Scores across all sites. The airlift samples from the Yorkshire Ouse and Derwent generated the highest BMWP Scores in all replicates compared. The mean BMWP Scores derived for each site confirm that the airlift sampler produced the highest BMWP Scores at 5 of the 6 sites, when comparisons are restricted to the deep-water sampling methods (Figure 2).



	Y.Ouse	Derwent 1	Derwent 2	Derwent 3	South Drove 1	South Drove 2	South Drove 3	New Bedford	Huntspill	Severn
◆ airlift	76	128	150	133	88			99	34	98
□ dredge	33	91			78	89	84	101	32	66
× long-h p-net	16	85			82			100	22	78
○ margin pondnet	54	116			110			127	52	46

Figure 2 Mean BMWP Score for each sampling method and site

The ASPT derived for each replicate sample generated similar trends to the BMWP Scores. The airlift produced the most consistent ASPT within sites. The mean ASPTs derived for each site confirm that the airlift sampler also produced the highest ASPTs at 5 of the 6 sites, when comparisons are restricted to the deep-water sampling methods (Figure 3).



	Y.Ouse	Derwent 1	Derwent 2	Derwent 3	South Drove 1	South Drove 2	South Drove 3	New Bedford	Huntspill	Severn
◆ airlift	4.50	6.06	5.97	5.98	4.37			5.02	3.65	5.17
□ dredge	3.84	5.49			4.33	4.46	4.39	4.81	3.44	4.38
× long-h p-net	2.72	5.86			4.50			4.94	3.21	4.95
○ margin pondnet	4.19	5.36			4.55			5.00	3.83	4.19

Figure 3 Mean Average Score Per Taxon for each sampling method and site

Taxon accretion rates

Smoothed 'species' accretion curves were created for BMWP scoring taxa using the software package 'Species Diversity and Richness - Version 2' (PISCES Conservation Ltd, 1998) to determine the number of samples required sufficient to capture all the taxa present at the site that could eventually be captured by that sampling method. This approach highlighted the differing results generated by choice of sampling method between sites. For the Severn and New Bedford sites, sampling method had least influence on the total taxa recorded, or on accretion rates. Two sites (Huntspill and South Drove) showed similar taxon recovery by airlift and dredge, with relatively poor recovery rates by the long-handled pond net replicate samples. The Yorkshire Ouse and Derwent displayed strongly contrasting taxon recovery and accretion rates between all methods. The long-handled pond net produced the poorest total taxa count at four of the six sites.

Sampling effort and yield were compared, in terms of the relationship between the calculated taxon accretion rate and numbers of animals recovered and identified. The standard RIVPACS sampling approach is designed to recover a minimum of 70% of the Ntaxa present at a site without compromising site quality assessment. Bass *et al*. (2000) selected an 80% recovery rate of the maximum Ntaxa recorded at each site for comparisons. The time required to achieve 80% recovery at each site was calculated by combining the known sort time for each sampling method, the number of samples and equivalent number of specimens requiring identification and counting (Table 9). It should be noted that the sample processing included more precise estimations of taxon abundance than applies in the standard RIVPACS approach, to aid sampling device yield comparisons.

Table 9 Comparison of time (hours) and the equivalent number of sample replicates required to recover 80% of the BMWP Scoring Taxa recorded at each site by the deep-water sampling methods tested. (Fastest options highlighted). Note variable results between BAMS series. N/A denotes the yield cannot reach 80% of the recorded taxa

BMWP NTaxa

	Airlift			**Dredge**			**LHPN**		
	Samples to yield 80% taxa	Sort time per sample	sort time + Identification	Samples to yield 80% taxa	Sort time per sample	sort time + Identification	Samples to yield 80% taxa	Sort time per sample	sort time + Identification
Y. Ouse	2	8.2	**20.4**	6	10.2	73.2	N/A	N/A	N/A
Y. Derwent	4	6.2	32.8	5	2.6	21.2	N/A	N/A	N/A
Y. Derwent 2	2	8	**20**						
Y. Derwent 3	3	8.3	31						
South Dr.	3	8.3	30.9	3	5.2	**21.6**	N/A	N/A	N/A
South Dr 2				3	8.9	32.7			
South Dr 3				3	7.3	27.9			
New Bedford	2	8.6	**21.2**	2	10.7	25.4	2	10	24
Huntspill	3	9.1	**33.3**	4	10.2	48.8	N/A	N/A	N/A
Severn	2	8.1	**20.2**	3	9.5	34.5	3	6.5	25.5

Inter-operator differences

If the biological information obtained for a site is highly dependent on who took the sample, then it is more difficult to assess spatial and temporal changes when different personnel have been used. It is, therefore, important to assess the sampling variability between operators.

In their study, Bass *et al.* (2000) assessed differences between operators in their values for the biological indices Ntaxa, ASPT, BMWP Score and total number of individuals per sample. This was possible at two sites, at the Yorkshire Derwent site, three operators each took six replicate airlift samples, and at the South Drove Drain site, three operators each took six replicate dredge samples. Tests for statistically significant differences between operators were performed using both parametric one-way analysis of variance (ANOVA) and non-parametric Kruskal-Wallis ANOVA by ranks. Inter-operator differences were not statistically significant for any index, for either the airlift or dredge sampling method. This may have been due to the small number of replicates and operators involved and hence the lower power of the test to identify differences. However, the estimates of the practical importance of inter-operator effects on total variance in index values, which was not biased by replicate or operator number, suggest that there is little or no inter-operator effect on ASPT values. For the airlift sampling method, the difference between operators may account for 20-30% of total replicate variation in both Ntaxa and BMWP score (which are highly correlated). For the dredge sampling method, difference between operators may account for 20-30% of total replicate variation in total number of individuals recovered. A more intensive replicated sampling study across a range of sites is needed to improve assessments of inter-operator effects.

This comparison of field sample operators excluded any potential bias introduced at the laboratory sample sorting/identification stage. Previous tests have indicated that sample sorting/identification errors are relatively small, when experienced personnel are used.

Margin Pond net Samples

Bass *et al.* (2000) also sampled habitats at the watercourse margin, separately from the deep-water zone, in order to compare the distribution of BMWP taxa between the margins (both banks) and the community in deep-water habitats. This also provided scope to assess the contributions to site quality status from deep-water and margin habitats and the effects of their contrasting representation at each site on Ntaxa and ASPT. The margin samples targeted the habitats accessible when using a standard FBA pond net (2m handle). The samples did not incorporate any manual search for fauna strongly attached to objects and fauna on the water surface film.

A series of six one-minute pond net margin samples were taken at each of the sites. The Ntaxa, BMWP Scores and ASPTs were examined as: (1) separate 1-minute replicates, (2) three 1-minute replicates from each bank, (3) two composite 3-minute samples, one from each bank. In addition, the margin pond net taxon composition was compared: (4) between sites, opposite banks of the same watercourse and with the contemporary deep-water sample replicates. Non-BMWP taxa, which appeared in some samples, were excluded from interpretations.

The 1-minute pond net sample replicates from the margin generally yielded higher Ntaxa and BMWP Scores than the deep-water methods at South Drove, New Bedford River and the Huntspill. On the Severn, margin sample BMWP Scores were most variable and generally lower than those from the deep-water samples, whereas margin samples yielded intermediate results from the Yorkshire Ouse and Derwent. The ASPTs for margin samples showed similar trends to the BMWP Scores. Two of the six sites yielded higher mean ASPTs from margin pond net samples than the concurrent deep-water sampling methods.

When the opposite banks were compared there appeared to be consistent differences between BMWP Scores for the two banks at two out of the six sites. The clear differences in results between opposite banks of the Huntspill and Severn were not evident in the ASPT values for the 6 replicates.

The degree of variability in taxon representation between 1-minute margin replicate samples was similar to, or greater than the deepwater samples at corresponding sites. Composite margin samples were generated by combining the number of different taxa recorded (Ntaxa) in the three 1-minute replicate samples from each bank which indicated that margin pond net sampling for one minute was less effective than sampling for three minutes. Nevertheless, 1-minute margin replicates still yielded higher scores than most deep-water replicates at the South Drove, New Bedford and Huntspill sites.

Where between-bank differences in margin replicate scores are notable (Yorkshire Ouse, Huntspill and Severn), the records of the watercourse margin habitats show a clear relationship between faunal richness and available habitat at the former two sites. The replicates with least taxa came from areas where aquatic vegetation was most poorly represented, in terms of estimated percentage cover (%EP) of emergent plants. (Table 10, correlation between Ntaxa and %EP: Yorkshire Ouse r = 0.79, Huntspill r = 0.71). The river margin habitats sampled on the Severn lacked any aquatic vegetation and the banks shelved steeply into deep water. Here there was no obvious reason for contrasting faunal richness between the two banks.

Table 10 Comparison of percentage cover of aquatic vegetation at margin pond net sample locations with faunal richness (BMWP taxa recorded). Shaded cells show where low plant cover and faunal richness coincide.

Sample replicate number	1	2	3	4	5	6
Yorkshire Ouse						
% emergent plant cover	20	15	30	50	75	40
% submerged plant cover	0	0	0	0	0	0
Number of taxa	12	9	12	13	15	15
BMWP Scores	54	33	44	55	71	65
Yorkshire Derwent						
% emergent plant cover	5	10	10	35	30	25
% submerged plant cover	10	5	0	2	5	1
Number of taxa	19	26	17	22	23	22
BMWP Scores	103	139	85	111	135	120
South Drove Drain						
% emergent plant cover	2	2	7	50	10	50
% submerged plant cover	98	98	93	50	88	50
Number of taxa	28	23	23	21	29	21
BMWP Scores	141	100	100	95	131	95
New Bedford River						
% emergent plant cover	50	50	50	50	50	50
% submerged plant cover	0	10	0	5	0	0
Number of taxa	25	28	21	24	26	28
BMWP Scores	134	145	98	119	128	137
Huntspill						
% emergent plant cover	95	75	95	60	50	90
% submerged plant cover	0	5	0	40	5	5
Number of taxa	15	15	17	8	12	13
BMWP Scores	58	59	69	27	47	50
Severn						
% emergent plant cover	0	0	0	0	0	0
% submerged plant cover	0	0	0	0	0	0
Number of taxa	9	8	6	16	10	15
BMWP Scores	42	33	20	69	39	72

The deep-water sampling methods generally excluded taxa strongly associated with emergent vegetation and other habitats confined to the watercourse margin. Contrasts in faunal composition were normally strongest between margin samples and the deep-water samples, but there was one notable exception to this trend. At sites where the dredge passed through vegetation during its retrieval, some additional elements of the margin fauna were incorporated into the sample which boosted the BMWP Scores.

Sampling Methods

The contrast in faunal composition between sampling methods was explored more fully. The frequency of occurrence of 'margin' taxa in the deep-water samples was examined, also the presence of 'benthic' taxa in the margin pondnet samples. Lists (Table 11) were compiled of candidate 'margin' and 'benthos' taxa covering all taxonomic groups with a known strong association with habitats confined to the watercourse margin or, conversely, open water habitats. Some sites had mid-channel vegetation present and consequently yielded 'margin' taxa from deep-water samples. This was particularly noticeable at South Drove Drain where, in addition, surface-skimming insects (Mesoveliidae and Gerridae) were obtained in dredge samples as they were lifted in the margin zone (Table 12). There was a considerably longer list of taxa confined to deep-water samples and some were captured in a high proportion of these samples (Table 13).

Table 11 Lists of candidate 'margin' and 'benthos' taxa, covering all groups with a known strong association with habitats confined to the watercourse margin or, conversely, open water habitats at deep-water sites

'Margin' taxa	'Benthos' taxa
Corixidae	Unionidae
Hydrometridae	Corophiidae
Mesoveliidae	Ephemeridae
Notonectidae	Aphelocheiridae
Gerridae	
Nepidae	
Hydrophilidae	
Calopterygidae	
Coenagriidae	
Baetidae	

Table 12 Occurrence of 'margin' taxa in the deep-water benthos samples. (n - number of sample replicates, out of 18, in which the taxon was present)

Site	Margin taxa	n
Yorkshire Ouse	Coenagriidae	1
Yorkshire Derwent	No additions	
South Drove Drain	Hydrometridae	2
	Notonectidae	5
New Bedford River	Notonectidae	4
	Gerridae	1
	Calopterygidae	2
Huntspill	Hydrometridae	3
	Mesoveliidae	1
	Gerridae	4
	Nepidae	2
	Hydrophilidae	2
Severn	No additions	

As anticipated, for all sites a combination of BMWP taxa recovered from deep-water and watercourse margin yielded higher Ntaxa than samples from just one zone. The combined totals of Ntaxa from margin pond net samples and each deep-water sampling method revealed that variable method combinations provided the highest Ntaxa at sites. The combined airlift and margin pond net samples yielded the highest Ntaxa at three of the six sites and at the remaining three sites their totals were within one or two taxa of the site maximum obtained from combining dredge plus margin pond net, or long-handled pond net plus margin pond net. Perhaps surprisingly the relative contribution from margin pond net samples did not consistently mirror the level of habitat complexity at sites. The River Severn margin pond net samples contributed seven additional taxa (to the airlift total) or eight additional taxa (to the long-handled pond net total), in spite of the complete lack of aquatic plants in the River Severn margins. In contrast, although South Drove Drain had extensive stands of aquatic plants both in the deep-water and margin zones, the margin pond net samples still boosted the Ntaxa by around 25%, when combined with Ntaxa yields from each deep-water sampler (Table 14).

Bass *et al*. (2000) did not undertake a detailed investigation into the relationship between Ntaxa from deep water and corresponding margin samples. This would be a useful analysis to determine if samples collected from the margins might be sufficient to describe site condition, and should be included in the design of any field test of methods. However, if samples from the margins are more heavily influenced by the condition of marginal habitat rather than the whole river, as is suspected, then the use of this technique alone would be unsafe.

Table 13 Occurrence of taxa confined to deep-water samples (n - number of sample replicates, out of 18, in which the taxon was present)

Site	Deep-water	n
Yorkshire Ouse	Dendrocoelidae	5
	Planariidae	9
	Leptoceridae	3
	Simuliidae	1
Yorkshire Derwent	Hydropsychidae	7
	Unionidae	3
South Drove Drain	Unionidae	2
New Bedford River	No additions	
Huntspill	Unionidae	17
	Leptoceridae	3
Severn	Corophiidae	13
	Heptageniidae	5
	Ephemeridae	3
	Aphelocheiridae	2
	Elmidae	10
	Hydropsychidae	10
	Brachycentridae	6

Table 14 Comparison of the numbers of scoring taxa (Ntaxa) recorded from deep-water samples, margin pond net samples and combined methods at each site. The combined methods yielding the highest Ntaxa are highlighted

Sampling method: (BMWP Ntaxa)	Site					
	Ouse	Derwent	South Drove	New Bedford	Huntspill	Severn
Margin pond net	24	34	37	36	23	25
Airlift 1	25	31	29	27	17	28
Dredge 1	19	33	30	29	15	25
Long-handled pond net	11	26	23	28	12	28
Combined airlift and margin pond net	31	38	40	36	28	35
Combined dredge and margin pond net	27	39	39	37	24	29
Combined long-handled pond net & margin pond net	27	37	39	38	26	36

4.4.2 Conclusions

Maximum taxon recovery from deep water samples

The Airlift yielded the highest mean number of taxa at four of the six sites, and the same number as the dredge at one site. The Long-handled pond net performed poorly.

Consistency and taxon accretion

Sampler performance varied between sites. In general, the airlift accretion curves flattened out after fewer replicates at higher Ntaxa and at noticeably more sites than the accretion curves for dredge samples. Some series of long-handled pond net samples also reached a taxon accretion plateau, but in these cases the Ntaxa were considerably lower than recovered by other sampling devices at the same sites. All accretion curves indicate that a single deep-water benthic sample taken from an area of 1.5 m^2 is not sufficient to recover 80% of the Ntaxa recorded from each site.

In terms of BMWP taxon representation, the airlift sampler performed more effectively than the dredge at most sites and required fewer sample replicates to yield 80% of the Ntaxa detected at each site. The dredge yielded very similar results to the airlift at three sites, but only when all six sample replicates were taken into account. The long-handled pond net under-performed in terms of recovering available BMWP Scoring Taxa and should be discounted as a reliable sampling method for deep-water benthos.

Comparisons of deep-water samples with contemporary margin pond net samples

The series of 3 one-minute pond net margin samples yielded higher mean ASPTs than any of the deep-water methods at two of the six sites.

The sampling duration necessary to include most of the taxa present in the watercourse margin was unclear because of the high degree of variability between 1-minute margin replicate samples, particularly those from the Yorkshire Ouse, Huntspill and Severn.

Taxon composition

As would be anticipated, the deep-water sampling methods generally excluded taxa strongly associated with emergent vegetation and similar habitats confined to the watercourse margin, though this did not apply at all sites. The contrasts in faunal composition were clearly strongest between margin samples and the deep-water samples, rather than between deep-water methods. There was a notable exception to this trend. At sites where the dredge passed through marginal vegetation at the end of its retrieval, some additional margin fauna were incorporated in the sample. Few taxa were recovered exclusively from deep-water benthic samples at more than one of the six sites, the Yorkshire Ouse and Severn yielding the highest numbers. Unionidae (3 sites), Leptoceridae (2 sites) and Hydropsychidae (2 sites) were the only BMWP taxa restricted to deep-water samples at more than one site.

Margin pond net samples were taken from both banks of the watercourse at each site. They indicated that there were faunal differences between the left and right bank at three of the six sites (Severn, Yorkshire Ouse and Huntspill).

Sample Processing Time

The time required to recover macroinvertebrates from the deep-water samples was strongly influenced by sample debris volume and this reflected site conditions, the sampled area and the characteristics of each sampling method. The sample processing time was comparable among the different methods tested, and least variable for the airlift.

An estimate of the average time taken to process sufficient samples to recover 80% of taxa indicated that the air lift was most efficient, requiring only 2 or 3 samples and less time at nearly all sites. However, it was noted that there are differing costs of manpower, equipment and safety aspects of the particular sampling devices that were tested. All devices require specific training in their use. The Environment Agency commissioned an assessment of the physiological aspects of using deep-water sampling devices (Rayson 2000). Subsequently, the Agency decided to exclude the use of the Naturalists Dredge for routine monitoring work, on safety grounds (Brian Hemsley-Flint pers. comm.). If, in future, the use of a smaller (lighter) dredge is envisaged, specific tests will be necessary to gauge its efficacy.

5. Recommendations

5.1 Choice of deep-water sampling methods

The most commonly used method to sample deep rivers is a sweep from the bank, either of the margins or by disturbing the substrate. However, previous workers have suggested that this approach, although simple and efficient, will overlook a number of taxa from the main channel. Sampling deep rivers efficiently will require the use of methodology designed for use in these deep habitats. Previous tests have shown the Air lift to be the most effective device for collecting macroinvertebrate samples from mid-channel habitats of deep rivers. Sample collection from an area of approximately 4.5 m^2 has been recommended. However, a combination of methods may be appropriate.

The long-handled pond net, used from a boat, under-performed in terms of recovering the available BMWP Scoring Taxa (Ntaxa) and should be discounted as a reliable sampling method for deep-water benthos.

Grabs are used occasionally, particularly in Europe, but they do not appear to be effective across a wide range of conditions (current, depth, substrate).

Dredges are also used, and can produce reasonable results, but do not appear to be as effective as the airlift.

The use of deep river techniques may have time implications for the processing of samples on site, which will have to be taken into consideration in any comparison of the techniques.

Results from widely differing watercourses confirm, unsurprisingly, that there is no single discrete deep-water macroinvertebrate community. Where sites included extensive submerged plant growth in deep water, then a range of additional taxa can be present. Also, the presence/absence of water flow dictates which taxa can persist at a site.

There has been to date no test of the effect of classifying a site as “deep” compared to “shallow” and hence using different methodologies to collect the samples. It has been assumed that a collection of macroinvertebrates from habitats in proportion to their occurrence is sufficient, and that both deep and shallow methodologies provide a comparable list of species from all habitats.

Deep-water sampling methods generally exclude taxa strongly associated with emergent vegetation and similar habitats confined to the watercourse margin. Contrasts in faunal composition were stronger between margin samples and the deep-water samples than between the different deep-water sampling methods. Margin pond net samples can yield higher mean ASPTs than deep-water methods; there is a potential for information loss at some sites if monitoring is confined to the deep-water zone.

The benthic and marginal areas at deep-water sites represent strongly contrasting habitats, with (to varying degrees) their own distinct macroinvertebrate assemblages. Although there is often considerable overlap in taxonomic composition, the abundances at family-level are frequently very different. Whereas deep-water samples may reflect water and sediment quality, the margin samples may be influenced more strongly by the range of available habitats and the way in which they have been managed or influenced by man (e.g. by boat traffic). Therefore, there are potential difficulties in interpreting combined margin and deep-water samples.

It is recommended that the following methods are included in any field trial during the next stage of the project:

- Dredge
- Air-lift
- Marginal pond netting

These methods should be tested at a number of sites of varying characteristics to ensure the general applicability of the recommended method. At each site replicate samples should be collected using each of the techniques under investigation. It is also recommended that the relationship between samples collected from deep water and the corresponding margin samples be fully investigated, to determine any inconsistencies between the two techniques.

Furthermore, it would useful to compare samples collected using deep water techniques to those collected using standard shallow water techniques, to determine if the classification of a site as “deep” has any impact upon the assessment of the quality of the site.

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Appendix 1. Questionnaire on Sampling for Macroinvertebrates in Deep Rivers

SAMPLING FOR MACROINVERTEBRATES IN DEEP RIVERS

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

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

Address:……………………………………………………….
………………………………………………………………

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**

<u>Question 4 – Criteria used for selection of sampling method</u>

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.