Manual for Biological Methods - Phase 1

Kings Environmental Services

R&D Technical Report E49

Further copies of this report are available from:
Environment Agency R&D Dissemination Centre,
c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

WRc

tel: 01793-511711 fax: 01793-514562 e-mail: publications@wrcplc.co.uk

Publishing Organisation
Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

Tel: 01454 624400 Fax: 01454 624409

Dissemination Status
Internal: Released to regions
External: Released to Public Domain

Statement of use
This report will be used to identify methods of biological assessment which are required to fulfil existing and future Environment Agency business needs. The information contained in this report will be used to prioritise the work to be undertaken by Phase 2 of this project and to produce the Phase 2 Project Initiation Document.

IC code: AN-03/98-OK-B-BBFU

Research contractor
This document was produced under R&D Project EMA-015 by:

Kings Environmental Services
Kings College London
Campden Hill Road
London
W8 7AH

Tel: 0171 3334403 Fax: 0171 3334500

Environment Agency's Project Manager
The Environment Agency's Project Manager for R&D Project EMA-015 was:
Sarah Chadd - Anglian Region

Manual for Biological Methods - Phase 1

Angela Mulgrew, Richard Thorne, Tony Bark, Peter Williams and Matthew Ball.

Research Contractor:
Kings Environmental Services

Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 4UD

R&D Technical Report E49

2

TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

GLOSSARY OF ABBREVIATIONS

ASPT	Average Score Per Taxon
AQC	Analytical quality control
BMWP	British Monitoring Working Party
BSI	British Standards Institute
BTO	British Trust for Ornithology
CCI	Community Conservation Index
BQOs	Biological Quality Objectives
CCW	Countryside Commission for Wales
CEN	European Committee for Standardisation
CPET	Chironomid Pupal Exuviae Technique
CPUE	Catch Per Unit Effort
DQI	Diatom Quality Index
DTA	Direct Toxicity Assessment (Whole Sample Ecotoxicity Testing)
EA'95	Environment Act 1995
ECN	Environmental Change Network
EIA	Environmental Impact Assessment
EN	English Nature
EPO	Environmental Protection Officer
FBA	Freshwater Biological Association
FCS	Fisheries Classification Scheme
GQA	General Quality Assessment
HMIP	Her Majesty's Inspectorate of Pollution
IFE	Institute of Freshwater Ecology
IFIM	Instream Flow Incremental Methodology
IPC	Integrated Pollution Control
ISO	International Standards Organisation
ITE	Institute of Terrestrial Ecology
JNCC	Joint Nature Conservation Committee
LEAPs	Local Environment Agency Plans
LQI	Lincoln Quality Index
MAFF	Ministry of Agriculture, Food and Fisheries
MTR	Mean Trophic Rank
NCC	Nature Conservancy Council
NMP	National Marine Monitoring Plan
NRA	National Rivers Authority
NVC	National Vegetation Classification
PHABSIM	Physical HABitat SIMulation
PIN	Policy Implementation Note
QA	Quality assurance
QC	Quality control
RBAKs	Rapid Biological Appraisal Keys
RCS	River Corridor Survey
RHS	River Habitat Survey
RIVPACS	River InVertebrate Prediction And Classification System
RSPB	Royal Society for the Protection of Birds
SACs	Special Areas of Conservation
SCAs	Special Conservation Areas

SEPA	Scottish Environmental Protection Agency
SERCON	System for the Evaluation of River Conservation
SNH	Scottish Natural Heritage
SPAs	Special Protection Areas
SSSIs	Sites of Special Scientific Interest
SWALP	Surface Water Abstraction Licensing Procedure
TDI	Trophic Diatom Index
UNECE	United Nations Economic Commission for Europe
US EPA	United States Environmental Protection Agency
UWWTD	Urban Wastewater Treatment Directive (Council Directive 91/271/EEC)

EXECUTIVE SUMMARY

This report describes the findings from Phase 1 of a multi-phase project to develop a Manual for Biological Methods and best practice, covering existing and external techniques, to improve the consistency and quality of biological information across all Environment Agency functions. The main aims of this scoping study were:

- to review methods and quality assurance procedures currently in use, being developed and of potential use to the Environment Agency and to identify gaps;
- to propose a structure and format of a method manual and the mechanisms for managing the documentation;
- to review the approach to the development of new national standard methods.

These objectives were approached by a three-stage process. During Activity 1, the views and opinions of Agency staff were canvassed by means of structured interviews and questionnaire. The interview/questionnaire programme covered all functions of the Agency by incorporating questions on the use of biological methods in relation to air, soil and water. Fifteen multi-function meetings were held throughout Agency Regions. Additional Agency staff were contacted by phone, email and fax. Although biologists were better represented in the consultation process than areas such as Integrated Pollution Control (IPC) and waste regulation, a range of views was obtained from all Agency functions. Activity 2 comprised a structured survey of a range of other relevant organisations, conducted by telephone and questionnaire survey. Activity 3, the review of published scientific and technical literature, was conducted in parallel with the other exercises.

The review of the use of biological methods with regard to Environment Agency business needs yielded the following general conclusions.

- Biological programmes within the Agency's activities are developed in accordance with requirements prescribed by legislation, government or Environment Agency policy, Regional interpretation of general duties placed on the Agency and local operational requirements. At present, biological methods contribute to meeting a substantial number of the Agency's business needs. However biological methods have the potential to meet many more existing and future Agency requirements.
- At present, freshwater macroinvertebrates are the biological group most frequently used by the Agency. This use is primarily with respect to river quality and pollution control and standard national methods and quality assurance procedures have been adopted (for example GQA and RIVPACS). Areas which require further development such as deep waters, headwaters and canals are the subject of current and planned Agency R&D. Some macroinvertebrate methods are being developed to meet other agency business needs, such as water resources.
- Some standard national and regional methods employing freshwater macrophytes and algae have been developed, primarily for eutrophication monitoring. Most of these methods and associated quality assurance procedures are undergoing further national or regional R&D. Aquatic macrophytes and algae are not currently used to their full potential and there is scope to use them to fulfil other Agency business needs.
- A suite of freshwater fisheries assessment methods is used by the Agency. Although methods are generally well developed, there appears to be a lack of standardisation in sampling, data collection, data analysis, data archiving, reporting and quality assurance procedures both between, and sometimes within Regions. The current development and

introduction of the national Fisheries Classification Scheme (FCS) provides a potential opportunity to harmonise fisheries data collection and use across the Regions.

- Marine and estuarine habitats have received considerably less attention than freshwaters. A few national and regional methods are available within the Agency but further development is required. The Marine Biology Group is addressing the issue of standardisation and formalisation of methods.
- Although conservation is an important element across the range of Agency activities, relatively few methods specifically directed at conservation issues have been developed or validated by the Agency itself, or adopted by the Agency as standard methods. The River Corridor Survey and River Habitat Survey are notable exceptions. A variety of standard conservation methods are used by external conservation organisations which could easily be adopted by the Agency.
- Other methods exist which are of potential use to the Agency, particularly in relation to IPC and waste regulatory functions. These include methods for the assessment of air quality, contaminated land and radioactivity and biomarkers. Currently, biological methods are not utilised within the IPC and waste regulatory functions of the Agency. This reflects the tradition of their precursors prior to the creation of the Environment Agency on 1 April 1996. However the report highlights potential areas where biological methods could satisfy existing or future needs of IPC and waste regulatory functions.

Key recommendations emerging from Phase 1 of the project include the following:

- the development of a comprehensive, efficient biological data archiving system and database within the Agency, which should ideally be linked to the databases of other relevant organisations should be addressed as a matter of priority;
- a comprehensive review and scoping study of the requirements of IPC and waste regulatory functions for biological methods should be undertaken;
- marine and estuarine biological methods including GQA classifications and rocky intertidal surveys should be further addressed by the Agency;
- the development of methods for the assessment of ecological integrity and ecosystem health, especially the use of biomarkers, should be seen as an important growth area within the Agency;
- a more detailed review of conservation needs for standard methods coupled with a critical assessment of methods developed by UK conservation bodies should be undertaken in order to facilitate their rapid adoption by the Agency.

In order to fulfil its many and varied functions and business needs, the Environment Agency will require a comprehensive suite of tested and standardised biological methods, each of which is fully documented and backed by appropriate quality assurance procedures. Meeting this requirement will entail the development and/or validation of a substantial number of additional biological methods. It is proposed that the development of new biological methods should be managed within the framework of the Agency's proposed Unified National Approach to Monitoring strategy. A Biological Methods Development Group, including representatives from key-player UK organisations involved with biomonitoring, should be established to identify and prioritise needs for new biological methods and feed proposals into the Agency's R&D programme.

1. INTRODUCTION

1.1 Project objectives

The present study was undertaken by King's Environmental Services (KES) and commissioned by the Environment Agency. The current report relates to a scoping study for National R&D Project E1D(96)5: Manual of Biological Methods Phase 1. Phase 2 will involve the production of a manual of best practice.

The overall project objective, as outlined in the project brief, is as follows:

To scope and review the needs of the Environment Agency for biological assessment methods in order to identify available methods; those which need to be developed; and to give recommendations with regard to the production of standard documentation and its management.

The specific objectives (as specified in the project brief) are outlined below:

- *to review and prioritise the need for biological assessment and reporting;*
- *to review methods currently in use, being developed and of potential use to the Environment Agency and to identify gaps;*
- *to review quality assurance procedures;*
- *to propose a structure and format of a method manual and the mechanisms for managing the documentation;*
- *to review the approach to the development of new national standards;*
- *to produce a report on the above which may be used as the basis for the justification to undertake a second phase, i.e. manual production and method development.*

1.2 Background

It is widely recognised that the development of rapid, low-cost techniques for environmental analysis is a prerequisite for estimating environmental health or stress. The development of biological assessment and monitoring is one of several such techniques. There is also an increasing awareness that simple chemical criteria are insufficient to provide a useful holistic assessment of environmental conditions.

Biological investigation provides information which underpins all of the Agency's activities. Physical and chemical monitoring, the regulation of discharges, waste disposal and industrial processes, the creation of physical habitat improvements and the Agency's input to local planning and development control all ultimately seek to improve the ecological health and diversity of our environment. Consequently, biological investigation provides an integrated assessment of the effectiveness of all these functions.

Biological data produced by the Environment Agency are likely to be increasingly challenged as the costs of maintaining and improving the environment are evaluated. Confidence in the validity of results is therefore of high priority. This can only be achieved by using standard methods and quality control procedures.

This study forms part of the Environment Agency's developing monitoring strategy and will identify the needs within the Agency for biological methods. The project addresses the need for biological monitoring in relation to water quality and resources, land and air contamination, radioactive substances, conservation status, biodiversity and sustainable development. Some of the Agency's needs in these respects are already well defined and standard methods are in use, or are at an advanced stage of development and testing to meet national or more local requirements. In other cases where a need has been identified, methodological development is at an early stage or is lacking. In some cases, the need or opportunity for the application of biological methods may not have been fully addressed, reflecting both the very recent establishment of the Agency and the extension of its remit beyond that of its predecessor organisations.

A manual of standard biological methods will need to address not only the methods themselves and their uses and applicability, but also the associated issues of quality assurance procedures and the structure and format of monitoring documentation, because these are intrinsic components of the successful application of any technique.

1.3 Project scope

It is important to recognise that biology within the Environment Agency is a very broad discipline which has current or potential applications across all functions. The project addresses this. Chapter 2 provides a brief description of the methodology used during the course of the project. Chapter 3 assesses the business needs of the Environment Agency for biological monitoring. Existing and potential individual biological methods are discussed in relation to their business needs in Chapter 4. The remaining chapters make recommendations for priority areas requiring development and the approach to the development of new national standards.

Throughout the report 'monitoring' is used in its broadest sense as a collective term for environmental monitoring and surveillance. According to Viewpoints of the Environment (Environment Agency, 1996a) '*environmental monitoring refers to the making of measurements or tests in order to demonstrate compliance or otherwise with pre-determined objectives , standards, or targets…*'. Alternatively, environmental surveillance '*refers to the making of measurements or tests in order to assess the comparative state (in space or time) of the environment*'.

Distinction of the terms quality assurance (QA) and quality control (QC) is necessary. QA is the overall process of ensuring particular methods are undertaken to a desired standard. It provides potential users with the assurance that the accuracy of the results is within controlled limits. Other components of QA include relevant staff training, intercalibration exercises and use of approved methods (van Dijk, 1994). QC is a specific quality check which forms part of QA procedures. It is concerned with '*how much variation is implicit in a process and with monitoring the process to detect changes in quality*' (van Dijk, 1994).

2. METHODOLOGY

The approach to the R&D project comprised three activities. The initial intention was that Activities 2 and 3 would progress naturally from Activity 1. However, the unexpectedly protracted process on organising Regional meetings resulted in the three activities being conducted concurrently.

2.1 Activity 1 Consultation with Environment Agency staff

The views and opinions of Agency staff were canvassed by means of structured interviews and questionnaire. A basic set of questions (Appendix A) was used as the basis for interviews and discussions. The set of questions was designed so that it could also be used as a stand-alone postal questionnaire where personal meetings could not be arranged. The questionnaire was sent to an initial list of Environment Agency primary contacts, identified by the project leader. It was requested that copies of the questionnaire were passed on to key personnel and individual subject experts within each Region.

In all instances the primary contact was of 'Regional Biologist' status or namesake equivalent and was responsible for arranging subsequent Regional and/or Area meetings. The schedule of Regional and/or Area meetings is summarised in Appendix B, where key contacts are highlighted. The first meeting was with Head Office at Bristol. Most other meetings were on a Regional basis, except for North East Region.

The number and diversity of representatives at each meeting varied. Some meetings encompassed individuals from a wide selection of Environment Agency functions such as biology, fisheries, conservation, water resources, water quality, Integrated Pollution Control (IPC) and waste regulation. Other meetings consisted solely of biologists. In general, Environment Agency biologists were well represented throughout the consultation phase while other functions such as IPC and waste regulation were less adequately represented. This was probably due to the lack of biological tradition within these functions in comparison to biological work undertaken under the auspices of the National Rivers Authority (NRA). Full details of meeting representatives are presented in Appendix B.

Excluding three project board meetings, a total of 15 meetings were held between KES and Environment Agency staff. The format of meetings was consistent throughout the Regions. The questionnaire was used as the basis of the meeting but not so rigid as to prevent the inclusion of issues not addressed by the questionnaire.

Relevant documentation, existing method manuals, quality assurance protocols and reporting procedures were either provided at the meetings or received later.

In practice, it was not logistically possible to meet directly with everybody. In such circumstances the set of questions was treated as a postal questionnaire or further information was volunteered.

After the project review meeting on 22 August 1997, further suitable contacts were suggested, particularly in relation to flood defence. These personnel were subsequently contacted by phone and post.

Overall, it is believed that the consultations were useful in establishing the Agency's perceived need for biological methods, and the extent to which those needs are currently met, or may be met through existing Agency research, either at Regional or national level.

2.2 Activity 2 Consultation with other organisations

Activity 2 comprised a structured survey of a range of other relevant organisations, conducted by telephone (to establish an appropriate and willing contact) and questionnaire survey. The nature and format of the questionnaire was modified to complement rather than repeat Activity 1.

Appendix C summarises the external organisations contacted by KES. Most of the consultation was undertaken by phone and post. However, meetings with English Nature (EN) and the Institute of Freshwater Ecology (IFE) were deemed necessary because the role of biological methods within the Agency with respect to these bodies is important.

2.3 Activity 3 Literature Review

Activity 3, the review of published scientific and technical literature, was conducted in parallel with the other exercises. However, the outcome of Activity 1 did provide in part the focus for Activity 3. This action identified potential methods, approaches and strategies by which outstanding Environment Agency biological assessment requirements could be met.

3. ENVIRONMENT AGENCY BUSINESS NEEDS

3.1 Introduction

The objectives of biological investigation and assessment within the Environment Agency are numerous. This chapter addresses these objectives by identifying the needs of the Environment Agency for biological methods. As far as possible, a distinction is made between current needs and developing or future requirements.

On 1 April 1996 the Environment Agency took over the responsibilities of the National Rivers Authority (NRA), Her Majesty's Inspectorate of Pollution (HMIP) and the waste regulatory functions of local authorities.

Prior to the formation the Environment Agency, substantial development work was undertaken under the auspices of the NRA leading to the development of standardised assessment schemes e.g. the General Quality Assessment (GQA) classification of river quality, which includes a biological window, and the development of standard national analytical protocols such as River InVertebrate Prediction And Classification System (RIVPACS). The development of biological methods for water is continuing within the new Environment Agency both at Regional level, and nationally through the Research and Development (R&D) programme. Recently an Environment Agency policy for the use of biology in aquatic systems has been devised (The Biology Strategy Group, 1997).

Within other areas that now fall within the remit of the Environment Agency, e.g. the functions of the former HMIP and Waste Regulatory Authorities, the development and use of biological monitoring approaches has been less widespread and standardised national biological protocols are generally lacking, although some are currently under evaluation.

3.2 Waste regulation and management

3.2.1 Existing needs

The role of the Waste Regulation & Management Policy Group of the Environment Agency is to provide a harmonised national approach to waste regulation and to improve waste management standards by providing relevant and up-to-date guidance notes and papers on waste management techniques.

The Environment Agency has a responsibility for:

- waste management licensing, including the registration of carriers;
- regulating the import and export of waste and control over the movement of waste;
- regulation of special waste;
- assessing waste disposal needs and priorities.

There is currently no regular use made of biological methods in exercising the Agency waste regulatory function. Statutory guidance to the Agency in the form of Waste Management Papers, makes scant reference to the use of biological methods despite the fact that a principal aim of the licensing regime is to prevent pollution of the environment (and hence harm to living organisms or the systems of which they form a part). Waste regulation staff generally rely on the developer of a site to undertake any monitoring of the effects of a landfill/waste disposal site.

3.2.2 Potential needs

In future Local Authorities will be approaching the Environment Agency as statutory consultees. The following paragraphs highlight the potential needs of the waste regulatory function of the Environment Agency with respect to biological methods.

It is now acknowledged that waste sites leak at a finite time and (statistically) measurable rate. In the past some work may have been undertaken in this respect, for example the assessment of tip leachate using sewage fungus. However, to date the regulatory organisations involved have generally not taken account of subtle changes which might result from chronic pollution caused by the slow release (and potential bioaccumulation) of toxic substances from landfills in particular.

Waste contaminated soil is commonly used by a developer for landscaping works under the terms of an exemption from waste management licensing. Some Regions have expressed the need for a mechanism for assessing the likely impact of these activities since it is an absolute requirement that such activities are only exempt if they can be carried out without risk to the environment. There is a potential use of biological methods as a tool for monitoring ongoing environmental impacts of sites.

Many other exemptions exist and some are conditional on waste being used in a manner which is 'beneficial to agriculture' or results in 'ecological improvement'. The latter is a particularly thorny issue which would benefit from some expert guidance. In the event of any dispute arising in relation to such exemptions it is doubtful that the Environment Agency is in a position to present much of an argument at present. Standard methods of assessment would be beneficial in this context. Large quantities of organic wastes from industry (apart from sewage sludge) are applied to agricultural land. It is intended that this application should be for 'agricultural benefit'. Closer monitoring of this practice has been identified as a key issue within the Agency. The meaning of 'agricultural benefit' is sometimes a contentious issue between the Agency and Agricultural Development and Advisory Service (ADAS).

Landfill restoration specifies the use of topsoil. It is understood that when topsoil has been stored for long periods, it can lose its 'biological activity' i.e. it will no longer sustain growth. There could be a need to establish appropriate definitions and properties of top soil for assessment.

Biological methods may be included within the regulatory process for waste in the future. This is especially true in the light of the Agency's broader duties in relation to conservation and the commitment to analyse the costs and benefits accruing from its actions.

3.3 Contaminated land

3.3.1 Existing needs

The Environment Agency has a responsibility for the regulation of contaminated land designated as 'special sites'. No such sites have yet been designated. No standard process of identifying contaminated land across England and Wales is currently in use. Once this process is underway, the Environment Agency has a duty to prepare and publish a report on the state of contaminated land.

Contaminated land/soil is a relatively new field to the Environment Agency and it is unlikely that the Agency has the necessary in house expertise, at present. Some expertise exists in the form of a National Policy Group in Land Qaulity Function based at Steel House in London. In addition the National Contaminated Land and Groundwater Centre has been set up specifically to deal with the complex issues of contaminated land. Some Regions believe that soil bacteriologists, entomologists and mycologists are required. There is expertise, however, with respect to pollution of controlled waters as a result of contaminated land run-off. According to IPC staff, biological monitoring of soil/contaminated land may be outside their remit but the information would still be useful.

3.3.2 Potential needs

Biological parameters have potential use as biomonitors and/or bioindicators in the assessment of contaminated land.

There is a future for biological monitoring in land management and remediation with respect to the following:

- for process monitoring and validation of remediation technologies, especially bioremediation, e.g. biosensors and geneprobes. Both as a client and as an environmental regulator, the Environment Agency may need to be able to evaluate the efficiency of a biological treatment regime and to appraise the quality assurance procedures instigated by the biotreatment company, by using biological as well as chemical methods. However, this may be limited to 'end of pipe' impacts;
- for assessing toxicity of soils and water samples containing a complex mixture of contaminants e.g. whole sample ecotoxicity testing (DTA, Direct Toxicity Assessment);
- for assessing the ecotoxicity of contaminated soils and groundwater e.g. by biomarkers, DTA, simple biota indexing during walk-over studies;
- for assessing the conservation potential of the industrial landscape by measuring the unique ecology of some of these sites e.g. conservation indices.

Gas and leachate monitoring do not include biological aspects and where necessary waste staff would seek advice from water quality. Biological monitoring may be necessary to fulfil future needs of such monitoring.

3.4 Integrated pollution control (IPC)

3.4.1 Existing needs

The Environment Agency has responsibility for:

- authorisations, licences and consents for emissions, discharges and disposals to air, water and land;
- monitoring compliance and enforcement, including prosecutions;
- monitoring environmental conditions and publishing relevant statistics;
- advice to government in setting environmental quality and other standards;
- advice and guidance to industry and others on best environmental practice;
- waste disposal facilities which are subject to integrated pollution control, for example the chemical recovery processes for the recovery of organic solvents or oils.

The Environment Agency has an objective to *'adopt across all its functions, an integrated approach to environmental protection and enhancement which considers impacts of substances and activities on all environment media and on natural resources'.* The Agency aims to maximise the benefits of integrated pollution control.

In carrying out its pollution control responsibilities, the main objective is to prevent or minimise, remedy or mitigate the effects of the pollution of the environment (Section 5 of the Environment Act 1995 (EA'95)). The Agency has to ensure that it has sufficient information regarding the level or potential level of pollution in the environment. The Agency must also follow developments in technology and techniques for mitigating and preventing pollution and its effects.

Section 81 of the EA'95 requires the Environment Agency to have regard to the National Air Quality Strategy in discharging pollution control functions.

3.4.2 Potential needs

The Environment Agency now has a duty to report on the State of the Environment. This includes air quality, contaminated land and radioactivity. Biological parameters have potential use as bioaccumulators and/or bioindicators of levels of air pollution and radioactivity.

IPC staff do not currently carry out biological monitoring on their sites, nor do they ask the companies to do such monitoring (under the self-regulation demanded by legislation). However, biological monitoring could be useful as a measure of harm. The Environmental Protection Act 1990 requires companies to 'render harmless' releases - if this does not entail excessive costs. IPC staff regulate releases to air, water and land. IPC staff rely on water quality staff to advise on a harm to water (from the biological and other perspectives) but there is limited experience on the air or land side.

The Environment Agency conservation sections have provided IPC staff with English Nature (EN), Joint Nature Conservancy Committee (JNCC) and Institute of Terrestrial Ecology (ITE) data on the impact of air and acid rain pollution on certain habitats and on Sites of Special Scientific Interest (SSSIs) generally. With the designations of large upland Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) there will be a need to monitor the impacts of air pollution. IPC are starting four year reviews of their consents which may force companies to revisit their Environmental Impact Assessments (EIAs) and take into account SAC and SPA designations. Currently, few of these EIAs consider ecological impacts or predict ecological changes resulting from development. Even fewer include mitigation measures. Biotic communities which could be affected by the consents are often neglected. In terms of IPC, some research in this area would prove useful.

3.5 Radioactive substances

Under the Radioactive Substances Act 1993, anybody wishing to keep or use radioactive materials requires to be registered by the Environment Agency. The accumulation or disposal of radioactive waste also requires an authorisation from the Agency.

A potential area of research would be the effects, sensitivity and tolerances of organisms to radioactive substances. Very little is known about the radiation tolerance of various species. For example, invertebrates may vary enormously in their tolerance. The question of natural background radiation and evolutionary adaptation of local populations would have to be taken into account.

Biological monitoring could be valuable because some species actively accumulate some isotopes at levels well above ambient concentrations. Ministry of Agriculture, Food and Fisheries (MAFF) carry out routine monitoring of a variety of species in coastal waters.

3.6 Water quality and pollution control

3.6.1 Introduction

With respect to the aquatic environment, the aim of the Environment Agency is to safeguard or improve the quality of rivers, groundwaters, lakes and canals, estuaries and coastal waters through the prevention and control of pollution. Most biological work within the Agency has focused on water quality and pollution control. This stems from progressive developments under the former NRA. The use of, and needs for, biological services within the NRA Water Quality function was investigated in 1995 (Pomfret and Reaston, 1995).

Biological programmes within the Agency's activities for water quality and pollution control are developed in accordance with requirements prescribed by legislation, government or Environment Agency policy, Regional interpretation of general duties placed on the Agency and local operational requirements for ongoing monitoring. Within the Agency, biological services provide an element of special investigation work.

3.6.2 European Union Directives

Under the statutory provisions of the Urban Wastewater Treatment Directive (UWWTD) (Council Directive 91/271/EEC) and the Nitrate Directive (91/6/76/EEC), biological monitoring is required to support chemical information in the identification of coastal, estuarine and fresh waters which are, or could become, eutrophic. Macrophytes and epilithic diatoms are used by the Agency in statutory monitoring under the UWWTD.

Biological work is needed to fulfil statutory requirements within the Dangerous Substances Directive (76/464/EC and Daughter Directives) to measure bioaccumulation of Red List and List 2 substances in biota and accumulation levels in sediment. Similar biological methods are necessary for compliance with the Titanium Dioxide Directive (78/176/EEC and Daughter Directives).

The EC Freshwater Fish Directive (78/659/EEC) defines the quality of waters needing protection or improvement in order to support fish life, ensuring that designated stretches of water are suitable for supporting fisheries (National Rivers Authority, 1994).

The forthcoming Water Framework Directive will require the establishment of ecological targets which may require the development and use of additional biological methods.

3.6.3 National Marine Monitoring Plan (NMP)

Some of the most extensive duties of the Agency regarding the monitoring of coastal and estuarine environments are those defined under the UK National Marine Monitoring Plan (NMP). This involves the monitoring of a network of UK estuaries and coastal waters, including sites which are not significantly contaminated. The specific objectives of the NMP (Marine Pollution Monitoring Management Group, 1994) are:

- to establish the spatial distribution of contaminants in different areas of UK waters and to define their current biological status, thus identifying any areas of specific concern;
- to detect trends in both contaminant concentrations and biological well-being in areas identified as being of concern;
- to measure long-term natural trends in physical, biological and chemical parameters at selected areas.

Biological aspects of the NMP include sampling of benthic macrofauna, oyster embryo bioassays and the measurement of various substances in biological tissues.

3.6.4 General Quality Assessment (GQA)

Introduction

The GQA consists of a number of parallel assessments, each providing a separate window to view the state of water quality in England and Wales (Environment Agency, 1996b). The first was the Chemical GQA, followed by the Biological GQA. The Aesthetic GQA is under development and a Nutrients GQA is to be developed. In addition, fish data can provide very long-term indications of water quality and are included in the criteria of 'likely uses' and characteristics of the chemical GQA.

Mandatory biological monitoring using aquatic macroinvertebrates affords a broad-based measure of water quality and can provide information about types of pollution neglected by chemical monitoring. The scheme aims to assess the biological status of rivers, estuaries and coastal waters in accordance with the national quinquennial survey programme required by the Department of the Environment, Transport and the Regions (DETR).

Running freshwaters GQA

a) Existing needs

The biological surveillance programme and classification developed for the 1995 river GQA survey proved successful and is to be adopted for future surveys. A standard national methods manual has been developed along with appropriate quality assurance procedures.

Macroinvertebrate techniques are the core of the Agency's biological assessment of water quality. Macroinvertebrate methods for GQA of shallow rivers in particular are the most advanced and thoroughly standardised throughout the country.

The National GQA dataset is used in the setting of Biological Quality Objectives (BQOs).

b) Potential needs

The frequency of the national GQA biological surveys may need to be reviewed if there is a need for more frequent national monitoring to satisfy the requirements of State of the Environment reporting or future Directives.

Many Regions feel that quinquennial surveying is insufficient and expressed a desire to undertake GQA annually or as often as three times a year. There is an inconsistency between Regions in the approach to macroinvertebrate monitoring between the GQA surveys. Some Regions attempt to maintain a rolling surveillance programme, utilising standard methodology on a subset of GQA sites each year. This is believed to provide a robust record, which can be used for long term planning and impact assessment. However, a desirable ongoing surveillance programme is often hindered by resource restrictions. Alternatively some Regions choose a targeted monitoring programme outside the GQA survey to specifically meet Agency requirements.

It was apparent during the consultation phase of the current study that shortfalls in relation to other freshwater habitats existed. Further work is necessary in relation to headwaters, temporary and winterbourne streams, canals and deeper waters, tidal rivers, artificial watercourses such as ditches and dykes, wetland ecosystems and groundwaters. Aspects of several of these are currently being addressed in the Environment Agency R&D programme.

Still waters GQA

The need for a classification system for still water bodies has been recognised. Previous R&D in this area produced a strategy for the classification of lakes (Johnes *et al.*, 1994). A recent scoping study on biological techniques of still water quality assessment has been completed (Williams *et al.*, 1996). GQA and the establishment of water quality objectives were considered in this report. Phase 2 of this project is currently in progress (Project Proposal Reference: A05(94)2 and Project Number: EMA012, 'Biological assessment of still waters - Phase 2').

Estuaries and coastal waters GQA

There is an identified need for the development of a GQA system for estuaries to replace the existing classification system, which is considered both dated and subjective. A previous R&D project (Codling *et al.,* 1995) reviewed the possible development of an estuarine classification system and concluded that this was not possible at that time. This opinion is shared by certain members of Agency staff who consider that estuaries are too variable to be classified on a national basis and should be managed individually.

Coastal water should be treated separately from estuaries since the practicalities and associated costs of monitoring may be markedly different in the two environments.

3.6.5 Toxic and nuisance algae

The Environment Agency has to ensure that controlled waters are of the quality required for their various uses. Toxic blue-green algae and other algal blooms are included in the Agency's role of State of the Environment reporting.

In freshwater, the Agency samples algae on a reactive basis in response to public, landowner or water manager concerns. Blue-green algal monitoring is defined in an Environment Agency Policy Implementation Note (PIN). The extent of sampling differs from year to year and from Region to Region. Where water samples are found to contain populations of potentially toxic algae at, or above, specific concentrations, standard letters will be sent by the Agency to the owner, and to the relevant Local Authority environmental health officer, the local MAFF office and to the local medical officer of environmental health.

Marine toxic and nuisance algae are also of concern to the Agency. Toxic algal blooms are relatively rare (Welsh Region, 1996) but other species such as *Phaeocystis* can cause scums and foams, which reduce amenity and give rise to numerous complaints. The Agency responds to reported blooms on an ad-hoc basis, although certain Regions conduct routine monitoring. There is an identified need for the development of standard procedures for coastal algae monitoring.

3.6.6 Pollution incident investigation

Existing needs

The Agency is required to investigate, trace and where appropriate prosecute, pollution incidents. Biological techniques are used to provide information for the assessment of pollution incidents, to provide evidence to support prosecution or remedial action such as fish restocking or to trace unidentified sources of pollution. This is a service provided by the Biology function at the request of the Water Quality function to fulfil statutory duties.

A draft Policy Implementation Note (PIN) is available for pollution incident investigations. Some Regions use this approach while others feel that the document is very specific for particular incidents and is consequently not always followed relentlessly. Refinement and finalisation of this document may be necessary.

Reported fish kills often provide the Agency with the first information on pollution incidents. Fish can be used to assess severity of pollution incidents, often being more effective than trying to detect a measurable water quality parameter.

Potential needs

Guidelines exist for the collection of biological evidence for pollution incidents and standard witness statements are recommended for prosecution cases. However, it is often not known at the time of sampling that an incident will lead to prosecution. Water quality staff would like a standardisation of biological investigation methods to ensure certain standards are consistently met, which uphold in court.

Category I and II incidents are generally investigated by field biologists within office hours but within 24 hours of notification by Water Quality staff of the incident. Some Environmental Protection Officers (EPOs) feel that biological samples are not taken soon enough in response to pollution incidents.

Longer-term, post-incident assessment on aquatic biota would be useful, for example the effects of smothering. This would provide longer-term information on ecological recovery from pollution incidents and supply contemporary data to support legal action. There is therefore a need to develop guidelines to assist in defining the scope and methods to be used in such investigations.

Currently, biologists are rarely involved in the investigation of marine pollution incidents. A recent notable exception was the Sea Empress oil spill in Millford Haven. For the implementation of biological assessments of pollution incidents, standard or guideline methods would be useful.

3.6.7 Operational needs

Existing needs

Biologists report on specific water quality issues. Methods have been developed Regionally for example for farm pollution and ferruginous minewaters. Due to their specific nature, such methods may be limited to certain natural areas, but would require standardisation before they could be extended nationally.

Potential needs

Further procedures should be developed for the biological assessment of aquatic pollution from contaminated land through run-off or groundwater seepage. Many biologists throughout the Regions voiced concern with regard to contaminated land. Such pollution is often episodic and not readily quantifiable by chemical water quality means.

It is becoming increasingly apparent that the inclusion of more biological criteria on receiving water courses for discharge consent reviews is necessary.

Biological methods are used in the determination of the effects of urban runoff. In some instances bioassay methods may be more appropriate.

Less frequent or future water quality problems and impact assessments may necessitate the development of additional methods.

3.6.8 Bioaccumulation

Existing needs

Most work in relation to bioaccumulation studies has been in relation to the marine environment. This is generally to meet statutory requirements, namely, Titanium Dioxide Directive (78/176/EEC and 82/883/EEC), Dangerous Substances Directive (76/464/EEC and its Daughter Directives) and Shellfish Directive (79/923/EEC). Some Regional operational marine pollution monitoring uses bioaccumulation studies.

Bioaccumulation has received considerably less attention in freshwater than in marine and estuarine habitats. Johnson and Vine (1993) provided guidelines for the selection of substances of concern for fish bioacummulation studies. It is suggested that bioaccumulation studies are necessary as part of the Agency's statutory duty to protect fish populations. In freshwater eels have received by far the greatest attention, primarily because they are oil rich fish and constitute a major component of the diet of otters. Other fish have been investigated to a lesser extent, as have certain other groups, such as *Gammarus*. In addition, there is a national programme investigating bioaccumulation in otters using animals killed on the roads. Following work carried out by the MAFF Working Party on Pesticide Residues (WPPR) an extensive survey of eels took place between March 1986 and August 1987. A further survey of commercial eel stocks took place in 1992 and eels were collected in several Regions. In 1995/96 a joint survey by MAFF and Scottish Environmental Protection Agency (SEPA) took place and the samples are still being analysed (Zaman, 1997).

Many substances listed in the Dangerous Substances Directive can be accumulated in biological material. For List 1 substances the regulations require that sediment and/or shellfish and/or fish samples should be collected downstream of discharges on an annual basis and analysed for a number of substances (Zaman, 1997). In practice only sediment is monitored on a national scale by the Agency, although eel tissue has been sampled for this purpose in some Regions.

Potential needs

Some staff would like to increase the extent of bioaccumulation work within the Environment Agency. Outside the statutory requirements for bioaccumulation work, bioaccumulation studies have a role where sources of pollution are poorly understood. Bioaccumulation is a potentially useful tool in the evaluation of chemicals that occur at levels too low to be easily or reliably detectable in the water column. A recent review of organochlorine pesticide bioaccumulation in fish and fish eating mammals (Zaman, 1997) recommended continued progress in bioaccumulation work.

3.7 Water resources

3.7.1 Existing needs

The Water Resource Act 1991 includes the need to *'promote the conservation of aquatic flora and fauna'* and the Water Act 1989 requires the setting of Minimum Acceptable Flows.

The management of water resources has major implications for habitat quality and availability, and hence for biodiversity, in rivers, wetlands, floodplains and in some cases still waters. The Environment Agency aims to manage water resources to achieve a proper balance between the needs of the environment and those of abstractors and other water users. Conservation criteria and river flow parameters were considered by the Environmental Advisory Unit Ltd (1993a).

Water resource management in the UK has historically adhered to discharge based methods in the setting of prescribed river flows, where typically, Dry Weather Flows (DWF) have been indexed by a low flow discharge statistic. The shortcomings of this approach, and the desirability of incorporating ecological and fisheries considerations, has been appreciated for some years by water resource planners. Several concepts have been developed and investigated within the Agency over the past decade and some approaches are outlined in the following paragraphs.

The Physical HABitat SIMulation model (PHABSIM) and the Instream Flow Incremental Methodology (IFIM) provide a problem solving approach to water resource issues in streams and rivers. Within the Agency most research on IFIM and PHABSIM has been in relation to salmonid fisheries. If PHABSIM is ever to be adopted nationally throughout the Agency or to include other taxa, rigorous methods for the collection and interpretation of biological data will be necessary. In the USA, IFIM is currently endorsed as one of the primary negotiating tools in disputes over flows needed to maintain ecological integrity (Gore and Hamilton, 1996). If it can be validated for use in the UK it could be applied in the same way.

It is clear that over-abstraction and low flows can impact the ecological status of watercourses. Historically granted abstraction licences exceed the ecologically acceptable maximum on many river systems. In problem areas, these licences therefore require review and rationalisation, and this process is now underway. Relevant R&D in this area include the development of a procedural manual for the assessment of low flow conditions caused by abstraction (Scott Wilson Kirkpatric, 1992).

The Surface Water Abstraction Licensing Procedure (SWALP) concept seeks to provide a nationally consistent means of protecting flows to achieve a better balance between the needs of abstractors and the environment (Barker and Kirmond, 1997). A key stage of the procedure is catchment evaluation which involves the determination of environmental weightings (EW). Each stretch of river is assigned an EW based on its physical character, ecology and fisheries. This in turn will dictate the degree and rates of abstraction acceptable to that river stretch. The refinement of biological data collection or methods may be necessary for abstraction licensing in the future.

Biological criteria to assess the impact of low flows are currently being developed. Anglian Region commissioned research on the River Wissey (Petts and Bickerton, 1997). This yielded a manual for using macroinvertebrate taxa and assemblages for assessing in-river needs and setting Ecologically Acceptable Flow Regimes (EAFRs). More research is required on linking flow, mesohabitat and macroinvertebrate assemblage.

3.7.2 Potential needs

Agency staff generally felt that biological methods are very much targeted to GQA monitoring and are not designed specifically to meet other needs such as Water Resources. There is a perceived need within the Water Resources function for relevant biological information, which is not available at present. Most pressing is the need for scientifically based methods for determining minimum acceptable flows, optimum water levels and optimum flow regimes, so that a best compromise between water resource (and to an extent flood defence) requirements and conservation objectives (aesthetic and ecological) can be achieved.

Water resources staff would appreciate information regarding 'normal' flow regimes for biota and how the biota reacts to abnormal flow regimes in order to assess the impact of drought. Low flow and drought studies require long-term, targeted monitoring programmes to investigate specific changes in taxa responding to varying physical, chemical and biological processes. In addition, the establishment of trigger points to indicate a need for increased monitoring or biological thresholds or the initiation of an impact would be extremely beneficial. As a result of the Habitats Directive (94/43/EEC) there is a need to assess/predict the impacts of abstractions on wetlands and estuaries.

3.8 Flood defence

The Environment Agency aims to provide effective defence and timely warning systems for people and property against flooding from rivers and sea.

Historically, flood defence (especially land drainage schemes) has frequently been managed with scant regard for environmental quality, fisheries and nature conservation concerns. On many river systems, the Agency's predecessors (stretching back through the NRA and Regional Water Authorities to the River and Inland Drainage Boards) have been directly responsible for major habitat degradation through insensitive land drainage operations. The legacy of earlier schemes is still very apparent in many areas.

Within the last two decades, there has been an increasing realisation that flood defence and habitat conservation need not be mutually exclusive and conservation input to flood defence works is now the norm. In this respect, the Rivers and Wildlife Handbook (Ward *et al.*, 1994) provides some excellent examples of the resolution of potentially conflicting requirements. All proposed flood defence works should incorporate an Environmental Assessment so that the implications for fisheries, ecology and habitat quality can be properly evaluated and, if necessary, mitigated.

Biological data are integral parts of environmental assessment work. However, less emphasis is placed on benthic communities than marginal or terrestrial communities. Flood defence staff would appreciate information regarding the relationship between physical management of mudflats, saltmarshes etc. and benthic communities. Biological input to flood defence activities may change in the long term as flood defence methods move towards more integrated, soft engineering approaches. There remains however, considerable scope for the further strengthening and formalisation of co-operation.

The management and/or protection of macrophytes are important considerations during flood defence works, for example weed cutting.

3.9 Conservation

3.9.1 Existing needs

The Agency's conservation duties

The Environment Agency's conservation role is complex in that although it is not a conservation organisation *per se*, its duties to conservation extend throughout its sphere of activity. The Environment Act 1995 places general and specific duties on the Environment Agency with regard to conservation. These duties are summarised below:

- Section 6 stipulates the Agency's duty *to promote* conservation but is limited to water and associated land;
- Section 7 conveys the Agency's obligations *to further* certain aspects of conservation when carrying out its functions. In terms of its pollution control functions, the Environment Agency is required to *have regard* for conservation;

- Section 8 specifies a specific duty of the all the Agency's functions in relation to sites of special interest;
- Under Sections 9, 39 and 62, the Agency has a duty to *have regard* to Codes of Practice, costs and benefits in exercising powers and to the purposes of National Parks.

Whilst there can be little doubt about the meaning of *conserve* and *enhance*, the precise meanings of, and distinctions between, the terms *promote*, *further* and *have regard to the desirability of* are more subtle and open to interpretation. The Agency's own interpretation of its conservation duties is set out in *'The Agency's Conservation Duties'* (Environment Agency, 1996c).

Despite the fact that there was a tradition of both proactive and reactive conservation initiatives within the former NRA (Sections 2 and 16 of the Water Resources Act 1991 imposed conservation duties on the NRA), conservation will inevitably, in future, play a more prominent role in the Agency's activities than was the case in any of the three predecessor organisations, or is currently the case within the Agency. This will apply to both the development of conservation policy at Regional, national and international (especially European) levels and to the practical application of conservation measures on the ground. The Agency's conservation activities will encompass all media (land, water and air) and will relate to flora, fauna, habitats, geological and physiographic features, natural beauty and amenity.

Development of species and habitat action plans (UK Biodiversity Action Plan)

In 1992, the UK signed the UN Convention on Biological Diversity which charges the signatories to '*develop national strategies, plans or programmes for the sustainable use of biological diversity, or adapt for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in this convention.*' In 1994 The Department of the Environment produced the UK Biodiversity Action Plan (Department of the Environment, 1994). The result was 'Biodiversity: The UK Steering Group Report' (Department of the Environment, 1995), which produced costed action plans for a short list of 116 species of the nation's most threatened and declining species. Middle (286 species) and long (1250 species) lists of species were also produced.

The Environment Agency's stated objective (Environment Agency, 1997a) is to participate fully in the development and implementation of the UK Biodiversity Action Plan. To this end, the Agency will have several roles.

- *Plan development* - the Agency is represented on the national group and on key sub-groups in the overall management structure of the UK Plan.
- *Contact point* - the Agency is the *contact point* responsible for several freshwater species, namely the crayfish; depressed river mussel; freshwater pea mussel; glutinous snail; little whirlpool ram's horn snail; otter; ribbon leaved plantain; river jelly lichen; shining ram's horn snail; southern damsel fly; vendace; water vole and one freshwater habitat, namely chalk rivers. The contact point for each species and habitat is responsible for stimulating action to achieve targets, monitoring results and reporting progress.
- *Lead partner* - The Agency has been identified as sole or joint lead partner for 12 species. The lead partner is responsible for preparing detailed work plans, directing resources and overseeing plan implementation. The Agency will work in partnership with other organisations in its capacity as *lead partner*, such as with the Wildlife Trusts in the case of the otter and with MAFF in the case of the Twaite and Allis shads.

- *Responsible agency* - The UK Steering Group has allocated responsibility to the Agency for nearly 100 actions (in whole or in partnership with others) in 60 different plans, primarily relating to the aquatic environment.

It is therefore clear that the Agency has substantial responsibilities regarding implementation of the UK Biodiversity Action Plan and that the success of many of the individual species and habitat plans will be dependent on Agency participation.

The Agency's contribution to the UK Plan has significant policy, action and potentially, resource implications. In some instances, additional R&D may be required, either to develop individual action plans, or to develop species-targeted monitoring programmes. In this latter context, it is possible that existing monitoring programmes, which tend to measure what occurs where, will be inadequate and that a shift in emphasis towards establishing ecological targets and measuring progress against those targets will be required.

Other legislative duties

In addition to the Environment Act 1995 and its precursors, a range of UK and EU derived legislation and international conventions and agreements directly or indirectly impose duties upon or have implications for the biological conservation duties of the Agency. These include, *inter alia*, the following:

- Wildlife and Countryside Act, 1981 and Amendment Act 1991;
- Habitats Directive (EC Council Directive on the Conservation of Natural Habitats of Wild Fauna and Flora (92/43/EEC));
- Wild Birds Directive (EC Council Directive on the Conservation of Wild Birds (79/4009/EEC));
- Ramsar Convention on Wetlands of International Importance;
- Bonn convention on migratory Species of Wild Animals;

These acts and conventions either afford protection to individual species, or they require the establishment of statutory designated sites.

Soft engineering

A further conservation orientated business need is the use of 'soft' or 'biological' engineering for ground stabilisation, particularly in the case of riverbanks. The use of vegetation for bank stabilisation is almost always preferable on aesthetic and wildlife conservation grounds, it will often be cheaper and in some cases may be preferable in engineering terms. Many engineers are sympathetic to these points and would prefer to use soft solutions where these are appropriate. However, river engineers are generally cautious in their use of biological materials and tend to opt for hard solutions, e.g. concrete or sheet piling, whose performance characteristics are well known and quantifiable. There is still limited experience in the field of soft engineering and quantitative data on the performance of different types of vegetation (i.e. its effects on bank erosion, bank accretion and other fluvial processes) in different situations is largely lacking. This is therefore an important area for further systematic research. Some recent R&D has begun to address these issues e.g. a joint Engineering and Physical Sciences Research council and Environment Agency scoping study (Thorne *et al.*, 1997) examined the use of willows (*Salix* spp.) for bank stabilisation.

The conservation and aesthetic rewards of the soft approach to river engineering will be particularly high for urban and suburban rivers, but so too are the potential consequences of bank failure or channel obstruction.

Cost-benefit analysis and conservation (environmental economics)

The value usually bestowed upon a natural resource is difficult to apply where conservation is concerned because there is no agreed currency for comparing wildlife and habitats to jobs, crops or oil reserves. Conservation value is therefore traditionally assessed in non-economic terms by a largely comparative process. However, the expanding field of environmental economics is one that attempts to place a monetary value on the presence of species or habitats, thus aiding the comparison of conservation against other land uses. This approach is of significance to the Agency as environmental costs and benefits must figure in the cost benefit analyses of its proposed actions. This may be particularly the case where potential environmental improvement schemes are competing for limited resources. Environmental economics has been addressed in existing Agency R&D (Postle, 1993).

Relationship of the Agency to the primary conservation bodies

In view of the Agency's potentially very wide ranging conservation remit, there is inevitably some ambiguity and overlap in the respective roles of the Environment Agency and the primary conservation agencies such as English Nature (EN) and the Countryside Council for Wales (CCW). The respective roles of these agencies are currently in the process of resolution, for example the Agency and EN have produced an initial concordat. However, this is primarily a statement of intent rather than an actual resolution of the issues.

In very broad terms, it is the role of EN and CCW (likewise Scottish Natural Heritage (SNH), Department of the Environment in Northern Ireland (DoENI) and the Joint Nature Conservation Committee (JNCC)) to advise government on such issues as nature conservation policy, on what is of nature conservation value, the designation of conservation sites and the legal protection of sites and species (through the Wildlife and Countryside Act, Habitats Directive, Birds Directive etc.). The role of the Environment Agency is more concerned with the implementation of conservation policy and legislation. However, the historic strengths and expertise of the various organisations is clearly of significance in the present and future determination of their respective roles. Thus EN and CCW have extensive long-term established expertise in relation to terrestrial habitats, some expertise in the marine environment, but a more limited tradition with respect to freshwater habitats. This is the exact converse of the inherited expertise and tradition of the Environment Agency. Thus, although the Environment Agency and conservation agencies (EN and CCW) will operate in partnership, it is logical to expect that for the foreseeable future, the Agency will continue to play a dominant role in freshwater conservation. The primary focus for terrestrial nature conservation in England and Wales, however, will remain with EN and CCW respectively.

Monitoring of conservation status in protected areas

Although the Environment Agency is not responsible for the designation of protected sites (this role falls to government on the advice of EN, CCW & JNCC), the Agency can be expected to play a significant role in the routine surveillance, monitoring and assessment of such sites. This will be particularly the case for river and wetland SSSIs and SACs, marine SACs and wetlands designated under the Ramsar Convention or as SPAs. The Agency (NRA) and English Nature have drawn up a *'Memorandum of Understanding on River SSSIs'* (National Rivers Authority and English Nature, 1995) which establishes a common purpose in the protection and management of river SSSIs. The Memorandum also extends to SACs and is intended to form a model for agreement on wetland SSSIs, SPAs and Ramsar sites. In practice, the Agency is the only organisation with the necessary infrastructure to do any meaningful monitoring in most of these areas. The biological monitoring requirements for such sites will clearly be different from or additional to any compliance monitoring relating to GQA or the UWWTD.

3.9.2 Potential needs

The assessment of ecosystem health and biological integrity

The forthcoming Water Framework Directive, if adopted, will place emphasis on integrated water resource and river basin management based on the setting of ecological targets. This potentially adds a new, conservation oriented, dimension to river basin management involving the principle of ecosystem health or biological (ecological) integrity. Biological integrity has been defined as *'the ability of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition comparable to that of the natural habitats of a Region'* (Karr and Dudley, 1981). This definition covers a much wider range of impacts than simply water quality and includes flow regime, habitat structure, exotic taxa and riparian impacts.

Methods to assess the integrity or health of ecosystems have received little attention outside the United States. The first method to address this issue was the Index of Biotic Integrity (IBI) (Karr, 1981). This used twelve separate measures or metrics to assess fish communities in Indiana and Illinois. These measures fell into three groups, which were measures of species richness and composition, trophic composition and fish abundance and condition. This method has proved to be a successful model for fish and has been adapted for other areas of North America and Australia. The use of fish for such methods in England and Wales is questionable because the degree of stock manipulation is great and this may hinder the usefulness and discrimination of any such method.

Multimetric methods have also been applied to macroinvertebrates. These include the Rapid Bioassessment Protocols I-III proposed by the US EPA (Plafkin *et al.*, 1989) and more recently the Benthic Index of Biotic Integrity (Kerans and Karr, 1994). Methods using macroinvertebrates may be more appropriate to the Agency but modification and calibration to fit conditions in the UK would be required. In addition it would be necessary to demonstrate that such a method could provide a type of information not yet provided by existing macroinvertebrate methods either singly or in conjunction.

Ecotoxicological techniques, for example the use of biomarkers, also have substantial potential for the direct measurement of the health of the environment, particularly in relation to the effects of chemical pollution. This area has been the subject of a considerable, but widely scattered, body of research effort in recent years. The use of biomarkers is also one of the research areas of the Agency's Ecotoxicology and Hazardous Substances National Centre. Although primarily seen as a water quality tool, biomarkers have potential conservation applications.

In the UK, very few existing national or local monitoring programmes currently involve the direct measurement of ecosystem health or biological integrity, rather an attempt is made to infer these conditions by proxy. Ecological integrity of still waters is being addressed within an ongoing R&D project (Project Proposal Reference: A05(94)2 and Project Number: EMA012). The scoping phase of this project identified taxa groups for the assessment of lakes, ponds, canals and ditches (Williams *et al.*, 1996). Ecosystem health and biological integrity are the ultimate goals of almost all environmental management, sustainable development and conservation initiatives. It therefore follows that the development of cost effective and reliable techniques for their direct measurement is central to many of the Agency's business needs.

3.10 Fisheries

3.10.1 Existing needs

Under the Environment Act 1995, the Water Resources Act 1991, the Salmon Act 1986 and in particular the Salmon and Freshwater Fisheries Act 1975, the Agency has a duty *'to maintain, improve and develop salmon fisheries, trout fisheries, freshwater fisheries and eel fisheries'*.

The monitoring, management and enhancement of freshwater fisheries is thus one of the core functions of the Agency. However, the statutory duty in relation to fisheries has significant implications for a range of other Agency functions, and fisheries data is of actual or potential value in meeting a variety of Agency business needs.

Fisheries advice on such subjects as fish health and stock assessment is provided to angling clubs, fishery owners and managers.

The management of marine fisheries is currently the responsibility of the Ministry of Agriculture Fisheries and Food (MAFF).

3.10.2 Potential needs

Throughout the Regions and at Headquarters, there is a widely held, though not universal, view that there could and should be a much more widespread use of fishery data, and that the potential role of fish in biological monitoring is currently largely unrealised. Although the high mobility and avoidance reactions of fish are sometimes seen as disadvantages in their use as biomonitors, many biologists and fisheries scientists see particular benefits in the use of fish.

The development and introduction of the national Fisheries Classification Scheme, which is currently under R&D (Project Proposal Reference: W2A(96)3, 'Use of semi-quantitative electric fishing methods for fisheries classification') provides a potential opportunity to harmonise fisheries data collection and use across the Regions and the potential to introduce a formal fisheries 'window' into the GQA. The forthcoming Water Framework Directive is likely to involve further duties for the assessment of fish assemblages.

3.11 Recreation and navigation

The Environment Agency aims to conserve and enhance inland and coastal waters and their use for recreation. It also has an objective to maintain and improve non-marine navigation.

Biological and conservation input may be necessary in relation to these activities. For example, macrophyte management is undertaken for the purposes of navigation and recreation.

Fisheries are a key recreational resource used by the public and thus receive a substantial input from the Agency in terms of surveillance, monitoring and management. The Agency also has powers to raise income through contributions from fishermen (recreational and commercial) and fishery owners, e.g. from rod licences for recreational fishing. Anglers are one of the Agency's major customer groups and their expectation is that fisheries should be proactively, routinely and openly managed for the benefit of their interests. In addition, keeping anglers and the general public aware of the status of fish stocks has its own inherent promotional benefits, e.g. the Thames salmon reintroduction programme.

3.12 Environmental Impact Assessment (EIA)

EIA is referred to as Environmental Assessment (EA) under UK legislation. UK legislation complementary to the EC directive on Environmental Impact Assessment (85/337/EEC) places a number of specific obligations on the Agency. The Agency has an important role to play in the field of Environmental (Impact) Assessment. This role includes the environmental assessment of its own proposals (e.g. flood defence works), its regulatory functions (e.g. the licensing of discharges, abstractions and waste disposal sites) and its duties as a statutory consultee for almost any public or private sector development proposal. All of the foregoing may have conservation implications on which the Agency will be expected to provide a reasoned opinion.

Environmental Assessments and biological data produced by the Agency and by others are likely to be increasingly challenged as the costs of maintaining and improving the environment are evaluated. Confidence in the validity of conservation data and environmental assessments is therefore of high priority. This can only be achieved by using standardised approaches, methods and quality assurance (QA) procedures.

It is, therefore, apparent that the Agency will require a full suite of methods for assessing the conservation value of habitats and features (terrestrial, marine and freshwater), for assessing and monitoring the conservation status of key species, and for assessing potential impacts on conservation value. Although the Agency has a direct need for such methods for evaluating its own programmes, these methods may be of more frequent use to the Agency in its role as statutory consultee. When judging the environmental assessments of project proponents or their consultants, the Agency can ensure that these have been carried out to an appropriate standard using established methods. When consulted at an early (scoping) stage of an assessment, the Agency can and should advise, not only on the key issues, but also on appropriate methods for their investigation.

North East Region (1996a) has produced a set of *'Guidelines for monitoring methodologies for water resources projects'*. These guidelines address the requirements for monitoring in environmental assessment and the methods outlined are intended to represent the best practice which the Agency expects others to follow. There is a clear case for producing such guidelines at national level covering all spheres of Agency activity. Although the Agency has produced guidance on scoping for the environmental assessment of projects (National Rivers Authority, 1995a and b; Environment Agency, 1996d), these are essentially checklists and do not provide details of specific assessment and monitoring methods.

It is generally felt that post-project appraisals and post pollution incident assessments should be longer term. Many Regions would like the adoption of formal monitoring of all post instream enhancement works.

3.13 Sustainable Development

In response to the Earth summit in 1992, the UK Government produced 'Sustainable Development: the UK Strategy' in 1994. Section 4 of the Environment Act 1995 lays down the principal aim of the Environment Agency as follows: *'It shall be the principal aim of the Agency (subject to and in accordance with the provisions of this Act or any other enactment and taking into account any likely costs) in discharging its functions so as to protect or* *enhance the environment, taken as a whole, as to make the contribution towards attaining the objective of achieving sustainable development mentioned in subsection (3) below.'*

The Agency's interpretation of its role and initial strategy for achieving this aim was set out in a recent guidance document (Environment Agency, 1996e). The Agency's Functions include, *inter alia,* Integrated Pollution Control; Waste Regulation; Contaminated Land; Water Protection; Water Management; Water Resource Control, Fisheries; Recreation; Navigation; Coastal Zone Management; and Land Use Planning. All of these functions are instrumental in achieving the overall goal of sustainable development and as such will also contribute, directly or indirectly, to the achievement of conservation and biodiversity objectives.

3.14 Environmental Change Network (ECN)

Founded in 1992, the Environmental Change Network (ECN) is the UK's long-term environmental monitoring network. It is designed to collect, store, analyse and interpret long-term data based on a set of key physical, chemical and biological variables which drive and respond to environmental change. ECN is a multi-agency programme which operates a network of terrestrial and freshwater sites throughout the UK.

The Environment Agency is responsible for monitoring at ECN freshwater sites. Wherever possible the recommended methods are close adaptations of existing, widely practised methods. ECN protocols have been produced for macroinvertebrates, macrophytes, epilithic diatoms, phytoplankton and crustacean zooplankton.

3.15 State of the Environment reporting

The Agency has a specific duty under the Environment Act 1995 to compile information, either by carrying out its own work or by obtaining it in other ways in order to enable it to form an opinion of the general state of the environment (Environment Agency, 1996a). On 1 April 1996 the Agency published its first environmental overview: *'The environment of England and Wales - A snapshot'* (Environment Agency, 1996f). This document is merely a starting point in the process of State of the Environment reporting that will need to be developed and improved over time. Currently biological information is included in fisheries, wildlife, biodiversity and conservation sections.

The Environment Agency reports on the quality of rivers and canals as part of State of the Environment reporting. The chemical, rather than the biological, component of the GQA was used to report the quality of rivers in 1995. However, the biological GQA could also be used in this context because standard methods and reporting are available and because the data sets are now well established, allowing trends to be revealed. Biological methods are not yet sufficiently advanced or standardised to play a role in reporting the state of other aquatic ecosystems (e.g. stillwaters, estuaries).

The Environment Agency has a responsibility to *'enable it to form an opinion of the general state of pollution of the environment'*. Nutrient status is included as a window in the GQA. Therefore long-term macrophyte monitoring of water quality may have a potential role in State of the Environment reporting.

Viewpoints of the environment (Environment Agency, 1996a) proposed the development of a national framework for measuring the State of the Environment that will serve the needs of the Agency itself and its many different customers.

The document identifies key issues to be addressed in the development of a national environmental monitoring and assessment framework. Issues that may have a significant biological input include:

- measurement of the status of key biological populations and communities;
- monitoring with respect to environmental quality standards;
- measurement of the health of the environment.

3.16 Local Environment Agency Plans (LEAPs)

One of the Environment Agency's corporate aims is to maximise the benefits of integrated pollution control and integrated river basin management. Local Environment Agency Plans (LEAPs) are the mechanism to achieve this on a local basis. The LEAP process is a forward planning process which builds on Catchment Management Plans developed by the former NRA. LEAPs address the full range of sometimes conflicting catchment demands with the aim of developing a unified management strategy with clearly defined objectives. The final stage of the LEAPs process is the production of an Action Plan which forms the basis for improvement to the environment over a timescale of five years.

An important element of a plan is the identification and prioritising of ecological, environmental and conservation needs of the aquatic and terrestrial environment of the Action Plan area. The use and development of biological methods and monitoring are fundamental in meeting these needs. LEAPs will also be the principal mechanism for the implementation, at local level, of the Agency's contribution to the UK Biodiversity Action Plan.

4. BIOLOGICAL METHODS

4.1 Freshwater macroinvertebrate methods

4.1.1 Introduction

Current status of invertebrate methods

At present macroinvertebrates are the group for which methods are, in general, most advanced and most thoroughly standardised between Regions. They have largely been used in the assessment of water quality, but have great potential in the fulfilment of other roles of the Agency because they are an important and widespread group of organisms and because there is already widespread expertise within the Agency in their sampling and identification.

Development of invertebrate methods

The use of the biota as an indicator of the quality of the aquatic environment stems from the early part of the present century and a range of approaches were investigated during the first half of this century. Macroinvertebrates soon became established as the preferred taxonomic group for use as water quality indicators for a number of reasons including their ubiquity and diversity, their wide range of sensitivities to environmental stress, their presence at virtually all sites throughout the year and their relative ease of sampling and identification. Major developments in the use of invertebrates for water quality monitoring included the development of the qualitative Trent Biotic Index (TBI) (Woodiwiss, 1964) and the semi-quantitative Chandler Score (Chandler, 1970). Both of these methods give a numerical score based on two community attributes, namely diversity (taxonomic richness) and the relative pollution sensitivity of each taxon. Both methods aimed at easy and rapid application by limiting the level of taxonomic identification required.

The national Biological Monitoring Working Party was established following the 1975 national River Pollution Survey with the remit, *inter alia*, of developing a biological classification of river water quality for use in future national river pollution surveys. The outcome was the Biological Monitoring Working Party or BMWP score (National Water Council, 1981). Taxonomic identification for the BMWP score is restricted to family level, with each family given a score of 1 (very tolerant) to 10 (very sensitive). The total score is achieved by summing the individual scores of each family present in the sample. The BMWP became firmly established in Britain during the 1980s as the standard biological method for General Quality Assessment (GQA) and related monitoring.

The TBI, Chandler and BMWP (and most other) scores share a common and fundamental problem. That is that in addition to water quality, the intrinsic physicochemical environment is also an important determinant of macroinvertebrate diversity in rivers. Thus even in a pristine river, scores are typically substantially depressed in the lowland reaches and may also be somewhat depressed in headwaters. Interpretation of the biological score therefore becomes potentially problematic. This problem was partially overcome for the BMWP by introduction of the ASPT (Average Score Per Taxon) which is commonly used alongside the basic BMWP. A low BMWP in conjunction with a high ASPT (i.e. a low overall diversity in which pollution sensitive taxa are well represented) would thus imply that water quality is satisfactory.

The problem is systematically addressed by RIVPACS (the River InVertebrate Prediction And Classification System (refer to Wright *et al.*, 1989, for an account of the development and underlying rationale of the system). RIVPACS is based on a large reference database of pristine sites covering all river types in mainland Britain. From a basic set of physical and chemical variables, the RIVPACS package predicts the invertebrate community that should be present at a site in the absence of environmental stress. RIVPACS can predict each individual species with its probability of occurrence, BMWP score or BMWP-ASPT. A comparison of expected and observed communities at a site therefore gives a measure of environmental stress. Although RIVPACS has been a standard Agency (and NRA) tool since the early 1990s, the system is subject to ongoing R&D.

This section describes standard procedures for collecting and analysing river invertebrates in conjunction with BMWP and RIVPACS for GQA and related operational needs. Methods developed for addressing more specialised needs and situations are also discussed.

4.1.2 National procedure for collecting and analysing riverine macroinvertebrates (BMWP, ASPT, RIVPACS)

Business needs

a) Existing:

- water quality assessments - GQA, operational needs and pollution incident investigation;
- water resources - within the water resources function of the Agency there is a perceived need for relevant biological information where macroinvertebrates may be useful;
- flood defence - the Agency needs to consider macroinvertebrate communities during its flood defence works;
- conservation - the Agency has been identified as the Contact Point and/or Lead Partner for eight species of macroinvertebrate as part of the UK Biodiversity Action Plan - Macroinvertebrates may be a useful group on which to focus for general assessments of conservation value and studies of rehabilitation - RIVPACS may be particularly useful in this context;
- fisheries - macroinvertebrate data is used by the fisheries function, not only for water quality assessments, but also because macroinvertebrates are a major source of food for many fish species at some stage in their life cycle;
- Local Environment Agency Plans (LEAPS).

b) Potential:

- State of the Environment reporting;
- macroinvertebrates will almost certainly play an important role in the assessment of ecological integrity.

Current status

These are the methods used for routine water quality monitoring and GQA. Standard methods are used and are well established throughout all the Regions of the Agency (Environment Agency, 1997b; 1997c; 1997d).

It is considered that for these purposes the present system is generally good and the RIVPACS model is being used for the development of other systems, for example PLANTPACS (Project Proposal Reference: W1A(96)2 and Project Number:W1/017, 'PLANTPACS Phase 1 and Phase2'). However, there are concerns that these procedures may be used for other purposes for which they may not be suitable because they form the most widely used and well established protocol. For example, the BMWP score is targeted towards organic pollution and may, therefore, not necessarily provide a good indication of other impacts. This means that there is a need for other methods of data analysis or interpretation to fulfil the other roles of the Agency.

Method summary

a) Sampling

Shallow waters

The sampling of macroinvertebrates from small rivers is generally achieved by kick-samples in conjunction with an additional search. Standard methods for the collection of RIVPACS compatible and GQA samples are used throughout the Agency.

Deep waters

Standard national procedures for the sampling of deep rivers are available and consist of dredge or airlift samples and marginal sweeps in conjunction with manual searches. Although these standard methods exist it is generally considered that the sampling of deeper waters is not adequately addressed at present. The use of artificial substrate samples has often been advocated in the literature but has never been widely adopted within the Agency. Clarification of sampling methods for deep rivers is one of the areas to be addressed as part of the R&D project 'Testing and further development of RIVPACS - Phase 3. Development of new RIVPACS methodologies' (Project Proposal Reference: A05(95)3 and Project Number: E1-007).

b) Sample handling

The handling and preservation of invertebrate samples varies between Regions and Areas within the Regions. Many samples are transported to the laboratory and identified live. In other Regions e.g. Welsh Region and Southern Region, formalin is used to fix samples in the field using a Regional procedure. A standard procedure for the sorting of these samples using a fume extraction system for individual sample processing within the laboratory is currently being prepared. In some Regions (e.g. South West Region and North West Region) samples are preserved with Industrial Methylated Spirit (IMS) in the field. Many Agency biologists feel that the use of formalin is not desirable but it is used in some Areas for the long-term storage of samples. IMS is also widely used as a short-term preservative.

The general view of Agency biologists is that the issue of preserving samples needs to be addressed further and that some sort of national guidance and standard procedures would be useful. If the use of formalin is to be eradicated on health and safety grounds, some workers need to be convinced that there is an adequate alternative.

There may be a need for more studies on how handling influences the data yielded by macroinvertebrate studies. Areas of interest include damage to invertebrates, predation (addressed by Hiley (1995) in a student project in North East Region) and deterioration of samples with various preservatives. It is noteworthy that Institute of Freshwater Ecology (IFE) routinely uses formaldehyde and this procedure was used for RIVPACS development.

c) Identification

Identification is customarily carried out to be compatible with the BMWP score. This broadly corresponds to family level for most groups. Some methods and special investigations may require species level identification.

d) Data analysis

BMWP scoring and RIVPACS are routinely used. ASPT (average score per taxon) is often calculated.

Several multivariate methods have been used by Agency staff to analyse macroinvertebrate data using the following packages, PRIMER, TWINSPAN, DECORANA and CANOCO. Multivariate methods are considered to be useful for detailed studies and can reveal subtle changes, for example, PRIMER has been used to study the influence of drought in North East Region and TWINSPAN in South West for the study of cress-bed impacts.

The potential for multivariate analysis would increase if species level data becomes more widely available.

There is an identified need for guidance for the use of statistics in general and multivariate methods in particular. Many members of Agency staff feel that multivariate methods particularly PRIMER may be very useful for a wide range of the Agency's functions but that adequate training is required. Also standard methods, or a range of recommended methods, are needed so that the same procedures (data transformations, linkage mechanisms etc.) are used throughout the Agency. PRIMER training courses are run by Plymouth Marine Laboratory and have been attended by Agency staff. Within the Agency a 'Statistics for Biologists' course is planned for the near future.

In addition, guidance on the interpretation of data is required, particularly for multivariate methods.

e) Quality assurance

The use of standard documentation for collecting and analysing macroinvertebrate samples ensures that methods are undertaken according to set protocols. Training courses for staff form part of the quality assurance scheme. A training video 'RIVPACS field sampling: Pond net sampling' has been produced. Analytical quality control (AQC) of macroinvertebrate identification, particularly when it is part of GQA surveys is well developed (Environment Agency, 1997d; van Dijk, 1994) and the AQC procedure is mandatory throughout the Agency. Institute of Freshwater Ecology (IFE) also carries out an external audit of macroinvertebrate samples (Kinley and Ellis, 1991).

Future developments

There have been some specific comments from Agency biologists regarding the possible improvement of RIVPACS. There is concern that the habitat variables are too broad to achieve an adequate description of a site. In addition, the database may need expansion particularly with reference to headwater sites, which are considered to be poorly represented at present. This issued is addressed in R&D Note 221 (Furse *et al.*, 1993). Temporary streams and winterbournes are specialised habitats that require further study and R&D. There is a relevant ongoing R&D project 'Operational mechanisms for protecting and enhancing headwaters - Phase 2' run by E. Chalk, North East Region (Project Proposal Reference: A05(95)3 and Project Number: 696). Certain Regions would like to see a refinement of the RIVPACS system on a local basis, since the database lacks streams characteristic of particular areas. In such instances better resolution of the system is necessary if it is to be used routinely.

Although currently a very useful tool, the Environment Agency recognises that RIVPACS methodologies still require development to broaden the range of waters for which they are appropriate. Some issues are being addressed in a current R&D project 'Testing and further development of RIVPACS – Phase 3. Development of new RIVPACS methodologies'

(Project Proposal Reference: A05(95)3 and Project number: E1-007). The project is at very early stages at present but the overall objective is to determine how improvements in RIVPACS should be implemented. Identified improvements which require only a limited amount of work will be developed in this project. Alternatively, where improvements need a substantial amount of work, scoping studies will be undertaken during this Phase 3 project to determine the extent of work required. Implementation of such developments will subsequently be carried out as separate daughter projects. Specific issues to be addressed include (Wright, personal communication):

- organisation of an international workshop and UK seminar on RIVPACS development;
- further development to include abundance data so that more subtle changes can be seen;
- more deep river sites and clarification of sampling methods for deep rivers;
- scoping study to assess the work needed to incorporate canals into RIVPACS;
- investigation into the potential of RIVPACS for assessing biodiversity;
- production of a wide report outlining the advantages of biological monitoring;
- inclusion of new variables, possibly from GIS;
- possible commercialisation of RIVPACS package;
- development of add-ons for educational purposes;
- possible development of 'dirty water RIVPACS' using data from 1990 and 1995 GQA surveys. This could be used to predict community changes as chemical conditions change;
- use of RIVPACS 3 database to look for patterns in the structure and function (e.g. feeding groups) of communities. This may shed light on the response of these attributes to stress.

Ultimately, RIVPACS IV software will be developed which incorporates all the modifications resulting from the Phase 3 project and its daughter projects. Presently the initiation of this project is the year 2000. Ideally development of RIVPACS IV will include structural alterations of the RIVPACS software to make it more compatible with WINDOWS, other databases and make it easier to extend and modify in the future.

The 1995 GQA data is currently undergoing Phase 2 of its evaluation as part of Environment Agency R&D (Project Reference: E1D(96)2, 'Analysis of 1995 biological survey data - Phase 2'). The objective is to enable biological targets to be set for rivers.

4.1.3 Biological Quality Objectives (BQOs)

Business needs

A method has been developed to meet the need of setting Biological Quality Objectives (BQOs). BQOs in turn are important in conservation, sustainable development, impact assessment, and water quality and to meet the needs of the forthcoming Water Framework Directive.

Current status

A provisional method has been developed for setting use-related targets based on the GQA methodology and classification routines (Biological Quality Objectives Sub-Group, 1997a). The development of the method is very recent and progress in this area is ongoing. Draft

BQOs have been set for all Regions using 1995 GQA data. Guidelines for local assessment and modification of BQOs have been drafted (Biological Quality Objectives Sub-Group, 1997b).

Method summary

a) Sampling

Biological GQA methodology and data is used. Refer to Section 4.1.2.

b) Identification

Based on Biology GQA methodology. Refer to Section 4.1.2.

c) Data analysis

An algorithm is used to derive the Biological Quality Objective (BQO). The 1995 GQA grades have been used as a baseline and no deterioration is assumed. Classes e and f in 1995 are allocated a BQO of d. If the resulting BQO is lower than the parallel River Quality Objective (RQO) expressed as River Ecosystem (RE) class, the BQO is raised so that RE1 gives a BQO of a, RE2 gives b, RE3 gives c and RE4, RE5 and RE6 gives d. In some instances allocation of a BQO of e may be unavoidable, for example in highly degraded channels in urban areas.

Compliance against targets is assessed using the standard statistical routines developed for the GQA system.

d) Quality assurance

GQA data national quality assurance procedures apply.

Future developments

After consultation a nationally consistent set of BQOs will be agreed. The application of this method with respect to the Water Framework Directive will be investigated.

4.1.4 Lincoln Quality Index (LQI)

Business needs

The Lincoln Quality Index (LQI) has use in water quality and Environmental Impact Assessments (EIAs).

Current status

This method was developed as an attempt to incorporate habitat quality into evaluations of water quality and define use-related biological targets (Extence *et al.*, 1987). LQI has received little attention outside Anglian Region within the Agency and its predecessor.

Method summary

a) Sampling

Sampling typically occurs with a hand-net and all habitats are sampled. Sampling is standardised by the amount of material examined rather than time.

b) Identification

Identification is to BMWP level.

c) Data analysis

Sampling sites are classified subjectively into two categories: habitat-rich riffles and habitat poor riffles/pools. The BMWP and ASPT are then used to give an Overall Quality Rating which can range from 0 to 7 and which relate to Chemical River Quality Objectives.

d) Quality assurance

Quality assurance procedures are not described. They are the same as for all routine work and applied to routine samples.

Future developments

This was a valuable attempt to set biological use-related targets which have been used to identify and prioritise impacts. With the development of RIVPACS and possibly Biological Quality Objectives (BQOs), LQI will become obsolete and cannot now be recommended for widespread use within the Agency.

4.1.5 Acidification

Business needs

This method meets water quality needs by detecting surface water acidification and assessing its impact. This aids in the development of pollution prevention strategies.

Current status

A method was developed to assess acidification in streams. It was developed using national data (Rutt *et al.*, 1990) and has been used operationally in Welsh Region. North West Region have also successfully used this method.

Method summary

a) Sampling

A one-minute kick-sample is taken from shallow fast-flowing riffles in the period between November and April.

b) Identification

Relies on the identification of 14 key families.

c) Data analysis

Presence and absence of combinations of key families places sites into four classes of acidification.

d) Quality Assurance

Quality assurance is not described.

Future developments

This method is designed for use in base poor streams only and therefore its use will be limited to certain upland areas of England and Wales which are the principal areas affected by surface water acidification. However, within such areas it is likely to be very useful. This method is currently under Agency R&D - 'Acid waters monitoring - indicator populations' (Project Reference: P2-090).

4.1.6 Ferruginous minewaters

Business needs

This method is related to water quality and impact assessment business needs.

Current status

This method was developed in Welsh Region and is used primarily in South East and South West Areas, where most discharges occur. It is used to assess the impacts of ferruginous minewaters on streams and rivers (Davies *et al.*, 1997). The method has been trialled nationally and priority lists have been produced.

Method summary

a) Sampling

A standard three-minute kick-sample in accordance with GQA methodology is carried out.

b) Identification

BMWP level identification is undertaken.

c) Data analysis

This method uses changes in BMWP score and/or a reduction in the abundance of high scoring families between upstream and downstream sites to give three classes of impact. Classification can also be achieved using juvenile salmonids.

d) Quality assurance

Quality assurance is not described.

Future developments

The use of this method is limited to areas where this particular water quality problem occurs. The method only works effectively in situations where minewaters are the only input because it relies on the presence of high scoring taxa in upstream reference sites. If it is to be used in other Regions, calibration may be required. Future developments could attempt to address conditions where the minewater is part of urban or industrialised inputs.

4.1.7 Rapid Biological Appraisal Keys (RBAKs)

Business needs

This method meets a water quality need by assisting in impact assessment and pollution prevention and control. The main potential benefit of RBAKs is their ability to provide rapid on-site assessments.

Current status

This method was developed in Welsh Region but has been used in other Regions such as South West (National Rivers Authority, 1995c; Rutt *et al.*, 1993). It is used to assess organic farm pollution.

Method summary

a) Sampling

One-minute kick-sample and estimation of sewage fungus percentage cover.

b) Identification

Relies on the enumeration of four key groups of macroinvertebrate (Heptagenids, Oligochaeta, *Baetis* and *Gammarus*) and the estimation of sewage fungus cover.

c) Data analysis

Flow chart yields five pollution classes (1, 2a, 2b, 2c and 3).

d) Quality assurance

Quality assurance procedures are not described in the literature. Some quality assurance has been applied to determine the precision of the technique but is not routinely used.

Future developments

This method is limited in its use to streams and small rivers with similar habitats to west Wales because it relies on so few key groups. Similar techniques for use in other Areas may have to use different key groups. A manual for producing further keys in areas dissimilar to West Wales has been produced (Rutt and Mainstone, 1994).

Other comments

The use of this method in detecting and monitoring farm pollution was the subject of National Rivers Authority R&D in 1995 (National Rivers Authority, 1995c).

4.1.8 Chironomid Pupal Exuviae Technique (CPET) for assessing canal water quality

Business needs

Water quality and pollution control needs are met by this method since it is used in the assessment of canal water quality and discharge impact assessment.

Current status

Based on 60 sites on canalised watercourses in Midlands, North East, South West and Thames Regions. This method has been designed specifically to assess canal water quality which is not covered in RIVPACS (Ruse, 1997).

Method summary

a) Sampling

Exuviae are skimmed off the water surface in areas where they accumulate.

b) Identification

Relies on the identification of 12 key genera.

c) Data analysis

Two methods are available; both of which yield five quality grades. Both systems rely on the percentage occurrence of the key genera. The first is a 'non-expert' scoring system in which scores are attributed to widely distributed, frequently occurring and easily recognisable indicator taxa. This is used to assess water quality in canals. Secondly a dichotomous key based on six of these indicators is provided for classifying canal water quality.

d) Quality assurance

Quality assurance is not described.

Future developments

Chironomid exuviae are, rightly or wrongly, perceived to be difficult to identify by many biologists and this may influence the use of this method. The performance of the method in relation to other water quality methods needs to be assessed. Furthermore, this method may be superseded by others for the assessment of canal waters developed as part of the still-waters research and development programme. If suitable other methods are developed, perhaps using family level macroinvertebrate data or algae, the use of chironomid exuviae may be of limited use in this context.

Other comments

The CPET is potentially applicable to all freshwaters. Its principal virtue is that it offers a simple sampling technique (exuviae are skimmed off the water surface) for sites such as canals and large rivers where the standard macroinvertebrate kick-sampling method is difficult or impossible.

4.1.9 North West bankside assessment

Business needs

This method potentially meets a variety of water quality and impact assessment related needs. It is used in routine survey work and pollution source investigations where the data is unlikely to be used as evidence in a prosecution.

Current status

It was developed and used in North West Region as a rapid method for quality assessment. Regional methods have recently been formalised (Pickering, 1997).

Method summary

a) Sampling

One-minute kick-sample, covering all available habitats, supplemented by a search of five large stones where possible. In deep waters, marginal sampling is recommended.

b) Identification

Identification is carried out in the field except for problematic taxa, which are brought back to the laboratory. The minimum level is BMWP family although further discrimination is permitted at the discretion of the worker. Sorting ceases if no new BMWP scoring taxa are found for two minutes. Abundance values below ten are recorded. Other abundances are estimated based on a log scale.

c) Data analysis

Based on ASPT and "richness", i.e. number of taxa.

d) Quality assurance

A method protocol has recently been produced to ensure consistency of approach throughout the region. Biologists receive training and an accreditation scheme has been proposed. This would involve all individuals undertaking bankside assessment being tested in the field to ensure that they are capable of reaching a satisfactory level of sample collection, sorting and identification under field conditions. There is no formal quality control mechanism but examples of all taxa identified are returned to the laboratory where one in ten is randomly selected for checking.

Future developments

This method is undergoing testing in North West Region. Its future use will depend on the results of this testing. There has been an attempt to formalise and standardise developments within the Region for several years.

4.1.10 Proposed methodology for the biological assessment of the impact of sheep-dip

Business needs

This method potentially meets water quality and environmental impact assessment business needs in sheep farming areas.

Current status

This is a draft method recently developed in Welsh Region to assess the impact of sheep-dip.

Method summary

a) Sampling

A one-minute kick sample is taken from a riffle. On the bankside, the abundance of each macroinvertebrate family is noted and the presence of any dead specimens recorded. An additional two one-minute kick samples are taken, along with a one-minute search so that the standard GQA macroinvertebrate sampling method is met. These samples are fixed in formaldehyde for further investigation, if required.

Upstream sites are also sampled with a one-minute kick. The macroinvertebrates found should be identified on the bank and returned to the stream.

b) Identification

Identification is to BMWP family level.

c) Data analysis

Pesticides typically cause a severe decline in the number of insect taxa and BMWP scores (often below 60). If sites appear to be affected, the source of the pollutant should be identified.

d) Quality assurance

An agreed procedure was written to ensure a consistent approach within the Region for sheep dip surveying in 1997.

Future developments

The development of this method is in its early stages and further testing is to be undertaken. The method is only appropriate to those areas suffering pollution problems from sheep-dip.

4.1.11 Method for using macroinvertebrates to assess in-river flow needs

Business needs

This method meets water resources business needs and has conservation implications.

Current status

The method, described in Petts and Bickerton (1997), has been developed following studies in the River Wissey and is used to assess in-river flow needs based on macroinvertebrate and physical habitat data. This is achieved by establishing the sensitivity of macroinvertebrate families to different end-of-summer low flows. This information can be used to set benchmark flows for the determination of Ecologically Acceptable Flow Regimes (EAFRs). This method was developed for chalk streams in Eastern England and the authors consider it applicable to other rivers of this type.

Method summary

a) Sampling

Historical or contemporary macroinvertebrate and flow data can be used. If historical data is not available extensive sampling is required.

b) Identification

If historical data is used the highest taxonomic level possible, which allows for consistency in the data set, should be used. For new samples, identification to the family level is generally adequate. Exceptions to this are that further identification is required if members of a family are likely to display variable habitat preferences. Higher levels are acceptable for difficult taxa (e.g. oligochaetes) and rare taxa which may not be useful indicators.

c) Data analysis

Analysis is relatively complex and requires the use of multivariate techniques. Habitat suitability curves are subsequently derived for the total number of taxa and key indicator groups.

d) Quality assurance

No quality assurance mechanisms are described.

Future developments

This method may not be suitable for rivers which have a more flashy flow regime, severe ponding or poor water quality. Further research is being carried out on the transferability of this method. The future of this method depends greatly on the results of the research into its suitability for other river types. Quality assurance is another area which needs to be addressed and a more prescriptive formal approach would be required if it was to be adopted as a national standard method.

4.1.12 Invertebrate Flow Index (IFI)

Business needs

The IFI method has been designed to detect low flow stress and with further development may provide a basis for determining ecologically acceptable flows. It therefore potentially meets water resources and conservation needs.

Current status

This method uses benthic macroinvertebrates communities to calculate Invertebrate Flow Indices (IFI). This technique is currently under development in Anglian Region and a paper is being produced for publication.

Method summary

a) Sampling

The method uses flow preference data derived from published ecological information and routine biological data collected using the standard Environment Agency RIVPACS methodology.

b) Identification

The method is designed to use species data but can be applied to family level data. However testing of the method suggested that some sensitivity is lost when family level data is used.

c) Data analysis

An Invertebrate Flow Index (IFI) is calculated from macroinvertebrate data based on scores assigned to invertebrate species on the basis of their flow preferences and abundance. As flow increases the IFI also increases. Low or declining IFI scores indicate low flow stress, if the river is historically capable of supporting species requiring more rapid flows.

d) Quality assurance

Since this method utilises routine biological data, quality assurance procedures appropriate for RIVPACS apply. Presently no other quality assurance procedures have been specified for this method.

Future developments

Standard Regional procedures for this method are in preparation. A method is being developed whereby the IFI can be used to identify ecologically acceptable flows.

Other comments

Testing of this method indicates that it works independently of other environmental factors which may increase or decrease IFI values. It appears to demonstrate effectively the impact of drought and abstraction on water bodies. The method is river-specific and increases and decreases in IFI values are relative to a particular river system.

4.1.13 Surface Water Abstraction Licensing Procedure (SWALP) method

Business needs

The Surface Water Abstraction Licensing Procedure (SWALP) concept seeks to provide a nationally consistent means of protecting flows to achieve a better balance between the needs of abstractors and the environment. This method therefore meets both water resources and conservation business needs.

Current status

The methodology builds on an approach developed by Yorkshire Water Authority in 1985/6, whereby all licenses determined under the policy were time limited to expire in 1996. The revised SWALP was applied by North East Region to the re-determination of abstraction licences during 1996/7. The new methodology aims to overcome the limitations of the Yorkshire Water method, for example, it can also be applied to lowland rivers. A SWALP guidance manual has been produced (Barker and Kirmond, 1997).

A key stage of the procedure is catchment evaluation which involves the determination of environmental weighting (EW). Each stretch of river is assigned an EW based on its physical character, ecology and fisheries. This in turn will dictate the degree and rates of abstraction acceptable to that river stretch. The ecological scoring system focuses on the known, or inferred, sensitivity of species to factors affected by reductions in flows. Macroinvertebrates and macrophytes are included in the ecological characterisation.

Method summary

a) Sampling

Historical or contemporary macroinvertebrate data can be used. If historical data is not available sampling is required.

b) Identification

A selection of macroinvertebrates of known sensitivities is considered. Generally family level data is adequate but species level data is necessary where sensitivity varies markedly within a family.

c) Data analysis

River stretches are assigned to one of six classes, with ecological scores ranging from 1 to 16. Classes are characterised by the types of sensitivity indicator taxa present. The overall environmental weighting is the aggregate of three environmental scores - ecology, fisheries and physical character.

d) Quality assurance

A guidance manual for SWALP has been produced which describes the environmental weighting system. The manual specifies that the reliability and applicability of the data used should be assessed. The level of confidence in the data should be noted along with actions that should be taken to improve the data. However, acceptable levels of confidence are not specified. In addition methods are not prescriptive and professional judgements often have to be made in assigning classes. This is not amenable to quality control procedures.

Future developments

The concept is now being trialled nationally and the River Tavy catchment has been chosen to determine whether the procedure is appropriate to Regions. The method will improve as knowledge of species/habitat relationships increases and more species are included in the scoring system.

Other comments

This method has considerable potential and is one of several biologically based methods (IFI, Section 4.1.12 and PHABSIM, Section 4.5.7) that contribute to meeting an important requirement of the Agency. However, some regions have expressed concerns over the degree of subjectivity involved in assigning ecological classes. More proactive sampling specifically for abstraction licensing may be necessary. In addition the procedures only characterise river stretches at that time. Longer term, predictive tools may need to be considered.

4.1.14 Community Conservation Index (CCI)

This is a method for the evaluation of the conservation value of macroinvertebrate communities. It was developed in Anglian Region (Extence and Chadd, 1996) and is being considered for use by other Regions. It is a method primarily designed for conservation purposes and is discussed in detail in Section 4.7.5.

4.1.15 Exposed river habitats

A recent R&D project by the Agency (Environment Agency, 1996g) has examined the biological significance of exposed river channel sediments (ERS). This is a method primarily developed for conservation purposes and is therefore discussed in more detail in Section 4.7.6.

4.1.16 Environmental Change Network (ECN) methods

Business needs

This method has been designed for Environmental Change Network (ECN) monitoring.

Current status

Freshwater protocols for monitoring of macroinvertebrates within the ECN programme were produced in 1997 (Pinder, 1997). The protocol covers both standing and running waters.

Method summary

a) Sampling

Sampling is undertaken at designated ECN sites and generally coincides with areas used for other ECN measurements. A standard three-minute kick-sample and one-minute hand search in accordance with RIVPACS methodology is carried out in running water sites or the littoral zone of lakes. Dredge sampling is recommended for deep rivers or lake margins.

b) Identification

Invertebrate samples should be sorted to species level. In cases where the necessary level of expertise is not available, minimum acceptable levels of identification are outlined in the protocol. Relative abundance is estimated for each taxon identified.

c) Data analysis

Data analysis is not described in the protocol.

d) Quality assurance

A written protocol has been prepared. The protocol specifies that site methodologies should not change from year to year to allow between year comparisons. No other quality assurance procedures are described in the protocol.

Future developments

Further revisions and developments to the protocol may be required as methods are tried and tested over a longer time scale.

4.1.17 Conclusions

Methods for the general evaluation of water quality are satisfactory and these are undergoing improvements. However, some areas of specific concern were raised by Agency staff, such as deep waters, headwaters and canals.

Many other methods using macroinvertebrates, which address specific problems such as farm pollution and conservation, have been developed on a Regional basis. Some of these methods have been discussed in the foregoing sections. With appropriate validation, several of the methods could probably be adopted as national standard methods.

Other business needs such as water resource issues could be addressed using invertebrates. However, at present, the fundamental relationships between flow regime and macroinvertebrate communities have not been established. A recent Environment Agency R&D assessed the use of ecological information in the management of low flows in rivers (Armitage *et al.*, 1997). Some work has been carried out by the Institute of Freshwater Ecology (IFE) and Institute of Hydrology (IH) on ecologically acceptable flows which derived habitat preference curves for a few specific invertebrate taxa. There are possible future business needs in which macroinvertebrates may be useful. There is a great deal of experience of macroinvertebrates within the Agency and they are likely to be an extremely useful group when addressing future needs.

4.2 Freshwater macrophyte methods

4.2.1 Introduction

At present macrophytes are primarily used within the Environment Agency as a water quality and conservation tool. Until recently the importance of macrophytes as water quality indicators was overshadowed by macroinvertebrates. It has become increasingly apparent that macrophytes fulfil aspects of water quality assessment, previously not addressed by macroinvertebrate groups. Furthermore, aquatic macrophytes are a well-recognised important group in their own right and play a role within many conservation protocols. They also have a significant part to play in meeting other needs of the Environment Agency.

This Section attempts to address present biological methods, which employ macrophytes. This includes mainly methods used within the Environment Agency but some attention is drawn to other methods not customarily practised by the Agency.

4.2.2 UWWTD method

Business needs

a) Existing

- water quality - statutory monitoring under Urban Waste Water Treatment Directive (UWWTD Council Directive 91/271/EEC);
- Local Environment Agency Plans (LEAPS) - UWWTD data may be included in 'status of the catchment' sections of LEAPS.

Eutrophication problems indirectly influence other functions:

- conservation - eutrophication can reduce species diversity and amenity value of aquatic systems;
- water resources - eutrophication can create problems for water abstraction.

b) Potential

- eutrophication monitoring outside the requirements of the UWWTD - there is likely to be Regional requirements for establishing trophic status of freshwaters in order to define appropriate management strategies;
- UWWTD data may be useful in the assessment of ecological recovery for post-project appraisals and post pollution incident assessments;
- long-term macrophyte monitoring of water quality may have a potential role in State of the Environment reporting.

Current status

Although currently under appraisal, a national standard method for the assessment of freshwater riverine macrophytes for the purpose of the UWWTD has been adopted by the Environment Agency (Environment Agency, 1996h). This document is based on previous work undertaken for Anglian Region (Anglian Region, 1994; Holmes, 1995; Holmes, 1996) and the Standing Committee of Analysts (Standing Committee of Analysts, 1987). This method is believed to represent best current practice.

Method summary

a) Sampling

Sampling methodologies are defined in the standard method document (Environment Agency, 1996h). The sampling principle is to estimate macrophyte percentage cover over a selected 100 m with an optional 400 m river stretch. This is achieved by wading the channel or in deeper waters via a TV camera or 'glass'-bottom buckets and grapnels.

The limitations of the sampling method are fully recognised in the methodology manual. These include the dependence of surveying on seasonal and weather conditions and the reduction in sampling efficiency in deeper waters and conditions of poor water clarity.

b) Identification

Identification is generally undertaken in the field to species level. Representative samples of unidentifiable species, algae and bryophytes are usually taken to the laboratory for identification or confirmation. Surveyors are recommended to keep dry specimens in a reference herbarium.

Since routine identification of macrophytes is a relatively recent development within the Environment Agency, identification can only improve with time. This implies that results between survey days or even years may show some inconsistency.

c) Data analysis

The Mean Trophic Rank (MTR) system is used to assess the trophic status of a 100 m river length. Calculation of MTR is described in the standard documentation. The MTR system is based on the principle that plant communities will respond to anthropogenic disturbances of the ecosystem. 126 aquatic plant species have been allocated a Species Trophic Rank (STR) ranging from 1 to 10. Plant species sensitive to eutrophication are assigned higher scores. MTRs are calculated for sites upstream and downstream from Qualifying Discharges (QD). Degraded ecosystems will display scores less than the theoretical maximum of an undisturbed ecosystem. Guidance on interpretation of the Mean Trophic Rank system has been addressed in a recent R&D Progress Report (Newman and Dawson, 1996).

d) Quality assurance

Some quality assurance procedures are addressed in the standard method document.

- Quality assurance prompts are issued throughout the manual. These appear to be relatively easy to adhere to.
- Inter-calibration exercises are proposed, where teams from different Areas undertake sampling together to compare levels of consistency. Throughout the Agency few Regions were capable of complying with these actions due to time and resource constraints.
- Staff receive continual accredited training.
- Quality assurance includes annual re-surveying by independent surveyors. However, no action levels are specified in the event of failure.

Analysis of 1994-96 survey results indicated that the estimation of cover was the aspect of methodology that displayed greatest variation but in most cases this was only one cover scale out.

The difficulty in establishing a comprehensive quality control system to the UWWTD method could be a drawback of the method. Diatoms and invertebrates are much more amenable to more traditional quality control procedures than macrophytes.

In terms of data analyses, quality assurance procedures are limited. Some quality assurance in relation to macrophyte data input is recommended. In addition, assessment of the confidence of the data is addressed.

Concern has been expressed regarding quality control with respect to contractors. Some Regions are unable to undertake UWWTD work themselves and have discovered identification discrepancies between accredited contracted surveyors and auditors.

Future developments

The 'Assessment of the trophic status of rivers using macrophytes' is currently under Environment Agency R&D at IFE (Project Proposal Reference: A05(95)2 and Project Number: 694, 'Assessment of trophic status of rivers using macrophytes').

The principle aim is to assess the MTR system using 1994-96 UWWTD data and to produce a procedural MTR manual to supersede other manuals. The prime focus will be on UWWTD but research will consider other applications of the MTR beyond its role in UWWTD reporting.

The procedure manual will contain a quality assurance section as a series of recommendations. A national training session based on the forthcoming procedure manual was planned for September 1997.

The R&D work is also investigating whether the 100 m stretch is adequate length for surveys or whether 500 m should be used in order to make data comparable with conservation data. It is likely that the macrophyte surveying over a 100 m stretch will remain as standard UWWTD practice whereas 500 m lengths will be adopted for other purposes.

Cost comparisons between macroinvertebrate and macrophyte methodologies are under examination, for example with respect to single and double manning.

A supplementary document considering both MTR and the Diatom Trophic Index (DTI) will be written. This will answer questions such as: are the methods complementary, are there situations where one method proves more beneficial, or should both methods be used in combination? Whereas diatoms respond quicker to water quality, macrophytes may be useful in that they consider both water column and sediment. The holistic approach would be to employ both methods simultaneously. One advantage of this is that similar findings enhance the likelihood that results are correct. This will strengthen the case for imposing limits to nutrient levels especially if different chemical results were observed or if macrophyte or diatom groups alone produced borderline results.

A database of UWWTD data is currently in production. The ultimate aim is a consistent Regional approach to macrophyte sampling, analysis and data input, which will automatically feed into and update a national database.

Other comments

Generally, feeling towards this system was favourable amongst the Agency Regions. However, the utility of the method can be hampered by the complete lack of macrophytes in some stretches of river.

A further constraint of the method is that plant communities will only show responses to phosphorus to a certain threshold limit. Beyond this, very little information regarding water quality can be observed.

A further perceived requirement is the development of improved sampling procedures with regard to larger rivers, headwaters and winterbournes. Certain Regions would also appreciate progress in brackish water/tidal rivers.

At present, some Environment Agency Regions are applying the MTR system for other purposes, for example low flow and forestry investigations. Some staff have applied the MTR system to river corridor data. However, the different survey and data formats prevent direct comparisons between them.

4.2.3 PLANTPACS

Business needs

PLANTPACS is proposed in routine water quality monitoring.

Current status

PLANTPACS will be a predictive system for macrophytes in rivers to determine environmental quality, analogous to RIVPACS for macroinvertebrates. This method is still very much in its early development stages. PLANTPACS is currently the subject of a scoping study as part of R&D (Project Proposal Reference: W1A(96)2, 'PLANTPACS- Phase 2' and Project Number: W1-017, 'PLANTPACS -Phase 1') being undertaken by IFE. The objectives of the scoping study are to investigate data availability and relationships and the identification of a technical approach. It is important that it provides additional information not yet provided by existing biological methods. 'PLANTPACS - Phase 2' has a budgeted project proposal (Project Proposal Reference: P2A(97)02.

4.2.4 Cladophora biomass

Business needs

This method is of use to the following functions:

- water quality;
- water resources;
- navigation and recreation.

Current status

Many Environment Agency Regions are concerned about the problems caused by *Cladophora*. The development of a method to assess *Cladophora* abundance and impact on aquatic systems, particularly chalk streams, would be useful. Welsh Region has undertaken some *Cladophora* monitoring based on the 'blue-book' methodology.

Method summary

Biomass is determined from replicates at random sites.

4.2.5 Plant bioassays

Business needs

These methods are important to the Water Quality and Pollution Control function.

Current status

The Standing Committee of Analysts (SCA), now part of the Environment Agency, published a 'blue book' on the use of plants as biomonitors of heavy metals in freshwaters in 1991 (Standing Committee of Analysts, 1991). These methods are not used routinely throughout the Agency Regions but some Regions have expressed interest.

Method summary

Mosses are probably the most recognised plants in heavy metal biomonitoring. Methods can employ indigenous species or involve transplantation of moss samples, along with their original substrate in nylon or muslin bags, from control to polluted areas. The responses or extent of metal bioaccumulation can be measured. Using the moss bag technique, samples are examined after a measured time scale and compared to the control areas. Conclusions on pollution levels and/or nature of the pollutants with respect to exposure time can therefore be determined. Recent literature in this field includes the use of the chlorophyll-to-phaeophytin ratio as an index of physiological stress in aquatic bryophytes in evaluating water contamination (Lopez *et al.*, 1997). Gstoettner and Fisher (1997) demonstrated the effectiveness of the Sphagnum moss, *Papillosum lindle* in assessing low, environmentally realistic metal concentrations. Higher aquatic plants and algae (e.g. *Entermorpha*) can also be used as bioaccumulators.

4.2.6 Monitoring of water resource projects (North East Region)

Business needs

This method meets some water resources and environmental impact assessment needs of the Agency.

Current status

North East Region has produced working guidelines for monitoring methodologies for water resource projects (North East Region, 1996a). This is Volume 2 of three volumes concerned with water resource projects in the Region. Volume 1 provides guidelines for scoping and environmental assessment of water resource projects. Volume 3 issues guidelines for environmental action plans to support a drought order or permit application. Volume 2 presents guidelines for monitoring of several parameters including macrophytes. The purpose of macrophyte monitoring is *"to assess the impact of low flows on the distribution, abundance and health of macrophytes, especially with regard to their importance as habitat and shelter for invertebrates and fish"*.

Method summary

a) Sampling

UWWTD sampling methods can be followed (Environment Agency, 1996h).

b) Identification

Identification is to species level.

c) Data analysis

For drought work, data analysis is mainly in the form of community descriptions. Some attempts at employing National Vegetation Classification (NVC) have been made but indicator species have proved more useful.

d) Quality assurance

Currently, quality assurance is focused around identification procedures. Second/third opinions are sought when identification is uncertain. In certain occasions, specimens are sent off for expert identification and advice.

Other comments

This method recommends sampling using UWWTD protocols. However, a distinct method for the assessment of low flows using macrophytes may need to be developed. In addition more proactive data acquisition in relation to low flows should be sought in order to predict future implications or forthcoming events.

4.2.7 Surface Water Abstraction Licensing Procedure (SWALP) method

This method is discussed under macroinvertebrate methods (Section 4.1.13). The same principles of ecological scoring apply except macrophyte data are used. The only difference is that all macrophyte data is species level (Barker and Kirmond, 1997).

4.2.8 Macrophyte method for lakes/reservoirs

Business needs

This method aims to meet water quality and environmental impact assessment needs.

Current status

This method is currently under development in Anglian Region (Anglian Region, 1997). The aim is to produce a standard method for assessing macrophyte communities and cover in lakes/reservoirs within the Region for eutrophication assessment and nutrient control. The method was trialed at Rutland Water in summer 1996. This method is similar to the ECN macrophyte monitoring method (Section 4.2.10).

Method summary

a) Sampling

An underwater video camera is used. An intensive semi-quantitative macrophyte survey is undertaken in a 100 m by 5 m area from the shore. Total and percentage macrophyte cover is estimated. A further transect from the measured area to beyond the growth of any attached plants is deployed. All species observed are recorded along this transect.

b) Identification

Identification is to species level.

c) Data analysis

Data analysis techniques are not described but the possible development of a trophic rank system for standing water species, similar to that used for riverine habitats was mentioned.

d) Quality assurance

A single sheet description of the method has been prepared but quality assurance procedures were not addressed.

Future developments

Method development is still in its early stages. Further work will concentrate on selection of representative sites and the necessary number of samples. Quality assurance procedures will also need to be addressed.

In addition to Regional initiatives such as the methods described here, biological techniques of still water quality assessment are currently under national R&D (Project Proposal Reference: A05(94)2 and Project Number: EMA012, 'Biological assessment of still waters - Phase 2'). A scoping study (Williams *et al.*, 1996) reported that multimetric techniques employing a combination of two biological assemblages were the most appropriate methodologies to adopt. It was recommended that aquatic macrophyte assemblages should be included in the assessment of water quality and ecosystem integrity of lakes, ponds, ditches and possibly in temporary and brackish waters.

4.2.9 Botanical survey of Scottish freshwater lochs

Business needs

This method is not used within the Environment Agency but may be useful in its development of methods for still waters.

Current status

Since 1983, Scottish Natural Heritage (SNH) have been surveying loch vegetation primarily to assess conservation status and for the development of a loch classification scheme (Scottish Natural Heritage, 1995). Other objectives of the surveys include the provision of baseline data against which to monitor change, the identification of vulnerable sites and sites already damaged and determination of the range and quality of loch vegetation.

Method summary

a) Sampling

Shallow water, deep water and emergent species are surveyed. All shoreline and shallow water plant species are observed by wading. Deeper water is sampled using either a double-headed rake or grapnel from a boat along sampling transects. Species are recorded using the DAFOR abundance scale (Dominant, Abundant, Frequent, Occasional, Rare). Emergent stands of vegetation are sampled and classified using National Vegetation Classification (NVC) methodology (Section 4.7.2).

b) Identification

Identification is to species level.

c) Data analysis

The method and classification is described in Palmer *et al.*, (1992) and site evaluation is in accordance with Nature Conservancy Council (1989).

d) Quality assurance

A Scottish Natural Heritage information and advisory note details the method which should ensure a degree of consistency in surveying in different areas. However, the document does not include specific quality assurance procedures.

Future developments

In Scotland the information collected is used in the selection of SSSIs and proposed SACs, Biodiversity Action Plans, research into acidification and eutrophication and ECN monitoring. However, it has potential in Local Authority planning such as Local Authority Agenda 21, in catchment planning and Scottish Environmental Protection Agency (SEPA) pollution monitoring (Scottish Natural Heritage, 1995).

4.2.10 Environmental Change Network (ECN) methods

Business needs

This method meets the needs of the Environmental Change Network (ECN) monitoring programme.

Current status

Trials of aquatic macrophyte method draft protocols (Environmental Change Network, 1997) for ECN monitoring were undertaken in 1997. Wherever possible common methods for lakes and rivers are used. The ECN method for running waters is based on the UWWTD method.

Method summary

a) Sampling

Bank vegetation is not recorded and only in-stream vegetation is sampled. Sampling methodologies are prescribed in the draft method document (Environmental Change Network, 1997) and should be carried out annually.

Macrophyte sampling for rivers differs from the UWWTD method in that presence/absence of macrophytes species in 5 m sections within the 100 m survey length is assessed as well as undertaking a 100 m and 500 m survey.

The protocol provides guidelines on selection of sampling points in lakes. Lake surveys comprise a shoreline and deep water survey. The shoreline survey involves wading an area 100 m in length and 5 m wide to record the presence of all emergent, floating and submerged macrophytes on a standard recording form. A deep water transect perpendicular to the shore is used to record plant species at 5 m intervals using Ekman grab sampling, grapnel hauls and visual observations using a bathyscope or underwater camera.

b) Identification

Identification is to species level. A checklist of aquatic macrophytes which occur in the UK is provided.

c) Data analysis

Data analysis procedures are not described.

d) Quality assurance

A draft standard document has been produced. Limited quality assurance procedures are included in this document. Collection and preservation of voucher samples for species confirmation is recommended. The use of trained surveyors is specified. The same quality control problems associated with the UWWTD method apply.

Future developments

The draft method for macrophyte monitoring at ECN sites is to be finalised shortly.

4.2.11 River Corridor Survey (RCS)

The RCS is a national method (National Rivers Authority, 1992) used by the Environment Agency primarily to assess potential conservation impacts of engineering works. It is also useful in the assessment of conservation status and in identifying areas of invasive plant species such as Japanese knotweed, Himalayan balsam and giant hogweed. Although primarily a type of habitat survey, the RCS incorporates aspects of general plant community assessment. This method is not treated here but is discussed in detail under conservation methods (Section 4.7.7).

4.2.12 River Habitat Survey (RHS)

The RHS (National Rivers Authority, 1996; Raven *et al.,* 1996) is a new system used by the Environment Agency for assessing the habitat quality of rivers and streams based on their physical structure. Plant communities provide habitat diversity and are vital to certain life stages of fish and other animals. Plants are considered good measures of habitat quality and diversity and are valuable biological criteria in the selection of river SSSIs. Collection of plant data for RHS is not as extensive as, for example, in Holmes's NCC river classification scheme, but is an important aspect of the system.

A more comprehensive overview of the RHS is provided in Section 4.7.8.

4.2.13 System for the Evaluation of Rivers for Conservation (SERCON)

SERCON (Boon *et al.,* 1997) is a holistic approach to the evaluation of the conservation value of rivers. The method has been developed by Scottish Natural Heritage (SNH) and is to be adopted by the Scottish Environmental Protection Agency (SEPA). It is closely linked to the RHS and is currently under investigation by the Environment Agency.

The method is discussed in detail in Section 4.7.13. SERCON embodies aspects of macrophyte surveying. Macrophyte communities in combination with other biological data comprise an important input to the model.

4.2.14 River classification/typing

Business needs

This is a tool for the assessment of the conservation value and restoration/rehabilitation potential of rivers.

Current status

The national river surveys carried out for the Nature Conservancy Council (NCC) attempted to provide a classification of rivers in Britain based on plant communities (Holmes, 1983a; 1983b; Holmes and Rowell, 1993). This method is not used by the Environment Agency but is used by conservation bodies.

Method summary

This classification system indicates which type of river is expected in any region of Britain based upon geology, altitude and physical features. In its broadest terms, similar plant communities are divided into four groups, A to D, which are further divided into smaller sub-groups.

4.2.15 National Vegetation Classification (NVC)

NVC methods are presented in Section 4.7.2. NVC is a plant community assessment method used extensively in the UK by English Nature, Wildlife Trusts and any other organisation involved in habitat assessment. Some Regions of the Environment Agency have also utilised NVC methodology. Recently a NVC for mires and aquatic plants has been published (Rodwell, 1992a; 1995).

4.2.16 Conclusions

The development of macrophyte methods for the evaluation of water quality are well underway and some of the limitations are being addressed via national R&D. It is recognised that macrophytes are important in distinguishing between organic and nutrient pollution. However macrophytes cannot be used reactively throughout the year in the same way that invertebrates can. The group may be more appropriate as a long-term strategic tool, for example in annual comparative studies. Furthermore, macrophytes expertise is currently less widespread in the Agency than, for example, macroinvertebrates. Good national baseline data is also scarce.

Aquatic plant communities play a fundamental role in the assessment of conservation value. It would be useful if macrophyte data was collected by different Environment Agency functions in a comparable manner. This would increase datasets and allow intercomparisons to be made. However in many cases this may prove too difficult.

Other business needs such as water resources could potentially be addressed using macrophytes and further work in this area is required. The use of standard macrophyte methods, in association with other biological assemblages to overcome their strong seasonality disadvantage, is recognised as significant in still water quality assessments.

Instream aquatic vegetation appears to be a much more useful indicator of aquatic conditions than marginal and bankside vegetation.

4.3 Freshwater epilithic algae

4.3.1 Introduction

Epilithic algae have assumed a greater role within the Agency over recent years because they have been used in the assessment of nutrient status. It has been suggested that eutrophication will become a more prominent issue in the near future as other water quality issues, such as organic pollution, become less severe. Algae and macrophytes are used in tandem to address this issue and are complementary because they often occur in different habitats. However, the opinion of many Agency staff is that algae are the more useful group because they are less restricted in the range of habitats which they can occupy, and because macrophytes are very seasonal.

4.3.2 Trophic Diatom Index (TDI) and Diatom Quality Index (DQI)

Business needs

a) Existing

Epilithic algae are primarily used within the Agency for the assessment of nutrient status. TDI and DQI methods meet a water quality and pollution control need under the Urban Waste Water Treatment Directive (UWWTD).

b) Potential:

- other water quality issues, such as acidification, heavy metal assessment and the measurement of suspended solids;
- conservation - diatoms may be useful in the monitoring of habitats such as chalk stream and saline lagoons - the use of diatoms has been proposed for monitoring river characteristics;
- assessment of ecological integrity;
- water resources - epilithic algae may be useful in the assessment of drought and low flows - the ratio of plankton types to settled types of diatoms has been proposed as a measure of flow conditions.

Current status

The Trophic Diatom Index (TDI) was developed as a direct response to the UWWTD. The Diatom Quality Index (DQI) is a revised version of the TDI with an inverted scale. This was developed so that direct comparisons can be made with the macrophyte Mean Trophic Rank (MTR) which is also used to evaluate water quality for the UWWTD. Standard methods for both the TDI and DQI are given in Kelly (1996) and are used in all Regions. The development and testing of methods is still under R&D (Project Proposal Reference: A05(95)6 and Project Number: 618, 'Development and testing of trophic diatom index').

Method summary

a) Sampling

Algae are sampled from cobbles or boulders, if available, using a toothbrush. The use of unglazed roof tiles as semi-permanent artificial substrates has also been proposed. Sampling can take place at any time of year although spring and autumn are recommended because nutrient concentrations are less variable and algal growth rates are greater. There is a research project being carried out by Goldsmith at University College London on the use of ropes as a substrate for algal growth.

b) Identification

Before diatoms can be identified they need to be cleaned and mounted on microscopic slides. The cleaning of diatom frustules requires powerful oxidising agents, which can be very dangerous and therefore it is imperative that adequate safety precautions are taken. Identification to species or genus level is achieved using the key given in Kelly (1996). About 200 non-planktonic (planktonic forms are given) valves are identified for calculation of the TDI.

c) Data analysis

The calculation of the TDI relies on the abundance, sensitivity and indicator value of the diatom taxa. The DQI is derived from the TDI.

d) Quality assurance

Quality assurance for this method has three components. The first is specified training which includes a distance learning package and pre-calibrated slides to evaluate competence. Agency staff have found this distance learning package very useful. The use of standard procedures is the second component of the quality assurance mechanism. Quality audits are carried out on 1 in 10 samples (1 in 5 during training) and this is the third part of the quality assurance mechanism. Several members of Agency staff expressed concern over the sustainability of the current audit arrangements due to increasing numbers of samples.

Future developments

The development and testing of this method is still under Environment Agency R&D (Project Proposal Reference: A05(95)6 and Project Number: 618, 'Development and testing of trophic diatom index'). Amendments to the methodology may arise following the outcome of this R&D.

Other comments

This method seems to be popular with Agency staff. Many were particularly impressed with the distance learning package. The only area of concern was the capacity of the current quality audit system to cope with increasing numbers of samples. Several workers also expressed interest in a database of algal images, which could be used to aid identification.

4.3.3 Environmental Change Network method for epilithic diatoms

Business needs

This method meets the needs of Environmental Change Network (ECN) monitoring.

Current status

Diatoms are sampled from both standing and running waters because they are good indicators of several environmental parameters such as pH and nutrient status (Patrick and Monteith, 1997).

Method summary

a) Sampling

Sampling should be carried out three times each year in the periods March-April, June-July and September-October. In subsequent years, sampling should be repeated on the original dates ± one week. If only one sampling is possible it should be in September. In standing waters, three sampling sites should be selected which are not influenced by inflow/outflow streams or other types of disturbance. In running waters, a 50 m length of stream coinciding with that used for macrophyte sampling is chosen. Three sites along this stretch are used. At both standing and running water sites, five permanently submerged cobbles from a depth greater than 30 cm should be brushed to remove the diatoms. The samples are preserved with Lugol's iodine. If epilithic diatoms are not available, epiphytic forms can be substituted.

b) Identification

Samples are sent to the Environmental Change Research Centre at University College London where they are cleaned and mounted. The slides are archived for future identification when funding becomes available. It is anticipated that 500 valves from each sample will be identified to species and their percentage abundance calculated.

c) Data analysis

None at present.

d) Quality assurance

No quality assurance mechanisms are described.

Future developments

This is a potentially useful data set and the first development must be the identification of these samples and subsequent analysis.

4.3.4 Still waters diatom method for use in Environment Agency R&D project EMA012 - Biological methods of still water quality assessment

Business needs

This proposed method would meet water quality and pollution control needs. It would also have potential in conservation assessments.

Current status

The scoping study for biological techniques of still water quality (Williams *et al.,* 1996) concluded that diatoms were suitable for assessments of lakes, ponds, canals and ditches. This method was developed specifically for an R&D programme and is designed to yield a representative sample to describe ecological integrity so that impaired and minimally impaired water bodies could be identified.

Method summary

a) Sampling

Diatoms should be taken from all available habitats. Sampling methods are given for epilithon, epiphyton, epipelon, episammon and artificial substrates.

b) Identification

Levels of identification are described.

c) Data analysis

Data analysis techniques are not described.

d) Quality assurance

Quality assurance is not described.

Future developments

Standard sampling methods may become important if algae are adopted as one of the groups used in the assessment of the quality of stillwaters.

4.3.5 Conclusions

In general, Agency staff tended to express a preference for macroinvertebrate methods over algal methods where possible, often stating that they are easier to identify. The prevalence of these opinions may simply be an artefact of the currently more widespread use of macroinvertebrates. However, certain individuals stated that they had not found diatom taxonomy as difficult as they had expected. As more workers become familiar with diatoms they may view algal techniques more favourably.

Freshwater epilithic algae are used extensively in water quality assessments elsewhere in Europe. In the UK the use of diatoms is becoming established for the assessment of nutrient status. Epilithic algae (and epiphytic, epipelic etc.) have received little attention for other purposes, although they have potential to provide a range of useful information. Epilithic algae could be used to address other water quality issues, such as acidification, heavy metal assessment and the measurement of suspended solids, because they show responses at the community level to various impacts. However, the need for the development of additional algal methods must be evaluated with respect to macroinvertebrate methods (current methods and future developments). Redundancy or overlap in function between algal and invertebrate methods should be avoided for the sake of efficiency. In Welsh and South West Regions the composition of sewage fungus is used to provide information regarding the extent and nature of pollution. 'The use of diatoms to monitor river characteristics' is proposed for Environment Agency R&D (Project Proposal Reference: E1D(97)4).

The future use of algae greatly depends on the ongoing stillwaters R&D programme that is evaluating the use of diatoms against other groups (e.g. fish in canals, macrophytes in ponds). If algae are not used in this context, their use is not likely to expand within the remit of the Agency.

4.4 Freshwater plankton

4.4.1 Introduction

Both phytoplankton and zooplankton currently receive little attention within the Agency. Exceptions are one off studies, such as the study of zooplankton in Lake Bala, monitoring of potentially toxic cyanobacteria and trophic studies in the River Thames (Bass *et al.*, 1997). Largely this is because plankton do not readily lend themselves to environmental monitoring. They are not as well studied as other groups of freshwater organisms, and still waters have historically received less attention than running waters. However, the general opinion among Agency staff, particularly biologists, is that plankton are not being used to their full potential.

The biological assessment of still waters is currently being addressed in an Agency R&D programme (Project Proposal Reference: A05(94)2 and Project Number: EMA012, 'Biological assessment of still waters - Phase 2') and the future use of plankton will greatly depend on the outcome of this research. Phase 1 of this project (Williams *et al.*, 1996) reviewed the use of phytoplankton in freshwater monitoring and noted that they have primarily been used to assess trophic status and, to a lesser extent, acidification. It also proposed groups which are most suitable for the evaluation of various types of still water, and concluded that phytoplankton are not suitable for any type at present because they are poorly known, display pronounced seasonal variation and because they have short life-cycles, making them poor indicators of intermittent water quality problems. Zooplankton are also poorly known and Williams *et al.* (1996) concluded that they are only suitable for the evaluation of temporary water bodies.

4.4.2 Anglian Region standard methodology for freshwater phytoplankton

Business needs

a) Existing:

- water quality - in the identification of potentially toxic blooms. The Agency does not routinely monitor algal blooms but investigates reports from field officers and the public. If there is a risk of toxicity, the Agency notifies the relevant bodies. In addition, the Urban Waste Water Treatment Directive and Nitrates Directive require phytoplankton to be monitored in freshwaters (Anglian Region, 1995a);
- State of the Environment reporting - the incidence of blue green algal blooms and scums are included in the Agency's State of the Environment report;
- fisheries - plankton are an important source of food for fish and may need to be taken into account within the fisheries role of the Agency e.g. biomanipulation studies.

b) Potential:

Phytoplankton are very important parts of lentic ecosystems but their conservation status and value has received little attention.

Current status

Anglian Region have been involved in the monitoring of algae for some time and this standard method (Anglian Region, 1995a) was developed to meet an increasing need for the study of both eutrophication and toxic algal blooms.

Method summary

a) Sampling

Guidelines for various types of sampling are given, including quantitative samples, surface samples, tube samples, profile samples using a Van Dorn or universal water sampler and blue-green algal samples. Samples are fixed with Lugol's iodine.

b) Identification

Extensive instructions regarding laboratory handling of samples are given. These include techniques of microscopy, sedimentation and enumeration of both solitary and colonial forms. Identification is to the lowest level possible depending on time, expertise and purpose of survey. This typically corresponds to genus or species level. The use of described keys and the Fritsch Collection of Freshwater Algal Illustrations held by the Freshwater Biological Association (FBA) can assist identification. A copy is held at the Haddiscoe Laboratory.

c) Data analysis

Algal data should be stored in a suitable database.

d) Quality assurance

The quality assurance mechanisms described deal with the evaluation of all possible sources of enumeration error, the documentation of these evaluations and procedures to correct any such errors. Quality control mechanisms addressed include the evaluation of sampling precision and accuracy, the calculation of confidence limits for algal counts (particularly for dominant taxa), data base quality control, taxonomic audits and training.

Future developments

These methods are extensive and may be useful to consider as the basis for formal standard methods.

4.4.3 Anglian Region standard methodology for freshwater zooplankton

Business needs

a) Existing:

- water quality - zooplankton communities can be used for monitoring acidification (Marmorek and Korman, 1993) but have received little attention in Britain;
- fisheries - plankton is an important source of food for fish.

b) Potential

Zooplankton are very important parts of lentic ecosystems but their conservation status and value has received little attention.

Current status

Anglian Region developed methods for zooplankton because they are an important group and exert grazing control on phytoplankton (Anglian Region, 1996).

Method summary

a) Sampling

Recommended quantitative and qualitative methods are given for the collection of zooplankters. A Patalas sampler is recommended for quantitative point samples from deep-water. Tube samples are recommended for vertically integrated samples. Net hauls can be used for semi-quantitative and qualitative sampling.

b) Identification

Methods for the concentration and preservation of zooplankters are given, as are methods for enumeration and estimations of biomass. The level of identification required varies depending on the experience of workers, the aim of the study and the morphology of the group. The levels routinely used by Anglian Region are given and range considerably from species level for *Daphnia* to order level for cyclopoids and calanoids.

c) Data analysis

A spreadsheet for handling zooplankton data has been developed at the Haddiscoe Laboratory.

d) Quality assurance

Guidelines for quality assurance of sampling, sample concentration enumeration and identification are given.

Future developments

Similarly to the Anglian phytoplankton methods, these methods may have potential for a more widespread use in the future if plankton becomes a higher priority to the Agency.

4.4.4 Environmental Change Network phytoplankton method

Business needs

Monitoring of phytoplankton chlorophyll a and species presence and abundance are required as part of the Environmental Change Network (ECN) monitoring programme.

Current status

Chlorophyll a can give an estimation of the productivity of a lake and indicate changes in community status. Community structure is also of interest because certain taxa, particularly cyanobacteria and diatoms may be relevant to particular water quality issues. The methods described below are presented in draft protocols (George, 1997a).

Method summary

a) Sampling

Standing waters should be sampled preferably fortnightly and not less than quarterly. Running waters should be sampled on a monthly basis. In standing waters, samples should be taken nearest the deepest point using a Lund tube or bucket in very shallow lakes. Various methods are suitable in running waters. Chlorophyll a is extracted using hot aqueous methanol and the optical density measured.

b) Identification

Species level identification should be carried out where possible and counts made. Colonial forms should be counted as the number of colonies per unit volume and filamentous forms by their length.

c) Data analysis

Details are not described in the draft protocol.

d) Quality assurance

No quality assurance procedures are described.

Future developments

The ECN database will be very useful for revealing long-term trends. The methods and expertise gained through its implementation may also be of benefit to other plankton sampling carried out by the Agency.

4.4.5 Environmental Change Network crustacean zooplankton method

Business needs

This meets the needs of ECN monitoring.

Current status

The crustacean zooplankton form a vital link between the phytoplankton and fish and their sampling is required as part of the ECN. Detailed surveys can be difficult to implement but an integrated sample can provide valuable information regarding seasonal or annual change.

Method summary

a) Sampling

Sampling is carried out using the methods described in draft protocols (George, 1997b). Samples are taken by a vertical net haul at the deepest point of the lake. Sampling should ideally be fortnightly but not less than quarterly.

b) Identification

Identification to species level is required.

c) Data analysis

Counts should be reported as the number of individuals of each species per litre.

d) Quality assurance

No quality assurance procedures are described.

Future developments

Similar comments to those given above for phytoplankton also apply to zooplankton.

4.4.6 Conclusions

The plankton are an important part of lentic ecosystems and need to be taken into account if lakes and other still waters are to be fully understood. However, plankton are currently not monitored extensively by the Agency and this may continue as the current R&D into still water methods is unlikely to develop planktonic methods. The priorities of the Agency may change in the future, and if this is the case plankton monitoring may become more important.

Plankton have been extensively used in toxicity testing and *Daphnia magna* and *Ceriodaphnia dubia* are very widely used ecotoxicological test organisms (Williams *et al.*, 1996; Water Research Centre, 1996) because they are easily cultured and maintained in the laboratory.

Agency staff have stated that plankton, notably diatoms, may be useful in the study of long term trends through paleolimnological techniques. Sediment cores for this purpose have been taken on occasion by the Agency (e.g. from Lake Bala and Cumbrian lakes). Paleolimnological data could be very useful in indicating unimpacted or target conditions for lake recovery, which may be difficult to define using contemporary biological data. The Somerset Levels were identified as an area where such information would be useful.

4.5 Freshwater fisheries methods

4.5.1 Introduction

At present, freshwater fisheries data are used within the Environment Agency for baseline assessments of natural fish population cycles and variability; in specific investigations such as Environmental Assessments in response to proposals which have potential to affect fisheries; in pre- and post-development monitoring; in pollution incident investigations and other impact investigations.

The primary purpose of freshwater fish data acquisition is to provide the necessary level of information for progressive management strategies which address issues that affect, or have the potential to affect, fish populations in England & Wales. This is primarily undertaken on a river catchment basis. As yet, there appears to be no consistent use of fisheries data for general environmental quality assessment, or use of fish communities as indicators of pollution or habitat degradation, despite the fact that methods currently used throughout the Agency potentially provide appropriate data for such applications.

Implicit under the Agency's duties is the need to protect fisheries within its jurisdiction from the risk of disease. In order for these duties to be carried out, assessment of potential impacts of water pollutants on the health of fish and fish populations is required. R&D Note 383 (Barnes and Hirst, 1995) on fish health indices as a marker of surface water quality covers the main assessment methods used and their current limitations and potential.

The National Fisheries Laboratory at Brampton in Anglian Region provides a national service, undertaking fish ageing, tissue analysis for heavy metals, pesticides etc. and disease monitoring. Most Agency Regions make use of this facility, sending live or frozen fish samples for disease assessment and fish scales for ageing. The laboratory has introduced a formal AQC procedure for its fish ageing service. In those Regions or Areas which still undertake a substantial part of their scale reading in-house, sub-samples of scales are often sent to Brampton for confirmatory ageing for AQC purposes.

A National Coarse Fish Centre is currently being set up at Kidderminster and a National Salmonid Centre at Cardiff. These two centres will co-ordinate research and development, the implementation of R&D outputs and the standardisation of procedures, as well as giving general advice to Regional fisheries staff.

4.5.2 The National Fisheries Classification Scheme (FCS)

Business needs

a) Existing

The perceived need for a national fisheries classification system is to enable clear comparisons of fishery data, to assist the Agency in fulfilling its statutory duties and to facilitate the communication of fishery information, both within the Agency and to third parties.

b) Potential

The FCS potentially affords an opportunity to incorporate a fisheries 'window' into the GQA.

Current status

The FCS (Mainstone *et al.*, 1994) is currently being introduced on a national basis.

Method summary

a) Basis of method

The FCS uses fish survey data in order to classify sites according to their relative fishery status. The scheme is based on a database of 949 sites selected to broadly represent the range of habitats encountered in England and Wales and for which both habitat and quantitative fish community data are available. Five quintile-based class designations, A-F, are employed, where Class A indicates that a site is in the top 20% of sites within the database. Either an Absolute Classification, where all sites in the database are considered, or a Relative Classification, which only considers sites of similar habitat in terms of width and gradient, can be used. The classification can be employed at four levels. Level 4 gives a whole-fishery grade, whereas Levels 3, 2 and 1, at increasing degrees of age/species separation, give separate grades for individual components of the community.

b) Data requirements

The method requires quantitative fish community data which can be obtained by any of the standard survey methods.

c) Data analysis

Data analysis and site classification is relatively straightforward and is based on the use of four proforma classification sheets (for classification Levels 1-4 respectively), with grades (A-F) derived from abundance tables for the Absolute Classification or from a series of gradient vs. density graphs for the Relative Classification.

d) Quality Assurance

The FCS is a straightforward system for classifying sites using fish survey data. There is therefore no specific QA requirement attached to the FCS itself, except to follow the published procedures. The QA requirement is associated with the generation of the survey data to which the FCS is applied.

Future developments

Probably the most immediate development priority is to make provision within the FCS for the use of semi-quantitative fish survey data.

The current development and introduction of the national Fisheries Classification Scheme provides a potential opportunity to harmonise fisheries data collection and use across the Regions and the potential to introduce a formal fisheries 'window' into the GQA.

Other comments

Several fisheries scientists felt that there was a need to extend the existing database on which the FCS is based and that there should be more attention to habitat data. However, such shortcomings are inevitable in any new system, and can be addressed in time as experience of the system develops (as was and is the case with RIVPACS).

Perhaps the biggest difficulty with implementation of the FCS is its requirement for quantitative (i.e. catch depletion) population data. Historically, most fisheries sections have collected quantitative fish survey data. However there is currently a growing trend towards the collection of semi-quantitative data (i.e. some form of Catch Per Unit Effort (CPUE) or minimum abundance estimate) in a high proportion of the Agency Regions. For example, North East, North West and parts of Southern Region undertake primarily semi-quantitative surveys, at least for routine monitoring purposes, whereas Midlands and Anglian still undertake primarily quantitative (catch depletion) surveys.

The rationale of semi-quantitative sampling is that it represents a better deployment of available resources, in that for routine monitoring and assessment purposes, a greater number of sites can be monitored more frequently. This provides a better overview of a catchment fishery than a few sites sampled infrequently in a fully quantitative manner.

The use of semi-quantitative data in the FCS will require either the development of sets of numerical conversion factors or standard statistical procedures for application to semi-quantitative data, or alternatively, the development of alternative sets of abundance (density/biomass) vs. river gradient graphs so that semi-quantitative data can be inputed directly to the FCS system. As the probability of capture will depend on the fishing method employed, the type of fishing gear used and the nature and habitat characteristics of the channel being fished, any calibrations will need to take account of these variables. The use of semi-quantitative data has been examined locally in some Regions and is the subject of a current R&D project 'Use of semi-quantitative electric fishing methods for fisheries classification' (W2A(96)3).

4.5.3 Fish surveys - aspects common to all fish capture survey methods

Introduction

Fish surveys for the purpose of stock assessment constitute a major component of the Agency's fishery work. A wide range of methods is employed including electrofishing, netting, trapping, hydroacoustic techniques and anglers' catch records. The specific method employed will depend on the fish species of interest and its life cycle stage, the physical nature of the habitat, the objectives of the assessment and the availability of resources. Most methods require large resource inputs of either manpower or equipment or both.

Individual catchments will usually have specific fisheries action plans, which will often constitute a formal component of a Local Environment Agency Plan (LEAP), a Catchment Management Plan under the former NRA. The physical characteristics of the individual river, the principal target species and Environment Agency Regional or Area requirements will determine the specific data collection method used.

Fish survey work is usually scaled down in periods of high temperatures because it is generally considered that a higher risk of fish handling mortality occurs. The collection of fish samples for laboratory analysis is not limited by season.

Design of fish surveys

Because of the labour intensive nature of fish surveys, the number and location of sampling sites and the frequency of sampling will usually be a compromise between scientific desirability and resource limitations. R&D Note 292 (Wyatt and Lacey, 1994) provides guidance on the design and analysis of river fishery surveys. However, although this guidance manual provides a great deal of useful information, it would appear not to be widely used and it is not regarded as particularly user friendly by Agency fishery staff.

Quantitative and semi-quantitative methods

Fish survey methods can generate quantitative, semi-quantitative or qualitative data on the communities and populations being surveyed. Quantitative population data is most frequently obtained by catch depletion methods (usually triple catch). Catch depletion population estimates are usually undertaken in conjunction with electrofishing but can also be undertaken using seine netting. The less frequently employed mark-recapture methods of population estimation require fish to be tagged or marked e.g. Pan-jetting. Mark-recapture can be used in conjunction with a wide range of capture techniques.

In general, semi-quantitative data is of two main types:

- derived from 'fixed area sampling', either from electric fishing (with or without stop nets) or seine netting;
- derived from 'fixed time' electrofishing, as is common for surveys of juvenile salmonids.

Both approaches yield an index of abundance, in terms of a 'minimum estimate' or 'Catch Per Unit Effort' (CPUE).

Fish sampling processing and enumeration

Data collection and analysis methods are often common to many survey methods. Therefore fish processing and enumeration techniques are discussed in this section rather than in the following sections dealing with individual survey methods.

a) Normal on-site data collection from live fish

Standardised measurements are normally taken from each fish on all surveys in England and Wales. In most cases, fish are returned to the water alive unless samples are required for further laboratory analysis. The following observations are typically undertaken:

- Fish are identified to species at site. In some surveys, minor species are merely noted and the abundance recorded only as orders of magnitude. For coarse fish, a size cut off of 10 cm (>0+ age group) is generally used. Fry <10 cm are noted and abundance determined in orders of magnitude.
- Fish length (fork, standard or total) in cm/mm is measured using a ruler fixed to a measuring board. Frequently only a sub-sample of fish are measured. Eels, and sometimes other species, may be anaesthetised before measurement.
- Fish are individually or bulk weighed (g) using an electronic balance.
- Scales are removed for ageing. Scales are taken from a sub-sample of each species by selecting an appropriate number of individuals across 5 cm length ranges. Other ageing structures used include otoliths (earstones) and the opercular bones which are taken for certain species, e.g. eel, tench and perch. Unlike scales, the use of these other ageing structures involves the death of the fish.
- The incidence of external anomalies are recorded on site. Each fish (or a sub-sample of the population) is examined for signs of physical deformity, wounds, injuries, and external parasites.
- Fish sex, and sexual maturity if appropriate, can be determined by examining adult fish during the spawning period.

All information is recorded on field data sheets or data logger.

b) Fish culled for additional studies

In cases when fish are removed it is generally for one or more of the following reasons:

- 0+ fish are difficult to identify in field and may be preserved in formalin or IMS and identified in the laboratory;
- when fish are diseased and/or parasitised, autopsies may be necessary for assessing pollution or parasitic incidences;
- fish culling, rescues and transfers are a necessary part of fisheries management, particularly in the summer months under low flow and drought conditions;
- for genetic finger printing studies (e.g. native brown trout) - it is often necessary to distinguish genetically divergent populations, strains or stocks within the same species;
- for quantitative description of diet - evaluating the quality and quantity of food available for 'target' species is an important aspect of assessing fisheries status and potential fisheries problems;
- for biomarkers studies - these are biological responses to xenobiotic exposure which can be a biochemical, histological and/or physiological alteration;
- for bioassays for the measure of specific environmental pollutants.

Data analysis and reporting

a) Availability of computer software for fish data handling and reporting

There is currently no nationally adopted software package for the analysis and presentation of fisheries data. However, a number of Regions and Areas have developed their own spreadsheet and database macros or database programmes (e.g. FINS) which include standard analysis and presentation of fisheries data. The development of fish stock assessment software has been the subject of previous R&D (Wyatt and Lacey, 1995).

b) Population estimates

A minimum estimate or CPUE is used for single catches, unless the capture method has been previously calibrated and the capture probability statistically defined. For multiple depletion catches, calculations include DeLury; Seber and LeCren; Carle and Strube; and Zippin. The Maximum Weighted Likelihood (MWL) method of Carl and Strube is generally regarded as the preferred method (Wyatt and Lacey, 1994). The Peterson method is generally used for mark-recapture population estimates. The density (numbers) expressed as individuals m^{-2} and the biomass of each species in grams m^{-2} can be derived from population estimates.

c) Further fish population dynamics analysis

Other standard analyses of fish data include length frequency histograms and age structure analysis; length-weight relationship ($\log_{10}$ transformed data); condition factor; year class strength; species composition and fish distribution patterns; counter and trapping data for salmon used for spawning escapement; exploitation rates; stock and catch relationship; stock and recruitment relationships; and number of spawners and egg deposition.

4.5.4 Electrofishing methods

Business needs

Routine survey, surveillance and monitoring for fish stock assessments. Fish capture method for special investigations, fish culls and fish rescues etc.

Current status

Electrofishing is a cost-effective sampling method and is widely accepted as the method of choice in streams and small rivers for juvenile salmon, brown trout and coarse fish population investigations. Electrofishing is the most widely used fish capture technique in all Regions of the Agency. However, the method becomes progressively less effective as channel dimensions increase, or when water conductivity exceeds about 1500 $\mu s\ cm^{-1}$. Although most frequently used in running waters, electrofishing is also employed in standing waters such as canals, ponds or the margins of lakes.

Method summary

a) Electrofishing equipment and basis of method

Electrofishing equipment induces an electric field by two immersed electrodes, a (usually) stationary cathode and a mobile hand-held anode. A petrol driven alternator supplies power to the electrodes via a control box unit, which provides either AC or pulsed or smooth DC current. Fish in the electric field will respond by some form of forced swimming followed by immobilisation, rendering them easy to catch. Electrofishing requires survey teams of between three and six people.

Battery energised 'back pack' electrofishing units are also available. However, the limited power available from battery operated systems means that they are really only suitable for use in the smallest streams. Nevertheless, their portability allows them to be used in remote locations, e.g. hill streams, where vehicular access is precluded.

For deeper waters, electrofishing may be undertaken by boat, using hand held anodes, or by the use of specially constructed boom boats, where variously configured sets of anodes are mounted on booms to provide a wide lateral coverage. Boom boats are particularly effective in canals, where the boom width can be matched to canal dimensions to provide an optimum electric field. Electric fishing methods for deep rivers are discussed in R&D Note 303 (Harvey and Cowx, 1995).

b) Site selection

Site selection for routine monitoring is based on ensuring geographical coverage of the catchment and is heavily dependent on the target species. The need for realistic site access is paramount and may often be the overriding determinant.

c) Quantitative sampling (primarily for Stock Assessment)

This method requires the use of stopnets or natural obstacles to fish movement, e.g. weirs/waterfalls, which isolate a river stretch. The isolated stretch is typically of approximately 100 m although shorter stretches, e.g. 50 m, are sometimes employed. The catch-depletion method, most often based on three successive catches, is then used for population estimation.

Electrofishing is most effectively used in shallow (<1.0 m) rivers, i.e. at wadeable depths. In such rivers, fish capture efficiency is generally high, thus giving reliable population estimates and the stringent Heath & Safety requirements (Code of Practice for Safety in Electric Fishing Operations, Environment Agency, 1996i) are most easily met.

The resource burden for quantitative electrofishing is high. A three to five person team can typically survey a maximum of two lowland river sites or three to four hill stream sites per day. However, under favourable conditions, high precision can be achieved yielding statistically viable density and biomass estimates. The major source of error usually stems from the high mobility of fish and the resulting patchiness in their distribution (this may be a particular problem with shoaling species such as dace and bream but is much less so for juvenile salmonids which tend to be territorial). Thus, although a population estimate may reliably reflect the particular 100 m stretch on the day in question, the extent to which the estimate reflects the river reach as a whole may be subject to significant doubt. Although not standard practice, the use of an additional 'semi-quantitative' electrofishing run beyond the stop-netted stretch as a check on representativeness is sometimes recommended.

d) Semi-quantitative and qualitative sampling (Relative population estimates for 'Catchment Overview')

Semi-quantitative electrofishing may be undertaken with or without stopnets and is based on one catch, often over a specified length of river (e.g. 25 m) or specified fishing period (e.g. 15 minutes). The approach is undertaken mainly in shallow wadeable depths i.e. depths <1.0 m, often with a single anode operator with one or two netspersons. Such semi-quantitative methods can be calibrated approximately against quantitative surveys on physically comparable channels.

The method is relatively resource efficient, enabling four or more sites per day to be surveyed, but yields only low precision population estimates. However, it provides a rapid method for population assessment.

e) Sampling of juveniles

For juvenile coarse fish, 'Point Abundance Sampling', which is a semi-quantitative method using adapted electrofishing gear, is sometimes used.

f) Data recording and analysis

Data recording and analysis is common to most fish-capture survey methods and is discussed in Section 4.5.3 above.

g) Quality assurance

With the exception of fish ageing, for which the Brampton Laboratory has established a formal AQC system, there is little in the way of standardisation of electrofishing survey methodology or subsequent data analysis and there is considerable variation in approach between Regions and between Areas within Regions. Although not strictly related to Quality Assurance, the stringent safety requirements for electrofishing do impose a degree of rigour in terms of the training standards and operating procedures of electrofishing teams.

Future developments

There have been significant advances in electric-fishing equipment over the years and these continue, driven in part by ever more stringent health and safety standards and in part by perceived shortcomings in equipment performance. Planned R&D includes the further development and improvement of back pack electrofishing gear (R&D Project W2A(97)6).

Other comments

Fish capture efficiency generally decreases as channel depth and width increase, particularly for smaller individuals and bottom dwelling species. The basic assumptions implicit in catch depletion calculations break down, so low population estimates may simply reflect poor catch efficiency rather than a low abundance of fish in the survey stretch.

The choice of quantitative or semi-quantitative methods, the use of either alternating current (AC) or direct current (DC) current, the number of anodes, the number of netpersons and the length and location of the survey stretches are generally matters of judgement by the fisheries team undertaking the survey. There is no standard protocol, and the 'rules of thumb' vary both within and between Regions.

There is no standard or nationally accepted procedure for determining the number of anodes per metre of river width or the number of netpersons employed. A commonly used ad-hoc rule is: <5 m channel width - one anode and one netperson; 5-10 m channel width - two anodes and two netpersons; >10 m channel width - three electrodes or split channel longitudinally and fish as two channels. Some fish survey teams operate with separate netpersons and anode operators, whereas in other teams, an individual may operate both net and anode.

4.5.5 Seine net surveys

Business needs

Routine survey, surveillance and monitoring for fish stock assessments.
Fish capture method for special investigations, fish culls and fish rescues etc.

Current status

This is a widely used fish capture and survey method in all Regions. It is generally employed at river sites where electric fishing is precluded either by channel dimensions (width, depth) or by saline influence (conductivity > about 1500 us cm^{-1}). Seine netting is likely to be more effective than electric fishing in ponds and the marginal areas of larger lakes and the method is widely used in these habitats.

Method summary

a) General points

Seine netting typically yields semi-quantitative (minimum estimate or CPUE) abundance data because capture efficiency is difficult to measure in many situations. However, fully quantitative multiple-capture seine netting techniques have been developed, for example the Anglian Water wrap around seine technique (Coles *et al.*, 1985), or other systems of netting within stop-net enclosed areas. With such methods, capture efficiency, and hence quantitative population estimates, are determined by means of either mark-recapture or catch depletion.

b) Micromesh seine netting

Micromesh seine netting is the most widely used method for sampling juvenile coarse fish and fry. Juveniles are usually preserved in formalin for subsequent laboratory identification and measurement.

c) Data recording and analysis

Data recording and analysis is common to most fish-capture survey methods and is discussed in Section 4.5.3 above.

d) Quality assurance

With the exception of fish ageing, for which the Brampton Laboratory has established a formal AQC system, there is little in the way of standardisation of seine net surveys in terms of net dimensions, net style or method of deployment. In practice, netting techniques must be tailored to individual site characteristics so there is probably limited scope for standardisation of procedures. The successful setting and drawing of seine nets requires considerable skill and experience. The most important aspect of quality assurance therefore relates to the training and expertise of the survey team. The incorporation of mark-recapture can provide a useful measure of capture efficiency.

Future developments

Seine netting is a very old and well established technique. Significant advances in either net design or survey methodology are therefore unlikely.

Other comments

Seine netting is frequently hindered by underwater obstructions including tree stumps and anthropogenic debris and is therefore often regarded as a method of last resort on many rivers.

Bottom dwelling fish such as eels are likely to be seriously under-represented in seine net catches.

Large scale seine netting may cause serious interference with boat traffic on heavily used navigable rivers. In such situations, approaches such as hydroacoustic surveys may be the only practical option.

4.5.6 Hydroacoustic surveys

Business needs

Hydroacoustics (sonar, echo-sounding) affords the most promising approach for the survey and monitoring for fish populations in sites such as lakes and reservoirs, large navigable rivers and estuaries where conventional survey methods such as electric fishing and seine netting are impractical.

Current status

Hydroacoustic methods have been employed in a variety of situations in most Agency Regions, but in terms of both equipment and applications the approach is still very much at the developmental stage.

Method summary

a) Basic principles of method

Hydroacoustics is the underwater use of echo-sounding. Echo-sounding and sonar are effectively synonymous, although echo-sounding is usually taken to refer to the use of a vertical echo and sonar to a horizontal echo. A target (e.g individual fish or shoal) can be determined in terms of its distance (echo time delay) and size (amount of energy reflected). Thus both the size and number of individuals can be determined, and, where a target species occupies a particular zone in a water body, e.g. charr, then population estimates may be possible.

b) Application of method

There is a wide range of echo-sounding techniques, ranging from basic information provided in the form of echo-graph printouts to more sophisticated methods of collecting and processing data electronically. When sampling, acoustic transducers may be stationary or mobile. They may be single beam, dual beam or split beam with low or high frequencies. Low frequency transducers (e.g. 70 kHz) are appropriate for sampling larger species but exclude smaller fish (e.g. < 50 mm). High frequency (e.g. 420 kHz) sounders are used for sampling smaller fish or plankton.

Hydroacoustic methods for fish surveys are discussed in detail in NRA R&D Note 196 (Duncan and Kubecka, 1993).

c) Quality assurance

Hydroacoustics for fish survey work is very much a developing science, thus formal quality assurance procedures have yet to be addressed. Perhaps the most important consideration therefore, is to recognise the inherent limitations of the technique and the data it provides. For example, the most obvious disadvantage in the use of echo-sounders is that they do not identify fish species. Therefore, a more traditional method is usually employed in conjunction with echo sounding for species identification.

Future developments

The use of hydroacoustics in fishery assessment and management is still at an early stage of development and significant advances in hardware specification and the application of the technique can be expected in the coming years. Military and engineering applications remain the major market for hydroacoustic hardware so that technological improvements to fish survey equipment may arise primarily as a spin-off from these areas.

Other comments

The potential advantages of echo-sounding include the speed of sampling and the low labour requirement compared with other fish survey methods. Echo-sounders can provide both temporal and spatial information. Because of the ability to survey a large area within a short time frame, hydroacoustics can be particularly useful for detecting species with a very clumped distribution, e.g. shoaling species which range over a large area. Unlike some methods used for monitoring migration (e.g. radio tagging, telemetry or surgically implanted acoustic transmitters), echo sounding is not stressful to fish.

One of the disadvantages of echo sounders is their inability to work in 'blind zones'. These are sections of water where echo-sounding results are not reliable, for example the top or bottom metre of water. Here alternative methods of sampling or assessing fish behaviour must be employed or the echo-sounding techniques manipulated to overcome the limitations. For example, upward facing or downward facing transducers may eliminate blind zones.

4.5.7 Other fish survey methods

Fish counters

Fish counters (either conductivity or acoustic based) are used primarily as a means of assessing adult salmon/sea trout run size. Counters on priority rivers may be placed up and downstream of major obstructions to fish passage. Video equipment or traps provide additional information on species and sex and provide a means of validating counter results. The design and use of fish counters are discussed in R&D Note 382 (Nicholson *et al.*, 1995).

Smolt traps

Smolt traps can be used to collect data on species composition, weight, length, age and general condition of migrants. Downstream traps also provide an opportunity to microtag wild smolts. They also afford a means of estimating salmon production in large catchments with limited populations.

Smolt traps can only provide approximate estimates of abundance, unless they are whole river traps. They require 24 hour operation and therefore have a large manpower requirement. Unfortunately, their efficiency decreases in conditions of river spates, when smolts are more likely to be moving downstream. The effects of post-trapping mortality on smolts are unclear.

Smolt traps are usually employed on rivers where electronic fish counters for recording adult run size are lacking.

Traps

Traps of various designs can be used but they are generally both species and size specific. Traps have been used for long term monitoring of populations in large lakes, e.g. perch in Windermere.

Fyke nets

These are essentially hoop nets with a 'leader' or with wing nets attached to the hoop at the mouth. The leader net extends perpendicularly from the mouth generally towards the shore. Fyke nets can be fished in still or running water and are often deployed near weedy cover to capture highly mobile, cover seeking fish species. They can be used on feeder streams to catch migratory fish, e.g. Arctic charr or lake trout on spawning migrations from lake to stream.

Gill nets

Gill netting is primarily used for collecting fish samples for further biological analysis. The method kills many of the fish captured. The fish are entangled in gill nets, which are set from a boat and left in position for a specified period, e.g. overnight. The chosen mesh size depends on the target species. For general survey work, a monofilament net with panels of different mesh sizes is often used.

Rod catch statistics

Rod catch statistics are collected for all migratory salmonid rivers in England and Wales and a substantial body of historical data exists. Declared catches provide an estimate of yield from a fishery and in many cases may be the only indicator of possible stock sizes of returning adults. However, catch data can be of highly variable quality and are influenced by the number of fish available for capture, the amount and quality of fishing effort, environmental variables and catch return rates.

In order to improve the quality of rod catch data, North East Region have introduced a log book scheme for anglers to record and report fishing effort and catches (North East Region, 1996b).

Anglers' rod catches, especially match records, are also used for the assessment of coarse fisheries, especially for locations where the use of conventional fish survey methods is problematic.

Redd counts

Counting the number of redds present is sometimes used to provide an estimate of salmon and sea trout in spawning success. However, this is not a scientifically recognised method because it is regarded as too subjective and it is often difficult to distinguish salmon and sea trout redds. Adverse weather conditions hinder reliable estimates of redds.

Cooling water intake screens

Fish capture via cooling water intake screens can provide valuable qualitative information on fish communities in situations where other forms of fish data are hard to obtain, as is the case for estuaries. For example, the power station intakes along the Thames Tideway provided the major source of information on fish recolonisation in the wake of water quality improvements to the estuary.

Trawling

Trawls, such as otter trawls, are sometimes used for the assessment of estuarine fish communities. Trawls provide qualitative and CPUE data.

4.5.8 Methods for tagging and marking fish

Business needs

The tagging and/or marking of fish generally fulfils one of two functions:

- population estimation by the mark-recapture method, or validation of capture efficiency of techniques such as seine netting;
- longer term surveillance to assess survival (e.g. stocked salmon parr survival, smolt survival at sea and adult return rate), dispersion and migration.

Current status

The marking and tagging of fish is widely recognised as an essential component of fisheries investigation and management activity.

Method summary

For straightforward mark-recapture investigations, where individual identification is not required, then simple marking, e.g. dye marking by Pan-jet or fin clipping, is frequently employed. More modern forms of marking include fluorescent elastomer markers, usually applied in the post ocular adipose tissue of left eye for juvenile salmonids, and other fluorescent markers requiring UV light for identification of marked fish.

For longer-term survival, dispersion or migration studies, where knowledge of the time and place of marking of each individual is important, then some form of coded tag is generally employed.

Modern implant tags are of small size, and can be used to tag smaller fish. The tags cause minimal tissue damage on entry, and the sub-dermal location avoids the chronic wound infections associated with all tags that protrude through the skin. Most microtags consist of a small coded wire, often injected into the cartilage of the fishes nose. These tags have good retention, enable individual fish to be identified but are not externally visible. They therefore require an additional means of identifying tagged fish, such as fin clipping or the use of an electromagnetic detector. Microtags generally require excision for microscopic reading although some can be read *in situ*.

Visual Implant (VI) tags generally measure about 1 x 2.5 mm and can be made of fluorescent material bearing an alphanumeric code for individual identification. They are applicator applied subcutaneously to anaesthetised fish in transparent or translucent tissue. Tagged fish can be easily recognised and the tags read with the naked eye or the aid of a magnifying glass. Experimental studies on a variety of species have suggested that wound infection rates are low, growth and behaviour are unaffected, and that retention rates may exceed 90% over one year, although some studies have indicated much lower retention rates.

PIT (Passive Integrated Transponder) tags generally comprise a glass encapsulated microprocessor which is placed in the body cavity or other benign site. Handheld or fixed detectors linked via telemetry to a central data station can read tags. Telemetry offers the advantage that the fish can be followed in water beyond the scope of visual observation. Also by the use of fixed stations, the movement of fish around an obstruction can be monitored. Tracking methods are described in R&D Note 33 (Scottish Fisheries Research Service, 1993).

Although primarily used for salmonid studies, the various types of tagging and dye marking can also be used for studies of coarse fish.

4.5.9 Methods for relating fish populations to physical habitat - IFIM using PHABSIM

Business needs

There is a currently a largely unmet need for methods for determining habitat requirements, especially in relation to river flows, for different species of fish. The lack of such methods imposes difficulties for such activities as impact assessment for developments, the review of abstraction licenses and low flow alleviation schemes, where scientifically derived and justified target flow regimes are required. The Instream Flow Incremental Methodology (IFIM) approach, especially Physical HABitat SIMulation (PHABSIM) model, potentially meets this requirement by providing a mechanism for defining ecologically acceptable flow regimes. In the USA, IFIM is currently endorsed as one of the primary negotiating tools in disputes over flows needed to maintain ecological integrity (Gore and Hamilton, 1996).

Current status

IFIM, developed and widely used in the USA, and especially its component programs comprising PHABSIM and similar models, currently offer the most useful approach for defining ecologically acceptable flow regimes for target species. PHABSIM has been the subject of at least three R&D projects (Bullock *et al.*, 1991; Johnson *et al.*, 1993; Petts *et al.*, 1996) and has been applied in a small number of specific investigations in several Agency Regions including Thames, Midlands, Anglian and South West (e.g. the River Wissey Investigations by Petts and Bickerton (1997)). PHABSIM has not been fully validated in the UK and its underlying rationale has been the subject of some past criticism. However, the PHABSIM approach is now widely recognised within the Agency, although it has not yet achieved the status of a standard method. To date, PHABSIM has only been used in relation to salmonids, although the model is equally applicable to coarse fish or any target aquatic species.

Method summary

a) The PHABSIM model

The IFIM procedure (Bovee, 1982) provides an estimate of habitat loss/gain with changes in flow regime. The IFIM itself is a set of concepts relating habitat suitability information for target species to physical habitat variables and can be used with flow, water quality, temperature etc. models for impact assessments. PHABSIM is a computer model comprising a suite of programs that predicts a change in a weighted measure of physical habitat area (Weighted Usable Area (WUA)) available to an aquatic species resulting from a change in flow regime. PHABSIM therefore provides a predictive quantitative measure of available physical habitat. PHABSIM does not and cannot predict a change in the abundance or biomass of a target species *per se*. However, it is commonly assumed that some sort of relationship between WUA and species abundance/biomass is likely to exist, or, at the very least, that acceptable levels of target species can be maintained by ensuring the availability of sufficient physical habitat area.

b) The underlying principles of PHABSIM

The PHABSIM model is based on the following underlying principles:

- the chosen (target) species exhibit preferences within a range of habitat conditions that it (they) can tolerate;
- these ranges can be defined for each species - in terms of Habitat Suitability Curves (habitat suitability indices (HSI), habitat utilisation curves);
- the area of stream providing these conditions can be quantified as a function of discharge and channel structure.

c) Application of PHABSIM

PHABSIM can be used to investigate either critical reaches which provide a particular (restricted) type of habitat or to representative (typical) reaches. Hydraulic simulations are based on at least three calibration streamflows from point measurements taken along transects within the reach. The hydraulic simulation is then combined with habitat suitability curves for target species (or life cycle stages) to define available habitat - the weighted usable area (WUA) - in the reach.

Habitat Suitability Curves (HSCs) must be constructed for the critical life cycle stages of each target species (i.e. juveniles may require quite different habitat to adults). HSCs are based on the fact that a functional relationship exists between a response variable (for PHABSIM the variables are depth, velocity and substrate/cover) and the degree to which the variable is "usable" over a scale of 0 (no use) to 1 (maximum use). HSCs can be derived from literature survey and expert opinion (Category 1 HSCs) or can be based on frequency analysis of microhabitat use derived from direct field observation and measurement in the river in question (Category 2 HSCs). In the UK, the development of Category 2 HSCs has been essentially limited to salmonids.

d) Quality assurance

Existing PHABSIM R&D reports do not specifically address the subject of quality assurance. However, a number of general points are applicable to any simulation model, namely:

- a model must be properly validated and its limitations clearly understood;
- the output of a model is dependent on the quality of the input data on which predictions are based;
- a model is only one of a range of tools for addressing a particular problem.

Future developments

PHABSIM is becoming widely recognised as a valuable management tool and the method has now been applied in a considerable number of countries including Australia, Canada, France, Norway, New Zealand and South Africa. Forthcoming Agency R&D projects include W6B(97)1 (Validation of hydroecological models on rivers in England and Wales) and W6B(97)2 (Appropriate habitat suitability curves for use with PHABSIM).

An extension of the use of PHABSIM to include coarse fish and invertebrates is clearly justified.

4.5.10 Methods for relating fish populations to physical habitat - HABSCORE

Business needs

a) Existing

Salmonid fishery management - HABSCORE is a system for measuring and evaluating stream salmonid habitat features.

b) Potential

HABSCORE has potential in Environmental Impact Assessment, conservation and identification of sites for habitat improvement.

Current status

HABSCORE was originally developed as an operational tool by the Welsh Water Authority and subsequently by the Welsh Region of the NRA to evaluate salmonid habitat in upland streams in Wales. Using data collected from over 600 notionally pristine sites in England and Wales, HABSCORE was further developed under R&D Projects 338 (Barnard and Wyatt, 1995; Wyatt *et al.*, 1995). HABSCORE is now nationally applicable in England and Wales and has been adopted as a standard method.

Method summary

a) Basic principle

HABSCORE is based on habitat data and salmonid population data derived from over 600 'pristine' (reference) sites in England and Wales. HABSCORE is an empirical model which predicts the average long-term density of fish that would be expected for the given site (river reach) if there were no impacts such as poor water quality and if recruitment were not limiting. HABSCORE is therefore comparable to the RIVPACS invertebrate package in terms of its basic concepts.

b) Data analysis

HABSCORE currently employs HABSCORE V software, a form of custom spreadsheet running under SuperCalc 5. Using the information from three HABSCORE questionnaires:

HABform (site habitat data),

MAPform (features of the site catchment),

FISHform (fish survey results from the site),

the software produces estimates of the expected populations, based on the Habitat Quality Index (HQS) and the degree of habitat utilisation (the Habitat Utilisation Index, HUI) for each of five salmonid species/age combinations (0+ salmon; >0+ salmon; 0+ trout; >0+<20 cm trout; >20 cm trout). Comparison of the predicted population and HUI gives an assessment of fishery performance. The HQS identifies areas of poor habitat and can thus be used as a basis for habitat improvement.

c) Quality assurance

Quality assurance is not addressed in the HABSCORE manuals (Barnard and Wyatt, 1995; Wyatt *et al.*, 1995) although detailed guidance on data collection and completion of the HABform, MAPform and FISHform is provided. As with all models, the output quality is dependent on the quality of field data collection.

Future developments

As with RIVPACS, there has been some criticism that HABSCORE does not adequately represent the full range of stream types within England and Wales. This can be addressed by an extension of the existing reference database.

Given the importance of coarse fisheries, especially in England, there is clearly a case for adapting the HABSCORE system to include coarse fish.

Other comments

Although the importance of habitat quality and availability to coarse fish, and the value of habitat information for the interpretation of fish survey data is widely recognised within Agency fisheries units, there is no national standard for collecting habitat data during fish surveys. In practice, the type and quality of habitat data collected during fish surveys is highly variable and may be entirely lacking. Even if HABSCORE is not extended to include coarse fish, the HABform component of HABSCORE provides an excellent basis for habitat data collection relevant to any fishery. Its routine use would impose a uniform rigour on this important aspect of fish surveys.

4.5.11 Conclusions

Future developments in analytical and reporting software

There is a clear need for a standard suite of programmes for the analysis and presentation of fisheries data. The software should offer a variety of presentation formats appropriate to the various customer groups.

Regional/national fish archives and availability of fishery data

There is a clear need for fisheries data to be held in comprehensive Regional computer archives, as is the norm for routine physicochemical data. At present, much potentially valuable information is scattered throughout local offices in hard-copy reports. It is therefore difficult to abstract the data, which is potentially wasted. Where centralised databases are held (for example the National Fish Laboratory holds records of all fish it has aged), then these can potentially be used for a variety of purposes, e.g. the production of a comprehensive set of standard national growth curves.

Quality assurance

Sampling data must be of known and sufficient quality to achieve the sampling objectives. Introduction of the Fisheries Classification Scheme will require standardisation and the application of more quality assurance (QA) procedures. The form which a QA system should take requires careful consideration and poses a number of potential difficulties. In the case of invertebrates it is relatively straightforward to define a standard sampling procedure and to implement a formal analytical quality control (AQC) system for sample sorting and identification. Accurate sorting and invertebrate identification requires considerable skill and is a major source of potential error. The nationally adopted invertebrate identification AQC system seeks to keep such errors within acceptable limits.

In contrast, each fish survey site must be individually assessed and the most appropriate survey method selected on the basis of experienced judgement and available resources. With the exception of 0+ juveniles, fish identification is very straightforward and identification errors are very unlikely. The one area where a formal AQC system is clearly appropriate is for fish ageing from scales or other bony elements. The National Fisheries Laboratory at Brampton has introduced its own AQC system for scale reading which involves independent re-reading of a proportion of scales with a defined permissible level of disagreement beyond which remedial action is implemented.

The current state of Environment Agency QA for fish surveying methods varies from Region to Region and is somewhat ad-hoc and informal but tends to follow a general pattern. The most important requirement for any fish capture survey method is to ensure constancy of capture efficiency. This is fundamental to catch depletion population estimates and essential for meaningful comparisons between semi-quantitative surveys. In order to meet this requirement, it is common practice for each member of a survey to undertake the same task at each site in a survey, thus at least ensuring constancy of effort.

Standardisation of fish and fisheries methods

Standard protocols for fisheries methods for the Agency as a whole are generally lacking, in particular the required level of precision in fish survey methods has not been specified. Within individual Regions, the degree of standardisation of methods is very variable. Past and current national R&D programmes are beginning to address the need for standardised methodologies in fisheries assessment. Whilst there is a clear case for a suite of national standard methods, these should not be overly prescriptive as survey methods must be sufficiently flexible to accommodate a wide range of individual site characteristics.

Use of fishery data and integration of fisheries with other Agency functions

At present, fisheries sections still appear to be somewhat stand-alone functions in several Agency Regions. There is considerable scope for the further integration of fisheries with other functions and for the wider use of fisheries data in biological and environmental assessments.

The Fisheries Classification Scheme

The current development and introduction of the national Fisheries Classification Scheme (FCS) provides a potential opportunity to harmonise fisheries data collection and use across the Regions and the potential to introduce a formal fisheries 'window' into the GQA.

There is currently a growing trend towards the collection of semi-quantitative fish survey data in a high proportion of the Agency Regions, as this is seen to represent a more cost-effective deployment of available resources. The FCS, however, requires quantitative data. The resolution of this conflict is an obvious priority.

4.6 Marine and estuarine methods

4.6.1 Introduction

Marine and estuarine habitats have received varying degrees of attention by different Regions of the Agency. The extent of work has largely depended on historical precedent, the availability of marine biologists and the presence or absence of important habitats and/or impacts.

The Environment Agency has a wide range of duties relating to estuaries and coastal waters. These broadly correspond to those in freshwater, although the principal concern is the protection of marine and estuarine ecosystems, rather than the protection of the water itself as a resource. The proposed designation of a substantial number of marine and estuarine SACs and SPAs is likely to increase the surveillance and monitoring requirements for these habitats. Fisheries are not the responsibility of the Agency in coastal waters, although migratory fish for which the Agency is responsible under the Environment Act 1995 utilise coastal and estuarine habitats.

There has been a concerted effort over recent years to co-ordinate marine monitoring on a national basis and this has largely been achieved through the implementation of the National Monitoring Plan (NMP). However, marine and estuarine habitats are still considered to be inadequately addressed by the Agency and there is a perceived lack of marine biologists within the Agency.

4.6.2 National Monitoring Plan (NMP) methods

Business needs

a) Existing:

- water quality, pollution prevention and control;
- conservation;

- in its State of the Environment report (Environment Agency, 1996f) the Agency described chlorophyll a levels and bioaccumulation of metals in shellfish as part of its report on the quality of estuaries and coastal waters;
- Local Environment Agency Action Plans (LEAPS) and coastal plans.

b) Potential

There is an identified need for the development of a GQA system for estuaries to replace the existing classification system, which is considered both dated and subjective.

Current status

The specific objectives of the UK National Monitoring Plan (NMP) are presented in Section 3.6.3. The scope and the monitoring requirements of the project are outlined in Marine Pollution Monitoring Management Group (1994). Some of the most extensive duties of the Agency regarding the monitoring of coastal and estuarine environments are those defined under the NMP. This involves the monitoring of a network of UK estuaries and coastal waters, including sites which are not significantly contaminated. North Sea Action Plan work is incorporated into the plan.

Biological aspects of the NMP include sampling of benthic macrofauna, oyster embryo bioassays and the measurement of various substances in biological tissues. NMP is considered a significant step towards the effective monitoring of marine and estuarine habitats and The programme is being implemented throughout the Agency. The National Marine Group has made considerable progress in standardising the methods used in the various Regions, but there has not yet been any formal standardisation.

Method summary

a) Sampling

The Environment Agency is primarily responsible for estuarine sites, as well as a small number of the inshore sites. Other organisations, such as MAFF, have responsibility for the offshore sites. In each estuary there are three sampling sites corresponding to the salinity bands 0-10, 10-20 and 20-30 parts per thousand at high water. These broadly cover the upper, middle and lower estuary. Benthic macrofauna should be sampled from each site as should fish and shellfish for bioaccumulation studies.

b) Identification

At present all marine identification work, including NMP, is carried out to species.

c) Data analysis

Data is forwarded to the NMP database co-ordinator in a specific format.

Various multivariate techniques and techniques such as PRIMER, TWINSPAN and DECORANA have been used by Agency staff to assess marine and estuarine data. PRIMER is considered very useful by many in the Agency. There is some concern that it may not be used properly or the full implications of its outputs understood without adequate training or experience. However, training courses run by Plymouth Marine Laboratory are available. A standard approved set of options (e.g. data transformation, mechanism of linkage) for each procedure within this package may be useful and perhaps these could correspond to the default choices.

d) Quality assurance

QA procedures have been applied to benthic macrofauna for NMP purposes. Ten percent of samples are sent to UnicoMarine for audit. This procedure has also been used for other studies (e.g. Sea Empress). This is an area being addressed at workshops by the National Marine Biology AQC Committee, particularly with reference to the auditing of work carried out by outside contractors. A macrobenthic field methods training workshop was conducted in 1997. This compared techniques for sampling and processing of marine/estuarine macrobenthic samples in the field and laboratory. The production of a report and video for training purposes to promote best practice was proposed.

In Anglian Region, five percent of samples are returned by the contractors for auditing and North East Region also audit contractor's work. It was felt that there should be a national protocol for contractor specifications.

Future developments

As mentioned previously, the National Marine Group has made considerable progress in the adoption of standard methods in the regions. However, formal standardisation is seen as a vital future development. A revised National Monitoring Plan is proposed for 1998.

Other comments

The use of species or higher levels of taxonomy in marine survey work is under debate. The obvious advantage of using higher levels of taxonomy is in the maximisation of the use of resources. The savings which such taxonomy could provide require careful investigation. Studies need to assess the quality of information which higher taxonomic levels can yield relative to species level investigations. The general opinion of marine biologists is that the fundamental work in this area has not been conducted.

For many marine and estuarine studies, the sampling itself represents an extremely large cost and effort if a boat is used. Many are of the opinion that information gained from such sampling should be maximised through species level identification and that relative to the costs of sampling the additional cost of this identification is justifiable. Furthermore, in many situations such as estuaries, higher taxonomic groups may only be represented by a few species and, therefore, the difference between the levels of taxonomy may not be great in practical terms. The scientific and practical justification for identification at levels above species requires further work. Some work on this subject, in offshore regions, has been carried out by Plymouth Marine Laboratory and concludes that the use of higher taxa not only represents a time saving, but also reflects 'well-defined pollution gradients more closely than species' (Clarke and Warwick, 1994). However, there is a lack of such research in estuarine environments.

4.6.3 Anglian region standard methodologies: estuarine/marine benthic macroinvertebrates

Business needs

This method meets the following business needs:

- water quality and pollution control - statutory obligations, pollution incidents and post pollution recovery and Regional operational monitoring;
- conservation - provides information on ecosystem quality;
- Environmental Change Network monitoring.

Current status

This represents an early attempt to formalise methods for sampling benthic macrofauna. The full methods are given in Anglian Region (1995b). These methods are generally used by all Agency Regions undertaking marine work, with only slight Regional variations.

Method summary

a) Sampling

Intertidal sampling methods comprise two components. A core method is applied to all sites and a supplementary method is used if coarse sediments (sands) are present. For the core method a minimum of five core samples (0.01 m^2) are taken. Supplementary sampling is achieved using the corer or a large box-core (0.1 m^2). Different methods are used for estuarine and coastal sites. In estuaries, five additional cores should be taken. In coastal areas a minimum of three box cores (preferably four) should be taken in addition to the normal core method.

Subtidal sampling is achieved with a 0.1 m^2 Van Veen or Day Grab. In estuaries, a minimum of three samples are required although five are recommended. In coastal habitats a minimum of five is required. North East Region sometimes use a box corer for subtidal sampling.

b) Identification

Methods for sieving, handling and preservation of samples are given, but methods for identification are not specified, although species level is assumed.

c) Data analysis

No method is specified.

d) Quality assurance

Various methods of quality assurance are given including the washing of samplers between sites, accurate recording of site and sample details, careful sieving and the checking of sorting and identification.

Future developments

These methods could form the basis of any standard methods for benthic macroinvertebrates developed by the National Marine Biology Group.

4.6.4 National standard methodology for marine macrofaunal benthic sampling

Business needs

This method meets marine water quality and conservation needs.

Current status

These methods were developed to ensure a standard approach in all Regions. The specific objectives (Barnett, 1993a) are to establish methods which:

- are scientifically defensible and produce data which are acceptable to the wider scientific community;
- are robust enough to meet the requirements of all normal investigations;
- are practical to use within reasonable constraints of equipment and manpower;
- have a minimum number of alternatives to reduce inconsistencies and the need for pilot studies.

These methods form the basis for current practice, incorporating macrofaunal sampling included in the NMP.

Method summary

a) Sampling

Methods for intertidal and subtidal soft sediments are given in Barnett (1993a) and Culling (1992) respectively. The methods given correspond closely to Anglian Region's methods described above, where they were developed. For various purposes, non-biological samples of sediment are required to accompany biological samples. Methods for the collection of sediment samples for the measurement of metals, pesticides, organics, particle size, redox potential and organic carbon are given in White (1993a).

b) Identification

Guidelines for sample handling and identification are given in Barnett (1993b) and White (1993b). As with other marine work, identification is carried out at species level.

c) Data analysis

No instructions regarding methods of data analysis are given.

d) Quality assurance

Standard procedure and guidance documents have been produced. Within each laboratory, checks should be made of sorting and identification.

Future developments

These methods are the basis for current practice in the Agency and will form the basis for any standard methods developed in the future.

4.6.5 Marine bioaccumulation methods

Business needs

a) Existing

Water quality and pollution control - Titanium Dioxide Directive, Dangerous Substances Directive, Shellfish Directive and Regional operational pollution monitoring.

b) Potential

Outside the statutory requirements for bioaccumulation work, bioaccumulation studies may have a role where sources of pollution are poorly understood. Bioaccumulation is an effective way of providing long-term information on temporal and spatial trends in the bioavailability of compounds. Bioaccumulation may also have a role to play in the detection of micropollutants (e.g. the study of oestrogenic substances using flounder in the Thames).

Current status

Most bioaccumulation studies undertaken by the Environment Agency are in relation to the marine environment. Most Regions which carry out marine studies conduct some form of bioaccumulation work. No national Environment Agency methods exist although established methods are available in the literature and are used by Agency Regions. Barnett (1990) presented guidelines for the establishment of a bioaccumulation programme. This document attempted to provide a framework for co-ordinating bioaccumulation work in the National Rivers Authority.

Method summaries

The following paragraphs summarise some examples of bioaccumulation work undertaken by Agency staff and highlighted during the consultation process of this project. No attempt is made to cover the numerous specific bioaccumulation studies carried out by the Agency.

In general during bioaccumulation investigations, sample collection and treatment of samples is carried out by Agency biologists and specialised Regional labs carry out tissue analysis. North East Region have included standard sampling techniques and devices for fucus, mussels, winkles, limpets, cockles and fish in their Regional Marine Centre method manual (North East Region, 1996c).

A method for the sampling, treatment and analysis of the mussel *Mytilus edulis* to monitor red list organochlorines in marine ecosystems was devised by ERL for the National Rivers Authority (ERL, 1993a). This document outlined how mussels should be gathered and described the laboratory procedures for the use of *Mytilus edulis* for this purpose.

A similar document for the sampling, treatment and analysis of the seaweeds *Fucus* and *Enteromorpha* to monitor red list organochlorines in marine and estuarine ecosystems has been produced (ERL, 1993b). This includes instructions on how to find and analyse seaweeds for bioaccumulation studies.

The principles and laboratory techniques presented in these documents may be useful in the study of other substances.

Other comments

Many marine scientists within the Agency still feel bioaccumulation is an under-valued tool and believe it to be particularly useful where benthic studies may be unsuitable (e.g. in areas composed of hard substrates). A national intertidal bioaccumulation programme is favoured by many biologists. Further guidance on the selection of organisms and contaminants for investigation would also assist Agency staff. One problem is that different labs have different analytical techniques. Therefore production of updated guidelines including quality assurance procedures with regard to bioaccumulation studies would ensure a consistent approach throughout the Environment Agency.

It would be useful to carry out a scoping study with the overall objective of establishing the value of marine bioaccumulation work to the Environment Agency. Specific objectives would determine:

- the extent to which bioaccumulation work is currently being used throughout the Agency's Regions;
- which current Environment Agency business needs are being met by this type of work;
- how other existing business needs could be fulfilled using existing bioaccumulation work;
- whether there are future business needs which could be met using bioaccumulation;
- the extent of existing or planned bioaccumulation work undertaken by other organisations such as MAFF so as to prevent overlap.

This should in turn ascertain whether the development of standardised national methods and approaches in bioaccumulation are necessary in the Environment Agency.

4.6.6 Marine conservation methods

Business needs

The Agency's duty to conserve and enhance biodiversity includes coastal waters and estuaries. Therefore, conservation needs to be taken into account as part of all the Agency's activities in these habitats including the construction of sea walls and other flood defence works. The assessment of conservation value is a problematic area for the Agency in all habitats, but can be particularly difficult in coastal and estuarine habitats where there is little expertise within the Agency. However, certain habitats, such as salt marshes and mud flats, have received the attention of other organisations, such as the Royal Society for the Protection of Birds (RSPB), and their expertise and records could be useful to the Agency. It is imperative that the Agency considers biology in relation to estuarine and coastal flood defence works.

The Agency also has specific conservation duties. As part of the UK Biodiversity Action Plan, the Agency is the lead partner, in conjunction with MAFF, for the Allis shad and Twaite shad, which enter lower reaches of rivers to spawn. In addition, the conservation of the harbour porpoise, starlet sea anemone, saline lagoons and seagrass beds require action by the Agency. Some marine and estuarine areas have been designated Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). The Environment Agency may have a significant input into the monitoring of these sites.

Current status

At present, the Environment Agency carries out very little conservation work in relation to the marine environment. However some of the existing methods generate data which may be useful in a conservation context. A biological protocol concerning environmental impact assessment requirements for new marine outfalls has been produced (National Marine Biology sub-group, undated). This detailed the steps involved in environmental impact assessments of marine outfalls and recommended which methods should be used.

Method summaries

No specific marine conservation methods are used by the Agency. However other organisations are currently investigating such methods

MAFF are conducting research which is relevant to the Agency. MAFF Flood and Coastal Defence Division is looking at the availability of information regarding the use of saltmarsh as a coastal defence. Later research will deal with the availability of data to support management decisions about flood and coastal defence policy. Currently, research is being undertaken on plant and invertebrate colonisation and the movement of sediments in estuaries.

The Joint Nature Conservation Committee (JNCC) is currently devising a methods handbook to be used in the measurement of biological change for the management of marine protected areas particularly SACs (Hiscock, 1997 draft). The aim is to tailor existing methods used by conservation bodies towards long-term monitoring of these sites. A marine conservation review workshop was organised for this purpose and some Environment Agency staff attended. The adoption of trigger levels to minimise impacts was discussed.

Future developments

Development of, or at least assistance in development of marine methods in relation to conservation should be a high priority for the Environment Agency. This is particularly important in light of the impending designation of marine SACs under the EC Habitats Directive (92/43/EEC).

4.6.7 Cockle (*Cerastoderma edule L.*) monitoring

Business needs

This method could potentially meet the following needs of the Agency:

- water quality - internal banding of cockle shells is a potential tool for determining the occurrence of pollution incidents;
- conservation - cockle populations are potential indicators of improving environmental conditions and may be appropriate in the monitoring of sensitive inter-tidal areas.

Current status

Cockle monitoring is not used routinely by the Agency and no standard Regional or National protocols have been developed. However, specific studies have been carried out by Agency staff and the methods used represent a potentially useful tool for the Agency in measuring environmental quality. For example, an investigation of the cockle (*Cerastoderma edule* L.) population on Seal Sands (lower Tees estuary), an internationally important area for migratory wading birds, was carried out in 1996 (Elmes, 1996). The following method summary is based on the procedures employed during this survey.

Method summary

a) Sampling

Four sites were sampled using a 0.1 m^2 corer, with ten replicates being taken at each site. In addition five 0.01 m^2 cores were taken at each site for macroinvertebrate analysis.

b) Identification

Samples were identified to species.

c) Data analysis

Number, biomass and age class structure of cockles was determined at each site. Age was determined by counting external growth bands of individuals. Internal growth bands in cockle shells were also studied. Internal growth bands are related to tidal immersions where perturbations in this regular pattern may indicate periods of stress.

d) Quality assurance

QA procedures were not described in the paper.

Future developments

Following cockle populations over a longer time period could be useful in long-term monitoring of environmental quality in this area. The appropriateness of this method should be considered for use in other Regions. This method could potentially be incorporated into existing estuarine monitoring programmes and bioaccumulation studies.

4.6.8 Rocky shore methods

Business needs

These methods are potentially useful to conservation in the assessment of environmental quality. The methods may also meet water quality needs.

Current status

The National Marine Group has not produced a protocol for sampling of rocky shores although Agency staff have sampled from this type of habitat. For example, a biological survey of Jackson's Bay, Scarborough, was undertaken by Bird (1993). The aim was to record possible ecological recovery after closure of the short sewage outfalls by comparing data from 1988, 1989, 1992 and 1993.

Method summaries

a) Sampling

This method refers to Bird (1993). Transects were used. Sampling points were identified using photographs and were located at 0.5 m height intervals from the low-water spring tide mark. At each sampling station three contiguous 0.25 m^2 quadrats were photographed and abundance estimates made of the algae and fauna. This was supplemented by general information taken within a 10 m band either side of the station.

b) Identification

Collected samples of algae and invertebrates were identified to species in the laboratory.

c) Data analysis

Abundance estimates were averaged for each station. Multivariate analysis of the dataset was undertaken using the PRIMER package.

d) Quality assurance

No specific quality assurance procedures were described in the document provided. However sampling between years was kept as consistent as possible.

Future developments

Many Agency Regions do not have any rocky shores and would not require the development of sampling methods. However, a standard method for sampling rocky intertidal areas would be useful to ensure a consistent approach among those Regions which currently undertake or would like to undertake such surveying. The Fields Studies Council (FSC) have produced a guide for rocky shore investigation (Archer-Thomson, 1991). The JNCC have also undertaken rocky shore surveys.

4.6.9 Conclusions

In general, marine and estuarine methods are available within the Agency, although formalisation and standardisation is typically required. The National Marine Group is addressing the issue of standardisation and formalisation of methods and is considered to be fulfilling a very useful role in this context by Agency staff.

To summarise, there are several areas requiring development which were identified by Agency staff and these are given below:

- formalisation and standardisation of marine and estuarine protocols;
- development of a method for sampling rocky intertidal areas;
- investigations into the relative merits of different levels of taxonomy for the study of macrobenthos, particularly in estuaries;
- development of marine and estuarine classification schemes;

- possible inclusion of marine taxa into the algal image database to help with the identification of marine taxa;
- production of guidelines for the management of contractors involved in marine work (including quality assurance);
- expand the use of UNICORN database, which stores biological and chemical data, so that data requests can be produced quickly and in a standard format;
- standard sampling should be prescriptive enough to ensure methods are adhered to but should incorporate flexibility for one-off investigations;
- a scoping study should be undertaken to establish the existing and future role of bioaccumulation work in estuarine and marine surveying.

4.7 Biological Conservation methods

4.7.1 Introduction

The use of conservation assessment methods within the Agency

This section considers conservation orientated biological methods currently in use by the Agency and reviews additional methods that potentially meet current and predicted Agency requirements.

Protected and non-protected areas

There are essentially two approaches to the conservation of flora and fauna. One aims to protect wildlife in designated sites where conservation is either the principal land use, or is at least a key determinant of land (or water) management policy and practice. The designation of sites is the province of EN, CCW and SNH. Although the Environment Agency has no direct role in the designation of sites, it is likely to have a significant role in their management and monitoring, particularly in the case of river and wetland SSSIs and SACs, marine SACs, Ramsar sites and SPAs.

The second approach bases conservation on the wider environment where the majority of flora and fauna live but where other land or water uses are the primary purpose. This second approach may require the evaluation of any piece of land or water, whatever its quality. This requires a robust approach with standardised survey, assessment and monitoring methods. It is within this second category that much of the Agency's conservation work will fall, because it impinges on all Agency functions in all media.

Criteria for the assessment of conservation value

Usher (1986) quotes the following criteria, which are an expansion of Ratcliffe's (1977) criteria set out in the Nature Conservation Review, as those that are generally used in the assessment of conservation value: diversity (both species and habitat); naturalness; rarity (species and habitat); area (extent); threat of human interference; amenity value; education value; recorded history; representativeness; scientific value; typicalness; uniqueness; availability; ecological fragility; position in an ecological and geographic unit; potential value; replaceability; wildlife reservoir potential. A further criterion could be endemicity; areas of concentrated endemism may have a conservation value (Margules & Usher, 1981).

The foregoing assessment criteria are relatively robust and can be applied to any site, irrespective of whether nature conservation is the primary land use. Furthermore, these criteria can be applied in a qualitative or quantitative manner. The chief merit of a scoring system is in arranging similar sites in order of quality by a systematic and standard procedure (Ratcliffe, 1986).

The development of methods for conservation value assessment

In the UK there is a historical bias towards the use of plant species in evaluating a site for conservation value, whether it be aquatic or terrestrial. Typically, site evaluation is based on direct observation and measurement of the biota, so that the biota itself is sampled to assess the quality of the site. This may be relatively simple and satisfactory when the primary objective of conservation is the vegetation itself. When the full range of biota is of concern, then the resource implications of surveying and assessing all groups becomes prohibitive in terms of both time and expertise. This has led to the development of assessment methods based on the concept that physical habitat availability, i.e. some measure of its structure and quality, can be used as a surrogate for direct observation of the biota. Whilst it could argued that the underlying rationale to this approach is overly simplistic, there are major potential benefits. For example, the approach allows for rapid site assessment, it can form the basis of predictive models and it provides a rational guide to environmental enhancement measures.

4.7.2 Community based methods - the National Vegetation Classification (NVC)

Business needs

The survey, classification, assessment, surveillance and monitoring of vegetation; conservation; Environmental Impact Assessment.

The NVC is likely to be of greatest value to the Agency in relation to wetland and flood plain habitats, where it can be used for characterising vegetation, identifying conservation priorities and for monitoring the effects of reduced or enhanced water levels.

Current status

The NVC was proposed in 'A Nature Conservation Review' (Ratcliffe, 1977) and was standardised in Rodwell (1991; 1992a; 1992b; 1995; 1996) on behalf of the Nature Conservancy Council. The system is intended to be used as the framework for the survey and evaluation of those habitats which can be defined in terms of plant communities. The NVC covers the full range of terrestrial and wetland communities occurring in the UK.

The National Vegetation Classification (NVC) is now the most widely used method in the UK for botanical surveys and conservation assessment. However, although some Agency Regions have used NVC for the classification of wetlands and flood meadows, its overall use within the organisation is currently limited.

Method summary

a) Sampling

The NVC is a method of standardising the recording of vegetational diversity within a surveyed area. The method is based on the quantitative botanical survey of a series of replicate quadrats in each vegetation stand (actual plant community), with quadrat size depending on the nature of the habitat in question.

b) Identification

Species level identification is required with abundance recorded as either percentage cover or on the DOMIN scale. Additional species (outside the quadrats) within the stand are also recorded.

c) Data analysis

Survey data are analysed using the floristic keys contained in Rodwell (1991; 1992a; 1992b; 1995; 1996), or it can be analysed by means of the 'TABLEFIT' software package produced by the Institute of Terrestrial Ecology (Hill, 1995)

The NVC provides a 'language' for dealing with vegetation in a systematic way and promotes ecological understanding when correlated with environmental conditions (Nature Conservancy Council, 1989). Used in conjunction with the basic site evaluation criteria (size, diversity, rarity, typicalness etc.) the NVC allows vegetation at any terrestrial or wetland site to be assessed in terms of its conservation value.

d) Quality assurance

Although the NVC is relatively rapid to apply, it requires considerable taxonomic skill and a good working knowledge of the system. Surveyors should therefore be trained in the application of the NVC and accredited for plant identification.

Future developments

The NVC is now widely tested and accepted and could be adopted by the Agency as a standard method without any further assessment or R&D. The classification is of sufficient importance to English Nature and its Welsh and Scottish counterparts that any further development and refinement will be undertaken by them.

Other comments

As already indicated, the NVC comprises the best available system for the survey, identification and assessment of plant community types (vegetation stands) and, because it is based on community structure, it is a valuable surveillance and monitoring tool.

4.7.3 Community based methods - Community Conservation Index (CCI)

Business needs

This method potentially meets business needs in the following areas:

- water resources - could provide useful information in relation to impacts of low flows;
- flood defence - in environmental impact assessment of flood defence schemes;
- conservation - in the assessment of conservation value and biodiversity;
- Local Environment Agency Plans (LEAPs) - CCI values could be easily reported in LEAPS and be used to identify Action Plan issues.

Current status

This is a method for the evaluation of the conservation value of macroinvertebrate communities. It was developed in Anglian Region (Extence and Chadd, 1996) and is being considered for use by other Regions. Devon and Cornwall Areas of South West Region have found it to be useful, although it may require some modification for this and other Regions.

Method summary

a) Sampling

Sampling is a standard three-minute kick sample according to GQA methodology.

b) Identification

Species level identification is required. Anglian Region carry out species level identification on many routine biological samples and, therefore, had a large amount of information regarding species distribution.

c) Data analysis

The CCI is based on two community attributes, namely the occurrence of rarities (each species is given a Conservation Score) and species richness (the Community Score derived from BMWP). CCI = average Conservation Score x Community Score.

d) Quality assurance

Quality assurance of species identification is not addressed. However, sampling method documentation exists to ensure sampling is carried out properly. Some staff training is undertaken.

Future developments

This index is a valuable attempt to assess conservation value but may need further evaluation and standardisation if it is to be adopted nationally, because Conservation Scores need to reflect individual biogeographic areas. As the index relies on species level identification, the issue of species level identification quality assurance would need to be addressed.

Other comments

The nature of conservation studies requires that species level identification is carried out and this raises certain issues because most routine work is currently carried out at family level. For species level work several issues need to be addressed, including the development of a national standard method, quality assurance and training. Some preliminary discussion has occurred with the IFE regarding the auditing of species level work and the IFE feels that it is capable of performing such a role.

Thames Region ranks its sites, in terms of richness, relative to the national database as a simple way of using macroinvertebrate data to evaluate and compare sites.

4.7.4 Community based methods - Invertebrates of Exposed Riverine Sediments (ERS)

A recent R&D project by the Agency (Environment Agency, 1996g) has examined the biological significance of exposed river channel sediments (ERS) and demonstrated their importance in supporting a wide range of invertebrates including many Notable and RDB species. ERS habitats, variously termed shoals, bars, berms, spits, sandbanks and shingle banks are formed and maintained by fluvial processes of sediment erosion, transport and deposition. ERS habitats are formed during flood events and exposed with falling water levels. ERS may be one of the few remaining semi-natural features of highly managed river corridors and may thus make an important contribution to biodiversity. The ERS project developed a draft methodology for the sampling (employing pitfall traps) and assessment of these habitats.

4.7.5 Other community based methods

Methods for aquatic macrophytes

Macrophytes are frequently used to assess the conservation value of watercourses, both in their own right and as measures of habitat quality and diversity. Two macrophyte methods for running waters are currently being developed within the Agency, namely the UWWTD method and PLANTPACS (Project Proposal Reference: W1A(96)2, 'PLANTPACS - Phase 2' and Project Number: W1-017, 'PLANTPACS -Phase 1'). These methods are described in Sections 4.2.2 and 4.2.3 respectively. The former method is now in use, although further R&D is underway, whereas PLANTPACS is at a very early stage of development.

Macrophyte methods are also being developed within the Agency's R&D programme in relation to standing waters (Williams *et al.*, 1996). None of these methods is being developed primarily for conservation purposes but nonetheless, they are likely to be useful tools in this respect.

River classification/typing

The national river surveys carried out for the NCC provided a classification of rivers in Britain based on plant communities. This method is discussed in Section 4.1.14.

Botanical classification of standing waters

Palmer *et al.* (1992) developed a botanical classification of lakes in Britain associated with trophic status. The system is based on presence/absence data for aquatic macrophyte species and introduced the concept of trophic ranking score. This system is not used routinely by the Environment Agency but modifications of the methods have been adopted.

Botanical survey of Scottish freshwater lochs

Since 1983, Scottish Natural Heritage (SNH) have been surveying loch vegetation primarily to assess conservation status and for the development of a loch classification scheme (Scottish Natural Heritage, 1995). This method, discussed in more detail in Section 4.2.9, is not used by the Agency but may be useful in its development of methods for still waters.

NCC ditch method

The former NCC developed a macrophyte-based ditch survey methodology (Alcock and Palmer, 1985). This method has been used in Welsh Region for impact assessment work and also in Midlands Region.

Methods for fish

The Agency and its predecessors have been involved in the development of fish survey and assessment methods for many years. Fishery methods have been developed primarily for stock assessment and management purposes but clearly produce information of value to conservation. Methods are particularly well developed for small to medium sized running waters. Survey and assessment methods are less well developed for large rivers, lakes, estuaries and coastal waters. Development of standard methods for assessing the status of rare fish species may be required. Freshwater fisheries methods are addressed in detail in Section 4.5.

Methods for aquatic invertebrates

In terms of GQA and pollution studies, aquatic invertebrates are the group for which methods are, in general, most advanced and most thoroughly standardised between Regions. Aquatic macroinvertebrates also have considerable potential as tools for the assessment of aquatic conservation value and biodiversity. RIVPACS may be particularly useful in this respect. However, to be of value in conservation work, invertebrate investigations ideally have to include species level identification. Family level identification is currently the norm. Section 4.1 gives a detailed review of aquatic invertebrate methods, including current and planned developments for RIVPACS (Section 4.1.2).

Only two freshwater invertebrate methods appear to have been developed within the Agency with the specific objective of conservation value assessment, namely the Community Conservation Index (CCI) and Invertebrates of Exposed Riverine Sediments (ERS) methods discussed in Sections 4.7.2 and 4.7.3 above.

Methods for other groups

With the exception of algae, and a few individual species such as otters, there is limited experience within the Agency in the survey, assessment and monitoring of other groups of organisms. For some groups however, voluntary conservation organisations operate long-term monitoring programmes and in some cases methods are well developed and standardised. A good example is the British Trust for Ornithology, who have developed a range of standard survey methods, e.g. Waterways Bird Survey (British Trust for Ornithology, 1992a); Common Bird Census (British Trust for Ornithology, 1993); National Low Tide Counts (British Trust for Ornithology, 1992b); Breeding Birds of Wet Meadows (British Trust for Ornithology, undated a); Wetland Bird Survey (British Trust for Ornithology, undated b).

These methods have potential for adoption as standards by the Agency with minimal additional development and have the advantage for site evaluation in that data produced by them would be directly comparable with national records for other sites. The Waterways Bird Survey method is the subject of an ongoing Agency R&D project (Marchant *et. al.*, 1996) examining its possible role within the Agency.

Assessment methods are also reasonably well developed for many species of mammals (bats are a possible exception) and for reptiles and amphibians. The JNCC has recently evaluated existing survey methods for amphibians and is developing proposals for standardising the way in which they are used. With the exception of high profile groups such as butterflies, methods for most types of terrestrial invertebrates are less well developed and far from being standardised.

On a slightly different theme, Clements and Tofts (1992) have developed a Hedgerow Evaluation and Grading System (HEGS) for assessing the conservation value of hedgerows based on plant species diversity and physical features.

Overall, there is a very wide range of methods that could be of value to the Agency in the discharge of its conservation duties. Some, as indicated, could probably be adopted with minimal further development whereas others would require additional R&D and validation. The most comprehensive bibliographic source of these survey and assessment methods is the Institute of Environmental Assessment's (1995) 'Guidelines for baseline Ecological Assessment'. R&D Note 107 (Environmental Advisory Unit, 1993) provides an outline review of nature conservation survey methodologies of potential use to the former NRA.

4.7.6 Habitat based methods - Phase 1 Habitat Survey

Business needs

All aspects of conservation - the primary value of the Phase 1 survey is that it highlights key features and therefore helps to focus more detailed assessments.

Current status

The Phase 1 Habitat Survey, developed by the former Nature Conservancy Council (Nature Conservancy Council, 1990; Joint Nature Conservation Committee, 1993) is the most basic and most widely used of all habitat based survey and assessment methods. The method is designed to generate habitat classification maps (using standard colours and symbols) together with accompanying 'target notes' to provide an inventory and audit of the ecological or wildlife resource of an area. The Phase 1 method is universally utilised and understood by UK conservation bodies and is widely familiar to, but not necessarily undertaken by, Environment Agency staff.

Method summary

a) Sampling

The field survey comprises essentially a walkover survey where all compartments and sub-compartments are classified according to type as defined in the Field Manual and all natural/semi-natural features (hedgerows, streams, outcrops etc.) and significant anthropogenic features are mapped. Features which cannot be mapped, such as observations on species, habitat structure or quality are recorded as target notes.

b) Data analysis

Data analysis consists of the production of colour coded, annotated maps using the colours, shadings and symbols specified in the manual and the writing up of the target notes. A scale of 1:10,000 is generally appropriate for mapping.

c) Quality assurance

Standard protocols have been produced. This document ensures consistent Phase 1 outputs by specifying colour coding and symbols for Phase 1 maps. Basic training in the use of the method and in the identification of the basic habitat (community) types is required.

Future developments

Significant further development of the Phase 1 method is unlikely.

Other comments

The Phase 1 Habitat Survey method could be included within an Agency Biological Methods Manual without further testing and in its current form.

The method is appropriate to rural and urban areas and covers terrestrial habitats, wetlands, coastal fringe and inter-tidal zones. The standard Phase 1 method is not appropriate for sub-tidal habitats which require a different (Phase 1 level) approach, e.g. SEASEARCH (Earll, 1992) which is a visual appraisal method using divers. Sub-tidal habitats are mapped and categorised using the Marine Nature Conservation Review (MNCR) classification (Hiscock, 1990). Inter-tidal and coastal fringe habitats can be mapped and categorised using either standard Phase 1 or MNCR classifications.

4.7.7 Habitat based methods - River Corridor Survey (RCS)

Business needs

The River Corridor Survey (RCS) provides an assessment of conservation value, a map-based inventory of the wildlife resource of river corridors, and ideally, suggestions for habitat improvement. Business need applications therefore include conservation and environmental impact assessment in relation to flood defence, water resources, water quality and any proposals potentially affecting flood plains.

Current status

The RCS is a nationally adopted, basic ecological technique designed to provide a consistent approach for gathering and recording of information. The method, originally developed by the NCC (Nature Conservancy Council, 1984) and further developed by the NRA (National Rivers Authority, 1992) is essentially an extended Phase 1 habitat survey specifically tailored to river channels and their riparian zones.

Method summary

a) Sampling

A detailed field methodology is provided in the RCS manual. The field survey comprises mapping of 500 m river sections, typically at 1:2500 scale. Information is recorded on plant communities and physical features in the Aquatic, Marginal and Bank Zones, together with tree species in the Bank Zone and habitat types and land use in the Adjacent Land Zone. The presence of notable species and critical areas are also recorded, together with representative channel cross-sections.

b) Reporting

The RCS output takes the form of an annotated map employing standard symbols and notations supported by a descriptive summary text, photographs and suggestions for enhancement. The output should convey key information in an easily understood format to practitioners in other disciplines such as flood defence.

c) Quality assurance

Quality assurance requirements are detailed in the RCS manual. The key points are detailed specifications for surveyors; appropriate timing of field work; appropriate training of surveyors to ensure technical competence and regular checking of the quality of RCS outputs.

Future developments

No further development of the RCS is planned.

Other comments

The newer habitat based river corridor methods such as the RHS (Section 4.7.8) and SERCON (Section 4.7.13) serve a somewhat different purpose to the RCS. The continued widespread use of the River Corridor Survey can therefore be expected.

4.7.8 Habitat based methods - River Habitat Survey (RHS)

Business needs

The River Habitat Survey (RHS) (National Rivers Authority, 1996) is a field survey method, which aids the assessment of habitat quality of rivers and streams based on their physical structure. It has been developed in response to the need for a nationally applicable classification of rivers based on their habitat quality. River management by the Agency and other equivalent bodies, in the form of regulation, operational works and advice to planning authorities, can then take full account of the need to protect highly valued sites.

Current status

Although still undergoing further development, the RHS has been adopted as a standard method in England and Wales and is currently being applied as a tool for the assessment of conservation status. It is being extended to Scotland and Ireland. A field methodology guidance manual was produced in 1995 (National Rivers Authority, 1995d)

Method summary

a) Basis of method

The RHS is based on the ability to predict, with statistical probability, those physical features which ought to occur at unmodified sites for the full range of river types in England, Wales and Scotland. A simple classification of habitat quality as excellent, good, fair, poor and bad is derived from the discrepancy between expected and observed features. The RHS provides four distinct but related outputs:

- a standard field survey method;
- a computerised database containing information from a national reference network of UK sites;
- a classification of river types based on the predictive model of physical structure;
- a scheme for assessing habitat quality.

b) Data collection (field survey)

Data collection is based on standard 500 m lengths of river and requires the completion of a four page proforma data sheet. Data requirements comprise two components:

- background information (largely map derived) relating to geology, slope, altitude, flow category etc.;
- field survey data (the observed and measured features of the 500 m stretch).

A wide range of physical attributes is recorded during the field survey, together with information on channel and bank vegetation. Vegetation is classified simply into broad classes (e.g. emergent reeds/sedges/rushes) so that it is vegetation structure rather than species composition that is recorded. However, plant species of note (both rare and nuisance species) and other incidental observations of animals etc. can be included.

c) Data analysis

Data is collected in a format that can be input directly from the RHS form to the computer model, the background data from the form giving the prediction of expected features. The model then compares the field survey data to the predicted features to provide the habitat quality assessment.

d) Quality assurance

Although relatively straightforward to apply, the RHS requires a substantial degree of rigour in the completion of the field survey and the entry of data. Surveyors therefore need to be appropriately trained and accredited in RHS use. Other QA procedures should take the form of spot check resurveys by a second surveyor to compare output results.

Future developments

The prototype reference-site network, which provides the prediction, was based on the Ordnance Survey 10x10 km grid squares. In England and Wales three sites, based on a standard 500 m length of river, per 10 km square were used. This is being extended and an enlarged reference database can be expected to increase the sensitivity of the method and may change the number and nature of the segment types and variants predicted by the model.

Other comments

The RHS is essentially an index of naturalness of a segment of river. There is potential to integrate the RHS into the GQA to provide one component of an 'ecological window'.

4.7.9 Habitat based methods - HABSCORE

HABSCORE is a system for measuring and evaluating stream salmonid habitat features. Although primarily a fisheries tool, the method has wider conservation potential. HABSCORE is an empirical model which predicts the average long-term density of fish that would be expected for the given site (river reach) if there were no impacts such as poor water quality and if recruitment were not limiting. HABSCORE is discussed in more detail in Section 4.5.10.

4.7.10 Habitat based methods developed in the USA - HEP, HES and IFIM

The Habitat Evaluation Procedure (HEP) is a selected species approach. It predicts the carrying capacity of an ecosystem for a particular animal species by using an understanding and inventory of the species' habitat requirements (Pearsall, Durham & Eager, 1986). HEP relies on the development of a habitat suitability index for the evaluated species, the data for this index is drawn empirically, invariably based on the population density in habitats with different features from which habitat preferences are inferred (Usher, 1986).

The Habitat Evaluation System (HES) follows HEP very closely except that habitat quality models are generated for habitat classes instead of for a particular species. HES models have been developed for several wildlife habitat classes in the lower Mississippi region e.g. swamps, bottomland hardwoods, lakes and upland forests. HES models are used to generate habitat quality indices.

The Instream Flow Incremental Methodology (IFIM) and the associated Physical Habitat Simulation Model (PHABSIM) were developed by the United States Wildlife and Fish Service. They take the rationale of carrying capacity being determined by certain physical and chemical conditions and seek to relate it to changes in the hydraulic regime of a stream. The ultimate aim of the IFIM is to determine an ecologically acceptable flow for a species. The method is discussed in detail in Section 4.5.9.

4.7.11 The Natural Areas approach

A potentially useful development by English Nature is the Natural Areas Approach. This has classified England into biogeographic regions called Natural Areas, of which there are 92 terrestrial including freshwater and 24 marine (Gardiner, 1996). They seek to classify areas with similar wildlife and landscape features into a natural rather than administrative units for the purposes of conservation. Core profiles for each area seek to identify the key habitats, species and geological features, their importance within the area and the issues facing them.

Gardiner (1996) showed that some habitat types correlate well with natural areas and this can be used to prioritise and deliver conservation measures in the most appropriate situations. One possible application of the Natural Areas approach by the Agency would be its integration with LEAPs. Natural Areas could be used to describe catchments in more detail in terms of distinctive components, including important habitats, species groups and hydrological regime. This could assist in setting priorities and focusing restoration related to both nature conservation and water resource management.

4.7.12 Countryside Information System (CIS)

The Countryside Information System (CIS) is a habitat-based commercial database developed for use in countryside planning and management. Countryside surveys take place every ten years and the next is to be undertaken in 1998. The CIS provides easy and flexible access to information about the rural environment in the UK. The CIS is a result of the countryside survey 1990, which established a framework of 508 one km squares containing 11,500 fixed quadrats. The survey uses the Institute of Terrestrial Ecology (ITE) land classification to obtain an efficient and representative sample of environmental variation in the UK. CIS is relatively widely used in the UK for the assessment of terrestrial ecosystems for the purposes of management, in terms of development, agriculture and planning.

4.7.13 Holistic methods - System for Evaluating Rivers for Conservation (SERCON)

Business needs

The System for Evaluating Rivers for Conservation (SERCON), which is still under development, has considerable potential as it integrates information on a wide range of attributes and attempts a holistic assessment of river quality.

Agency business needs potentially addressed by SERCON therefore include:

- conservation (both conservation value assessment and the identification of opportunities and priorities for river and riparian rehabilitation and enhancement);
- Environmental Impact Assessment (of any proposal affecting a river or its flood plain).

Current status

SERCON is still under development, primarily by Scottish National Heritage (SNH), but it is intended for use in the whole of Great Britain. It is being adopted by the Scottish Environmental Protection Agency (SEPA) and its use by the Environment Agency is under consideration.

Method summary

a) Basis of method

SERCON is essentially a combination and integration of methods for evaluating different aspects of the conservation quality or value of rivers. The method is described in detail by Boon *et al.* (1997). SERCON is designed for use at the catchment or subcatchment scale and rivers are evaluated as a series of contiguous stretches termed Evaluated Catchment Sections (ECSs), typically of 10-20 km length. The principal focus of SERCON is on the physical, chemical and biological features of river channels and banks, riparian zones and associated floodplains. The evaluation uses a slightly modified subset of the standard conservation criteria (Ratcliffe, 1977). In all, 35 attributes are grouped to contribute to the overall assessment of six criteria: Physical Diversity, Naturalness, Representativeness, Rarity, Species Richness and Special features.

b) Data requirements and collection

The data requirements of SERCON are substantial and data must be collected from a variety of sources. Data relating to water quality, invertebrates and fish are likely to be available from existing Agency (or SEPA) monitoring programmes. Other biological data is likely to be obtainable from other conservation organisations and some of the physical data can be map derived. Attributes within the criterion of Physical Diversity, as well as some in Naturalness, Representativeness and Special Features require field survey. The River Habitat Survey (RHS) (Section 4.7.8 above), which works alongside SERCON, effectively provides the field survey input.

c) Data analysis

Each of the 35 attributes (or impacts) is scored, then weighted and combined to produce a composite index for each of the six conservation criteria. The scores and indices are then fitted into the SERCON classification (A-E) of conservation quality. SERCON can be used either in conjunction with a printed manual, or as a PC version running in Microsoft Windows. The PC version incorporates an extensive photo gallery as part of an on-screen help facility, and can provide a range of output reports, including both text and graphics.

d) Quality assurance

Quality assurance should present the Agency with relatively few difficulties. The Agency's own routine monitoring data is, for the most part, already quality assured and survey methods contributing to SERCON, such as the RHS, will have their own QA procedures. The primary focus for quality assurance will therefore be training in the use of the SERCON methodology and regular monitoring of the quality of SERCON outputs.

Future developments

SERCON is still relatively untested and the first priority for its future development is to ensure that the system operates efficiently and produces results that are reliable and repeatable. Further development and testing is taking place under the auspices of SNH. This includes assessing compatibility with the Agency's RHS methodology. The testing of SERCON is also included within the Environment Agency's planned R&D programme (e.g. Project Proposal Reference: WIA(97)9, 'Conservation evaluating using SERCON - Phase 2').

Other comments

SERCON potentially provides a broad based assessment of river quality rather than one based solely on water quality or physical feature. The need for this kind of assessment has been highlighted by the anticipated EC Water Framework Directive, with its emphasis on ecological quality and ecological targets. The elements considered to contribute to ecological quality, the monitoring of which will be necessary to fulfil the demands of the Directive, correlate well with those used by SERCON.

SERCON is clearly a robust approach, in that it integrates measurements of a very wide range of physical and biological attributes. However, the views expressed by some Regional biologists and conservation officers suggest that SERCON may not be particularly popular, primarily because it is perceived to be overly complex and demanding in terms of data input requirements.

4.7.14 Indices of ecological integrity

Methods for measuring ecological integrity have been developed in the United States, the first such method being the Index of Biotic Integrity (IBI) (Karr, 1981), but they have received little attention in Europe to date. However, there is now an increasing focus on 'ecosystem health', driven in part by the potential requirements for ecological targets in the forthcoming Water Framework Directive. This type of approach may become more important in England and Wales in the future. Possible needs for, and applications of, methods such as indices of ecological integrity are discussed in more detail in the chapter on Business Needs (Section 3.9.2).

4.7.15 Summary and conclusions

Despite the relatively high profile of wildlife conservation within the overall remit of the Agency, it is not currently well provided with standard methods for assessing conservation value, for conservation oriented management and monitoring or for defining ecological requirements for integration into such activities as water resource and flood defence management. Methods developed for other biological purposes are, of course, of greater or lesser value to conservation management. However, it remains the case that a major part of conservation input is based on professional opinion, rather than on the use of standard methods backed by rigorous quality assurance procedures. This may render conservation staff vulnerable to criticism or challenge in potentially confrontational situations such as public inquiries.

One area where ecologically significant information is most notably inadequate is that of soil flora, fauna and fungi. There is also a paucity of methods for assessing conservation value in marine and estuarine environments. The availability of monitoring methods and survey data for subtidal habitats falls far short of that for inland waters, wetlands and terrestrial habitats. The imminent designation of a substantial number of marine SACs and the monitoring requirements that this will impose (including upon the Agency) indicates that the development of methods in this field is a high priority (refer to Section 4.6.6).

Very few methods specifically directed at conservation issues have been developed or validated by the Agency itself, or adopted by the Agency as standard methods. The River Habitat Survey (RHS) and River Corridor Survey (RCS) are the notable exceptions which have been developed as national standard methods. The Community Conservation Index (CCI) for assessing the conservation value of aquatic invertebrate assemblages is a simple method developed in Anglian Region that has potential for national adoption and fulfils an Agency requirement. A 'conservation capability' is also planned for RIVPACS. Several other Agency developed methods, e.g. the UWWTD method, are likely to have conservation applications.

A variety of other UK conservation organisations, however, have developed methods to meet their own conservation needs. Some of these methods, such as the Phase 1 Habitat Survey and the NVC protocols developed by English Nature, or some of the bird census methods developed by BTO, are robust, extensively tested and widely recognised. Where these fulfil a perceived Agency need, they could be adopted as standard Agency methods with little or no additional R&D. Some of the other potentially useful methods may need substantial development and/or validation before adoption.

A particularly valuable and relatively rapid R&D exercise would be a more detailed review of the Agency's current and future conservation needs and priorities, coupled with a detailed appraisal of the robustness and applicability of methods developed and used by UK conservation organisations. This exercise would set priorities for action and identify methods either for immediate adoption or those which could be adopted in the short-term with minimal further development. This could lead to rapid progress over a short period of time.

The potential applications of habitat based methods and models such as PHABSIM are substantial. One of their major attractions is that they provide quantitative biological information (or at least express biological requirements) in the language of environmental engineers and resource planners. Methods of this type clearly merit a significant R&D investment to determine their robustness, limitations and applicability.

Holistic methods such as SERCON are potentially powerful tools with wide applicability, because they integrate a wide range of physicochemical and biological attributes. However, the correspondingly more onerous data requirements may be seen as a disadvantage. Simpler methods for assessing ecological integrity, such as a development of the multimetric Index of Biotic Integrity proposed by Karr (1981) may provide a more practical approach to meeting the requirements of the forthcoming Water Framework Directive.

4.8 Whole Sample Ecotoxicity Testing (DTA)

4.8.1 Introduction

The Agency structure which deals with ecotoxicity and hazardous substances issues is currently undergoing a period of significant change and development, as the National Centre for Direct Toxicity Assessment and National Centre for Toxic and Persistent Substances are being merged, along with the Chemical Assessment Unit of the Department of Environment, to form a National Centre for Ecotoxicology and Hazardous Substances. This centre will have five sections dealing with pesticides, chemical specific issues, nutrients, whole sample (DTA) issues and new chemical notifications.

Whole sample (DTA) ecotoxicity testing is still a relatively new tool for the Agency and has received limited and variable attention in the Regions, although the use of chemical specific ecotoxicological data from testing performed outside of the Agency has been used for a long time. However, it is potentially a very useful tool and the formation of the new National Centre provides an ideal opportunity for the development and implementation of an effective national strategy.

4.8.2 Business needs

Water quality

Whole sample (DTA) ecotoxicity testing can be used to indicate the possible effects of effluents on receiving waters and there is great potential for the establishment of toxicity based effluent control standards. These may be more successful at indicating the environmental impacts of effluents than traditional consents based on chemical parameters. Toxicity testing can also provide information regarding the potential impacts of mixtures of effluents and complex discharges. This area is being developed at present (Environment Agency, 1996j; 1996k; 1997e).

Urban run-off is an important factor in the determination of river water quality in some areas (e.g. the River Tame) and toxicity testing could be used to address this issue.

Whole sample (DTA) ecotoxicity has a potential role in groundwater monitoring.

Waste Regulation

Whole sample (DTA) ecotoxicity could potentially fulfil other business needs of the Agency such as landfill leachate monitoring. These methods may also have a role in the assessment of contaminated land and in special waste classification and hazard assessment.

4.8.3 Current status

Extensive research has produced a draft manual for direct toxicity assessment (Water Research Centre, 1996). A wide range of methods were reviewed and evaluated with respect to 17 selection criteria. Ten species were selected for inclusion in the draft manual. Three freshwater methods, three marine methods and four rapid tests were included in the draft manual. A relatively low number of tests were chosen to ensure consistency of approach and good data quality. Many of these methods are new to the Agency for whole sample testing and have not been tested in operational conditions. The DTA method guidelines are currently undergoing major revision.

Throughout the Agency there are approximately 12 microtox kits and in the past there have been both laboratory and field based toxicity tests carried out by Regional staff.

4.8.4 Quality Assurance (QA)

The National Centre for Ecotoxicology and Hazardous Substances is developing methods for whole sample ecotoxicological testing along with quality control schemes to ensure the quality of data generated. Eventually, much of the testing will be performed by commercial testing laboratories as part of self-monitoring procedures. The National Centre will ensure that testing is only performed by laboratories known to be capable of producing quality information. A laboratory approval (accreditation) scheme is proposed (Environment Agency, 1996l) in association with a register of approved laboratories (Environment Agency, 1997f). Quality assurance is an important area which needs to be addressed, including relevant training and sample collection.

4.8.5 Future developments

The new National Centre aims to introduce a nationally consistent approach to whole sample (DTA) testing. It will be responsible for relevant policy, training, research and for the accreditation of commercial ecotoxicity test laboratories performing regulatory work. Agency staff at the Regional and Area levels will require advice on how ecotoxicity tests may be applied to water quality issues in their Region or Area, subsequent interpretation of data and the use and management of contractors. A Regional and Area representative may be useful in this context.

In addition to general ecotoxicological measurement, the National Centre for Ecotoxicology and Hazardous Substances will be developing and/or validating laboratory based tests designed to measure specific biological effects. These often include more long-term effects such as neurotoxicity, tetratogenicity, sex-hormone disruption, carcinogenicity, mutagenicity and immunotoxicity. These methods could be used for improving hazard assessments of single chemicals, radionuclides and complex mixtures and for waste classification.

4.9 Other methods of potential use to the Environment Agency

4.9.1 Introduction

On 1 April 1996 the Environment Agency took over the responsibilities of the National Rivers Authority (NRA), Her Majesty's Inspectorate of Pollution (HMIP) and the waste regulatory functions of local authorities. The consultation process for the current project revealed a somewhat grey area in terms of the role of biological methods with respect to the latter two functions.

At present, the Environment Agency does not undertake biomonitoring of air pollution. In the UK the only air quality monitoring is from the emission itself which is usually the responsibility of the company, and normally undertaken by local authorities primarily in relation to urban air quality. In general, IPC staff do not undertake any off-site monitoring. Biological methods are available with respect to aerial emission monitoring and larger scale monitoring. In the future the Environment Agency may be required to use these methods directly or require the information for auditing purposes.

Plants are the most widely recognised group for air quality biomonitoring. Literature in this field is very extensive and there is a suite of methods available. A variety of plant species/communities have been proposed as biomonitors/bioindicators of air contamination. Furthermore, specific plant species or communities are commonly used to assess the impact of air pollution on vegetation and forest ecosystems. Most air pollution monitoring using plants is practised with bryophytes or lichens.

Biological methods with regard to contaminated land assessment and monitoring are not presently used by the Agency. However, contaminated land assessment is a big area for development within the Agency and it is generally believed that biology will play a higher profile in the future. Both plants and animals have been proposed in contaminated land assessment.

Biomonitoring of radioactivity is not carried out by the Agency but the need for specialised research in this area has been recognised.

The Agency may not have a direct role in biomonitoring of air and radioactivity levels and contaminated land but it may have a future auditing role. A brief synopsis of biological methods used in air quality, contaminated land and radioactivity assessment is presented below.

The potential role of biomarkers as a useful tool in pollution control, conservation and ecological integrity has been recognised by the Agency. Biomarkers are discussed in Section 4.9.9.

4.9.2 Air quality assessments using bryophytes

Business needs

Section 3.4 addresses in detail the potential biological needs of IPC. Biomonitoring of air pollution may be useful in relation to the following:

- in maximising the benefits of integrated pollution control;
- in preventing or minimising, remedying or mitigating the effects of the pollution of the environment;
- in State of the Environment reporting;
- in Environmental Impact Assessment.

Current status

Bryophytes are more commonly used as elemental bioaccumulators rather than bioindicators in the assessment of air contamination. In particular they have the ability to indicate the presence of heavy metals and their concentration gradients. The use of bryophytes constitutes an effective method in air pollution monitoring for many reasons.

- Many species are widely distributed and grow in a range of habitats.
- Bryophytes are small and easy to handle.

- Most species are evergreen and can be surveyed all year round.
- Bryophytes lack a cuticle and a root system and obtain nutrients as particulates and in solution directly from atmospheric deposition. They have good bioaccumulating ability, particularly for heavy metals, where metal concentrations reflect deposition without the complication of additional uptake via a root system.
- Comparisons of fresh samples with herbarium specimens enable retrospective analysis of metal pollution.
- The ability of bryophytes to accumulate elements in very high concentrations aids chemical analysis of the tissues and may facilitate the detection of elements present in very low concentrations in the environment.
- The annual growth increment is relatively easy to detect in mosses which makes them desirable for temporal studies (this is particularly true of *Hylocomium splendens*).

Air quality biomonitoring using bryophytes is not practised by the Environment Agency. However, these plants, particularly mosses, have been used in numerous studies of air pollution in the UK and Europe. Published literature in this area is extensive. Moss techniques using indigenous moss populations to identify and monitor geographical patterns in heavy metal atmospheric pollution are well established in Europe. The United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (1993) produced a manual for integrated monitoring, programme phase 1993-1996, the overall purpose of which is in monitoring and assessing the effects from air pollutants in the environment. Numerous countries are involved in the programme but Sweden was appointed lead country and Finland took responsibility for data handling. Nordic countries in particular play a high profile within the framework, particularly in the development of methods. Monitoring metal chemistry of mosses is included in the programme, and techniques are applied as a practical tool in establishing and characterising heavy metal deposition sources. Detailed standard sampling and analytical procedures are prescribed in the manual.

A booklet has been published by the Nordic countries regarding monitoring of heavy metal deposition in Europe using the moss technique (Ruhling, 1994). Similar methodologies to those detailed by UNECE (1993) are prescribed.

Such long-term, larger scale monitoring is extremely useful and also enables transboundary ameliorative action to be taken.

Method summaries

a) Sampling

The design of a sampling strategy should consider factors such as finance and resources, desired accuracy of results, study time-scales, size of study area, extent and type of pollution.

Sampling can involve indigenous species or transplanted species. This will ultimately affect the type of species selected and to some extent the chemical analysis techniques deployed. In metal deposition biomonitoring, species selection criteria include the availability of the species, its tolerance, its bioaccumulation characteristics and ease of sampling (Wolterbeek and Bode, 1995). Additionally, the species utilised and its effectiveness will depend to an extent on the elements to be monitored.

The density and location of sampling sites will depend very much on the type of survey. Larger scale surveys covering larger areas will obviously require more sites than studies investigating point emission sources. In the latter, sites are frequently spaced along transects or gradients in relation to the pollution source. The number of sampling sites should be adequate to detect gradual changes across the study area. If indigenous species are to be utilised, the number and location of sites will depend on the natural distribution of the species. If transplantation techniques are used, choice of sites is at the discretion of the investigator.

In bioaccumulation monitoring studies, the standardisation of sample collection is recommended (Puckett, 1988). This could include the general area of collection (e.g. forest), the specific area of collection (e.g. position on tree) and the quality and quantity of sample.

b) Chemical analysis

Standardisation of sample preparation and analytical techniques is important (Puckett, 1988). Sample preparation varies, for example, in washing and drying procedures. Differences also exist in the analytical technique adopted.

Results are more appropriate when background elemental levels in the plants are also measured (Seaward, 1995). Generally, a large number of elements are chosen for analysis because the benefits of obtaining large amounts of data outweigh the extra effort, especially when the extent of fieldwork is independent of the number of elements chosen for analysis (Wolterbeek and Bode, 1995).

Contamination during collection should be avoided. Replication of samples is recommended for accurate results. Consistency of measurement units aids comparative studies.

The choice of analytical method will depend on the purpose of survey. Some analytical methods are non-destructive (e.g. neutron activation) and are useful for repetitive surveys such as baseline studies. Samples can also be archived and used at a later date for additional analysis. Destructive techniques include atomic absorption spectrometry and inductively coupled plasma analysis.

c) Data analysis

Univariate and multivariate data analysis techniques have been used in moss surveys of heavy metal contamination. Other sources of heavy metals besides atmospheric deposition can contribute to metal concentrations in moss samples (Steinnes *et al.*, 1992). Ideally an accurate interpretation of results from large scale moss surveys should include an assessment of the contribution from other sources. This can be undertaken using multivariate analyses techniques such as factor analysis (e.g. Sloof and Wolterbeek, 1991).

d) Quality assurance

QA procedures are rarely discussed in the literature. Standard national and international (e.g. UNECE, 1993) protocols ensure that a consistent approach is taken during surveys. National and international standards exist for laboratory techniques. Replicate sampling is often recommended. Training of surveyors is important particularly when most methods involve identification of species. Resurveying and audit procedures should be considered in QA procedures. Levels of quality control could be applied to statistical data.

Future developments

Many methods and extensive expertise exist for bryophyte monitoring of air pollution among academics and research groups throughout Europe. The development and adoption of standard methods by the Agency would therefore not be too laborious. Validation of procedures would need to be undertaken and formalised quality assurance procedures would also need to be developed.

4.9.3 Air quality assessments using lichens

Business needs

Business needs mentioned in Section 4.9.2 apply.

Current status

Lichens are the most widely recognised plant group for air quality monitoring. The role of lichens in standardised multi-national and national monitoring programmes is primarily in the bioindication of gaseous air pollutants. Lichen communities growing on tree bark (corticolous species) and walls and rocks (saxicolous species) show changes in response to air pollutants, sulphur dioxide (SO_2), fluoride (F), nitrogen (N) deposition and ozone (O_3).

Standard methods for epiphytic lichen monitoring is prescribed in the UNECE International Co-operative Programme on Integrated Monitoring under the Convention on Long-range Transboundary Air pollution (UNECE, 1993). Site selection, sampling methodologies for lichen cover and lichen thallus vitality and Pollution Sensitivity Index (PSI) calculation are considered in the protocols.

Northumbria Area, North East Region appear to be the only Area of the Environment Agency which have attempted any proactive action on the issue of biomonitoring of air quality. A literature survey was commissioned and a staff member undertook a relevant course. It was concluded that there was enormous potential for lichens to be used in air pollution monitoring. Despite the inherent difficulty in monitoring a targeted atmospheric output in urban/industrial areas, lichens do have a role as general ecological health indicators. However, as yet no methods have been deployed in the Northumbria Area.

Burton (1986) found that the use of lichens in gaseous pollutant monitoring was based mainly on species distribution observations and to a lesser extent on chemical analyses and lichen transplants. Recent developments show an increased emphasis on the use of biochemical and physiological responses as indicators of air pollution, probably due to technological advancement.

Method summaries

a) Mapping

Most species distribution investigations involve mapping. Distribution mapping of common and sensitive lichen species is a relatively simple and inexpensive method of air quality monitoring. The method distinguishes areas with varying degrees of pollution. Studies can be in relation to point emission sources such as power plants and smelters, a general source area such as an urban area or industrial complex, or as a means of producing baseline data for a previously unsurveyed site, and in pre-development appraisals (Showman, 1988). Species distribution monitoring can investigate spatial or temporal patterns. However, the method is more useful with prior knowledge of lichen sensitivity to air pollutants and historical and/or natural or control data of the study area.

A practical progression of species distribution maps was the development of zone mapping. Zone maps classify areas using the number and type of lichen species present, which indicate the extent and/or distance from the pollution source. Burton (1986) reviewed the earliest zone mapping studies. Hawksworth and Roses' (1970) qualitative scale relating mean winter SO_2 ($\mu g/m^3$) with certain epiphytic lichen assemblages on acidic and basic tree bark remains the key paper on zonal mapping and is cited and utilised extensively in the literature. Ten zones were devised, with Zone 1 species indicating SO_2 levels >170 $\mu g/m^3$ and Zone 10 representing 'purity'. Although the scale has proved effective in monitoring the spread and extent of SO_2, doubts have been cast on its application in areas encountering reduced levels or qualitative changes in air quality (Richardson, 1988).

b) Response methods

Additional information in lichen monitoring studies can be gained from observing morphological changes and the health status of lichens. Quantifiable physiological changes can be examined as a measure of pollution stress. The advancement of laboratory techniques has aided the development of such procedures.

The following physiological parameters have been proposed as bioindicators in air quality monitoring (Alebic-Juretic and Arko-Pijevac, 1989; Silberstein *et al.*, 1990; von Arb and Brunold, 1990; Silberstein *et al.*, 1996):

- the extent of cell membrane damage;
- red autofluorescence in photobiont cells indicate healthy cells;
- Chlorophyll degradation represented by the ratio of optical density at 435 and 415 nm (OD 435/415) in pigment extracted with dimethyl sulphoxide;
- photosynthetic rate;
- ATP content.

c) Transplant methods

Transplantation exercises are frequently used to demonstrate or assess effects of gaseous air pollution on lichens transplanted from a clean to a polluted environment (Levin and Pignata, 1995; Gonzalez *et al.*, 1996).

d) Sampling

Various sampling methods are available in lichen monitoring, depending on the nature of the method deployed (a to c above) and desired output. Some sampling methodologies used to measure lichen presence and abundance include estimation of lichen cover, lichen frequency, lichen diversity and species density.

e) Data analysis

Calculations of Indices of Atmospheric Purity (IAP) examine the effects of a pollutant source on lichen communities. IAP was devised by Leblanc and DeSloover (1970) but modifications of the formula have been designed (Ammann *et al.* 1987; Herzig and Urech, 1991; Loppi and Corsini, 1995; Loppi *et al.*, 1996). It is a quantitative phytosociological approach requiring the collection of data such as frequency and/or percentage cover and a factor of tolerance to toxicity. IAP values generally increase as communities become more complex, further from the pollution source. These values can also be plotted on a map, which in turn can be used to determine IAP zones. This method is applied on a smaller scale, generally in urban and industrial surveys, but some regional applications have been used.

Sweden is particularly experienced in the use of lichens in air pollution monitoring. Long term monitoring within the Swedish National Environmental Monitoring Programme (PMK) is undertaken in much the same way as the UNECE collaborative studies. Poor correlations between lichen occurrence and measured pollutants in an area imply that other factors may be responsible for lichen trends. In this way the importance of air pollution in an area in relation to other environmental factors can be assessed. An array of statistical approaches has been implemented to assess such situations. Brakenhielm (1996) and Brakenhielm and Qinghong, (1995) reported on PMK results and applied First Principal Component Analysis (PCA) and partial Redundancy Analysis (RDA) to the data. Weighted Mean Sensitivity (WMS) was used as the most effective index of air quality.

f) Quality assurance

The comments mentioned in Section 4.9.2 apply to lichen biomonitoring of air quality.

Future developments

Increasingly, species distribution studies are concerned with mapping re-colonisation in areas. This is in response to a decline in SO_2 levels since the 1970s and increases in other pollutants such as nitrogen oxides (NO_x) and ammonia (NH_3). For example, in 1988/89, van Dobben and de Bakker (1996) updated previous surveys of epiphytic lichens in The Netherlands.

Lichen biomonitoring of air quality is a useful, relatively inexpensive technique supported by a wealth of international expertise. The value of lichen monitoring to the Agency with respect to its IPC function should therefore be assessed.

4.9.4 Air quality assessments using fungi

Business needs

Business needs from Section 4.9.2 apply.

Current status

Published literature regarding fungi in air contamination monitoring is limited in comparison to lichens and bryophytes and techniques are not as widely recognised. However, a promising and relatively simple method is described below.

Method summaries

Dowding (1994) described a method of using leaf yeast, *Sporobolomyces roseus*, in the assessment of air quality. Leaf yeasts are found on a wide variety of leaves in temperate regions and actively discharge spores at night. They are highly sensitive to SO_2, can provide a current assessment of air pollution and results can be obtained within one week. Furthermore, sampling work in Hamburg established quantitative relationships between leaf yeast numbers and SO_2 levels, where a regression line was derived between the natural logarithm of counts and mean SO_2 concentration for the previous four days. Yeasts responded to SO_2 levels in the range 0-100 μgm^{-3} (Dowding & Richardson, 1990).

The disadvantages of the leaf yeast method are its reliance on weather and seasonal conditions. Leaf yeast growth is restricted to the time of year when deciduous trees are in leaf and show variations with time of year, which will vary with location and country. Sporulation is enhanced in wet conditions so that weather conditions on the days immediately prior to collection affect numbers significantly.

Future developments

It is unlikely that fungi will be adopted by the Agency for air pollution assessment in light of the numerous other biological techniques available. However, the foregoing method may be useful for educational purposes since it has been carried out by schoolchildren successfully in the past.

Changes in diversity and abundance of soil and tree fungi have been measured in forests suspected of suffering from air pollution stress.

4.9.5 Air quality assessments using algae

Business needs

As before (Section 4.9.2).

Current status

The use of algae in air pollution monitoring is gaining in importance in response to increasing nitrogen deposition over recent decades. Green algae respond positively to increased nitrogen deposition (Bates *et al.,* 1996). Algae have been included in epiphyte recolonisation studies (Bates *et al.,* 1996), where *Desmococcus viridis* decline was postulated to be a consequence of decreasing SO_2 levels in London, UK.

The use of epiphytic algae as bioindicators of air quality has been hindered by the lack of a non-destructive, non-laborious sampling method. Hanninen *et al.* (1993) proposed a reliable, replicable method, which overcomes these obstacles and allows time series analysis. This method was based on photography, with digital image processing used to estimate the chlorophyll density of the algal layer. Detailed methodology along with calibration and testing aspects is available in the paper.

Since 1986, aerial green algal monitoring has been carried out annually in about twenty reference sites as part of the National Swedish Environmental Monitoring Programme (PMK). The abundance and colonisation of mainly *Pleurococcus vulgaris* (*Protococcus viridis*) growing on needles of Norway Spruce (*Picea abies*) were related to atmospheric deposition. Detailed methodologies are given in Brakenhielm (1996) and Brakenhielm and Qinghong (1995).

UNECE (1993) prescribed sampling methods for aerial green algae in their manual for Integrated Monitoring Programme Phase 1993-1996. The method basis is similar to the Swedish format but the following modifications/additions are provided: precise details on tree selection; a four point scale is used in assessing algal thickness; numbers of annual shoots which have more than 50% and 5% needles left are observed; and recommended sampling time is July-September.

Future developments

Standard methods exist for algal monitoring. These would require validation if they were to be adopted by the Agency.

4.9.6 Air quality assessments using higher plants

Business needs

Business needs outlined in Section 4.9.2 apply. In addition, more international initiatives with regard to air pollution effects on forests and crops may be implemented in the future. The Environment Agency in its new integrated role may play a part in such initiatives.

Current status

Higher plants have been used in air quality monitoring but to a lesser degree than lichens and bryophytes. Higher plants have appeal as indicators in air pollution monitoring in highly polluted areas where lichens and mosses are often absent. Higher plants act as biomonitors in the assessment of aerial heavy metal contamination by means of their bioaccumulative properties. However, bioaccumulation monitoring is complicated because higher plants not only intercept pollutants from atmospheric deposition but also accumulate metals from the soil. Plants also demonstrate morphological and physiological responses to heavy metal pollution, some of which can be utilised in biomonitoring. Examples of air pollution and higher plants investigations are presented below.

Method summaries

Most work with regard to plants and gaseous pollutants is in relation to the effects of air pollution, particularly ozone, on crops. The National Crop Loss Assessment Network (NCLAN) was established in the 1980s in the USA. The responses of the most important agricultural crops to ozone were investigated using open top fumigation chambers. Similar experiments in Europe followed. Since 1990 the United Nations Economic Commission for Europe (UNECE) (Benton *et al.*, 1995) has co-ordinated an experimental programme to compare ozone responses to crops by comparing ethylene diurea (EDU) treated crops with untreated plants. EDU protects the plants against elevated ozone concentrations.

Certain plant species are highly sensitive to particular air pollutants and show specific responses to pollution effects. These indicator species can be used to detect, recognise and monitor the presence or absence of pollutants. Visible injury to leaves is the most obvious indicator of air pollution damage. For example, ozone creates speckled brown spots which appear on the flat areas of leaf between the veins (interveinal necrosis), and hydrogen fluoride produces brown necrosis at the tip or edge of the leaf. A manual has been produced which provides guidance on the identification of air pollution injury to vegetation (Taylor *et al.*, 1990). This comprehensive document also includes deciduous and coniferous trees.

Tobacco plants (variety Bel-W3, Bel-C and Bel-B) are common bioindicators of ozone injury (Heggestad, 1991; Gimeno *et al.*, 1995). Measurements of phytotoxicity are used to determine if ozone levels are above critical concentrations for plant damage. Leaf Injury Indices (Mignanego, 1992) and Air Pollution Tolerance indices (Agrawal *et al.*, 1991) are frequently calculated. Leaf tip necrosis on gladioli is a common bioindication technique in hydrogen fluoride assessment.

The assessment of forest damage by air pollution is included in the UNECE integrated monitoring programme (UNECE, 1993). Foliage vitality is measured annually by assessing defoliation and discolouration. Standard sampling techniques are prescribed in the manual. A recent synopsis of tree health in the UK has been published as a consequence of national surveying encompassing a range of measurement parameters (Department of the Environment, 1993).

Future developments

The critical loads concept designed for the protection of crops, forests and habitats from air pollution effects is gaining profile in the UK and Europe (Bull, 1991; Benton *et al.*, 1995; Brown *et al.*, 1995; Sanders *et al.*, 1995; de Leeuw and van Zantvoort, 1997). This has mainly been the focus of conservation agencies such as English Nature or specialised research groups. The Agency may have a future role in this area.

4.9.7 Contaminated land methods

Business needs

Business needs of the Environment Agency in relation to contaminated land are detailed in Sections 3.2 and 3.3. In summary there is a future for biological monitoring by the Agency directly or in its capacity as an auditor in the following areas:

- land remediation;
- landfill restoration;

- to fulfil future needs in relation to gas and leachate monitoring from waste sites and contaminated land;
- with respect to exemptions of waste management licensing.

Current status

Within the Environment Agency, IPC and waste regulation staff do not use biological methods. Environment Agency staff feel that there is a shortage of biological tools available in the assessment of contaminated land/soils. There is minimal biological focus within the Environment Agency current R&D programme in relation to waste regulation and IPC. In many cases, knowledge is sufficiently advanced to develop biological assessments, but the problem is a lack of reliable, comprehensive data. In addition, deteriorated soils are patchy and localised thereby making conclusions very difficult. Monitoring of soil/contaminated land would be site-specific and would vary depending on the level of remediation required.

Agency staff are confident that some methodologies could be applied - e.g. SOILPACS (ITE) or the use of grasses/macrophytes as indicators of contamination. North East Region have used photographic surveillance to audit herbicide use as a means of checking that users are spraying where they claim to be.

Method summaries

In Norway, contaminated land clean-up action plans have been developed which consider three different ambition levels for principal clean-up goals (Antonsen and Folkestad, 1993). Goals for groundwater quality, soil quality, watercourses and fjords were established. Most Norwegian research in this area relates to biological treatment methods. However, since a large proportion of the sites lie along the coast or on watercourses, Norwegian authorities are generally more concerned about leachate and emissions than actual soil quality. However, Norway is currently developing criteria for the assessment of soil pollution. For example, the setting of threshold values such as the No Observed Effect Concentration (NOEC) for organisms in the soil is under consideration. However, due to insufficient data for most substances this would prove difficult. Alternatively, LC_{50} values could be used.

A variety of bioindicators has been postulated in the assessment of soil use and pollution. Paoletti *et al.* (1991) proposed invertebrates as bioindicators of soil use. This work was based on observations in the aquatic environment. Similarly soil communities respond to chemical residues and other environmental stresses in many different ways.

Determination of methyl-mercury and mercury content in deer tissue and browsed foliage were used in Slovenia to evaluate environmental pollution of the mercury mining regions (Gnamus *et al.*, 1995). Total mercury contents of the tissues of deer inhabiting the vicinity of the mine were nearly 100 times higher than those of the control sites.

Shtina and Dorochova (1994) demonstrated the potential of soil algae in the bioindication of soil pollution. The advantages of soil algae as bioindicators include ease of identification; their quick response to changing soil conditions; the cheapness and simplicity of algal cultivation and a similar reaction to soil conditions to that of higher plants. Monitoring involves studying natural algal communities and observing species or groups which are characteristic of soil peculiarities. Pollution can be assessed by measuring changes in the quantity of algae, the rate of reproduction or disappearance, chlorophyll content, the intensity of photosynthesis or elemental accumulation by algae. Indices of species diversity, autotrophy or scale of saprobicity and trophic level can be calculated. The analysis of microcosms could be applied.

Gregson *et al.* (1994) discussed the role of plants as bioindicators in preliminary contaminated land assessment. The visual appearance of plants, in combination with the presence of particular key species or assemblages may provide clues to the existence and type of contamination at a site. The authors suggested that the presence of mature trees at a site indicate that the site may have been disused for a relatively long period of time, implying that any contamination present is likely to be historical rather than of recent origin. The occurrence of young saplings growing alongside mature trees may indicate the existence of a balanced ecosystem. An obvious indication of the presence of landfill gas is the presence of shallow rooting and leaf loss in trees. Shallow rooting systems may also suggest contamination at depth. The presence of bare patches in an otherwise well-vegetated area is a common indication of a potentially contaminated site. Although many factors can cause this effect, the additional presence of deposits on the soil surface, staining and odours generally imply contamination rather than say, soil infertility. Metals exhibit toxic effects on plants such as inhibited root growth, depressed shoot and leaf growth and chlorosis of younger leaves.

Table 4.1 shows some examples of plant indicator species which may provide guidance to the particular type of contaminant present at a site.

Future developments

Development of an improved critical load methodology for toxic metals in soils is proposed for Environment Agency R&D, the overall aim of which is to produce a national diagnostic GIS tool for use in the UK (Project Proposal Reference: P4D(97)1, 'Development of critical load methodologies for toxic metals in soils and surface waters'). Other future R&D projects include the 'Development of microbiological test methods for contaminated soils' (Project Proposal Reference: P5C(98)2) and 'Development of ecotoxicological test methods' (Project Proposal Reference: P5C(97)3). The former will review the effectiveness of microbiological test methods for contaminated soils and develop further tests to assist in the risk assessment of contaminated sites. The development of ecotoxicological test methods is aimed at monitoring the toxicological effect of contaminated soils on ecosystems in order to assess risk from contaminated soils more closely.

Table 4.1 Examples of indicator species in contaminated land assessment (from Gregson *et al.*, 1994)

Species	Common name	Waste or contaminant
Armeria maritima	Thrift	Cu (inland sites)
Silne vulgaris	Bladder campion	Zn (inland sites)
Agrostis tenuis	Common bent	Cu, Zn, Cd, Pb
Minuartia verna	Vernal sandwort	Cu, Pb, Ag, Zn
Festuca ovina	Sheep's fescue	Zn, Pb, Cd
Viola lutea	Mountain pansy	Zn, Pb
Attriplex spp.	Orache	Salinity e.g. power station ash

There is also a project running in Thames Region in conjunction with the Institute of Terrestrial Ecology called 'Biological stress indicators of contaminated land'. This is looking to develop a suite of biomarkers for the investigation of contaminated land and correlating the exposure of earthworms to bioavailable pollutants to allow conclusions to be drawn as to ecosystem health. The output from this work will be extremely useful to biological method development in this field.

Scottish Natural Heritage (SNH) is currently in the process of developing a comprehensive programme for the requirements of soil monitoring and this will include biological aspects. The current trend is likely to be increasing standardisation of soil monitoring across Europe and the development of biological methods will have to take account of this.

4.9.8 Radioactivity methods

Business needs

The Agency issues authorisations for the accumulation or disposal of radioactive waste. Therefore a potential area of method development to meet this business need could be in relation to the effects, sensitivity and tolerances of organisms to radioactive substances.

Current status

In the UK the National Radiological Protection Board (NRPB) believe that biological assessment methods are not appropriate because radioactivity is present at such low levels.

Monitoring of the effects of radioactive substances is done by a separate branch of the Environment Agency who issue annual reports.

Method summaries

The RPII (the Irish equivalent of NRPB) have looked into potential biological indicators of radioactivity in the past. The use of pollen and sheep faeces has been proposed.

In northeastern Italy samples of moss carpets growing in forest vegetation have been used to map radioactive fallout (Giovani *et al.*, 1994), where the best bioindicator proved to be *Ctenidium molluscum*.

Future developments

Two Environment Agency R&D topics in the field of environmental radioactivity have been proposed for the near future. One aspect is a review of current understanding of the environmental impact of radioactive discharges on non-human species to provide a basis for possible laboratory and field studies on relevant species and habitats (Project Proposal Reference: P3C(97)1, 'Review of environmental impact of radioactive discharges on non-human species'). Further research will focus on the potential impact of radioactive discharges on non-human species to aid in future assessment and provide possible input to future activities (Project Proposal Reference:P3C(97)2, 'Studies of the environmental impact of radioactive discharges on non-human species').

4.9.9 Biomarkers

Introduction

This is a rapidly developing area of pollution science. A biomarker can be defined as a measurable change in a physiological, genetic, cytological or biochemical process within an organism that indicates environmentally induced damage. Responses can be induced by any type of stress but specific ones may be indicative of particular types of stress. The biomarker should be relatively easy to measure and should preferably indicate the damage caused by specific pollutants.

The underlying concept of using biomarkers in biomonitoring is that contaminant effects occur at the lower levels of biological organisation (i.e. at the genetic, cell and tissue level) before more severe disturbances are manifest at the population or ecosystem level. Biomarkers that provide direct evidence of contaminant exposure include detoxification enzymes, DNA alterations, metallothioneins, whereas biomarkers related to histopathology, immuno-competence, general bioenergetic condition reflect effects at both the organism and suborganism level.

Business needs

Biomarkers have a potentially significant role within pollution control functions of the Agency. One approach to the use of biomarkers involves measuring a suite of selected exposure and effect indicators at several levels of biological organisation from biomolecular to the community level (Hugget *et al.*, 1992). Measurement of these selected biological responses to stress permits early detection of environmental problems and provides insights into causal mechanisms between stress and effects that may ultimately be manifest at the population and community level.

Biomarkers may have a role in conservation in the assessment of ecological integrity.

Current status

The Environment Agency are keen to adopt biomarker techniques and believe they have enormous potential. The National Centre for Ecotoxicology and Hazardous Substances is currently performing R&D on specific and general biomarkers in freshwater ecosystems as part of a NERC Environmental Diagnostics project. The use of biomarkers is included in a proposed R&D project to investigate methods for assessing the ecological health of the environment (Project Reference: E1D(97)2).

Future developments

In the long term, biomarkers could be linked in with bioaccumulation and toxicity testing since each of these methods provides different and progressive information. The use of biomarkers, like biomonitoring in general, has several advantages over total reliance on the more traditional measurement of chemical residues in the environment and the use of standardised toxicity bioassay as a basis for evaluating the potential exposure or effect of contaminants.

Firstly, biomarker responses may be integrative of complex mixtures of contaminants in the environment which even rigorous chemical screening may not detect and thus biomarkers reflect the cumulative, synergistic or antagonistic effects of contaminants on biological systems. Secondly, the responses are real in that they are field-based on resident populations rather than selected test organisms in the laboratory. Conventional toxicity tests have limitations because they usually do not account for the effect of chemical speciation in the environment and accumulation through food chains. Finally, some physiological biomarkers are reversible, at least in the early stages of manifestation. Thus an appropriate suite of biomarkers can be used as an early warning system to ensure the protection of the integrity of the whole ecosystem. This cannot be achieved by conventional tools of environmental monitoring including both classical chemical or biological assessments alone. By linking cause (pollution) and effect (biological response), biomarkers bridge the gap between these conventional tools, greatly strengthening the assessment of environmental degradation (McCarthy & Shugart, 1980).

Table 4.2 gives some examples of field studies using metallothioneins as biomarkers of pollution which shows that the methods are coming into wide use internationally and that standard test techniques could be identified to provide a suite of biomarkers for Environment Agency use.

Methodologies for different biomarkers are not described here because they are essentially laboratory analytical procedures on animals collected from the field. Methods can be obtained from the research literature cited by Peakall (1995) and the other references in this Section.

Table 4.2 Examples of field studies employing metallothioneins as biomarkers of pollution

Species	Environment	Measurement	Comments
Rainbow trout (wild or caged)	Campbell river polarography	Differential pulse linearly with Zn	Hepatic MT increased
Limpet	Bristol channel polluted coastal sites	GFC and AAS	Increased levels of MT with increased tissue Cd concentration
Perch	Clean and polluted regions of the river Eman, Sweden	Differential pulse polarography	Hepatic MT increased linearly with hepatic Cd concentrations

4.9.10 Conclusions

Of all the foregoing methods, air quality biomonitoring is probably the most well established in terms of biological methods. Although it is generally easier to biomonitor water quality than air quality, many Environment Agency biologists believe that effort towards the latter has been weak. In Ireland, IPC licensing from stacks is now the responsibility of their new Environmental Protection Agency. Over the past five to six years, staff have also been monitoring cattle herds to assess air pollution impact on animal health by taking blood samples etc. Apparently MAFF embark on similar herd monitoring. However, for the Agency, plants are probably the most promising biological tool in aerial contamination investigations. The value of plants in air pollution studies is evident from the discussion above.

At present, biomonitoring of aerial emissions is more relevant to the Agency than larger-scale surveying. The Agency would need to validate any methods prior to adoption by itself or its customers. An extensive national Environment Agency review of the value of biomonitoring methods in air quality assessment is required. Since literature in this area is vast this could potentially be an enormous task. The first stage should establish existing methods which could meet existing or future Environment Agency business needs. The feasibility of adopting such methods should be addressed. The ease with which these methods could be standardised and formalised, including quality assurance procedures, would also need to be assessed.

A combination of physiochemical and biological air monitoring is advocated if a holistic picture is to be represented. With increasing legislation and emphasis on conservation, monitoring the impact of air pollution and acid rain on individual species, communities or ecosystems in their own right is gaining profile.

Contaminated land is a growing area of development for the Agency. IPC and waste regulatory staff have expressed interest in the use of biological based methods in the assessment, monitoring and bioremediation of contaminated land/soils and their released gases and leachates. Some methods for these purposes exist.

An overview of the need of IPC and waste functions for biological methods with respect to contaminated land is required. In comparison to air quality, novel methods may need to be developed for the purposes of contaminated soils and effluents. Whole sample ecotoxicity testing would play an important role in method development.

Not only the Environment Agency but the UK as a whole has limited expertise in biological assessment of radioactivity. In the near future, the onus will probably be placed on measuring the effects and tolerances of radioactivity on biological parameters. Current R&D is focusing on this area of research. Outputs from this may provide information which will aid the development of bioindication and biomonitoring of radioactivity.

Biomarkers offer enormous potential in meeting pollution control and conservation needs of the Agency but substantial research is required within and outside the Agency before their use in future pollution control and monitoring strategies is considered. Some work is currently being undertaken by the Agency.

5. GENERAL CONCLUSIONS AND RECOMMENDATIONS RELATING TO METHODS

5.1 Introduction

Table 5.1 summarises findings from the main activities of this project. The matrix classifies types of biological method in terms of their current level of standardised use and development i.e. national, Regional or recent/current/proposed R&D. For the latter method status, the project number or formal title are not included in the matrix. This is simply due to space constraints and so key words have been used to identify areas of Environment Agency R&D.

Standard or well established methods practised by other statutory and non-statutory organisations are included (under *'Selected methods'* heading). The number of methods used by other national and international organisations is vast but only a selection is represented in the matrix. In many cases, the Environment Agency could adopt these methods directly or subsequent to modification to meet specific Agency needs. With the expanding role of the Agency such methods are necessary if it is to *'adopt across all its functions, an integrated approach to environmental protection and enhancement which considers impacts of substances and activities on all environment media and on natural resources'.*

The final category of method type is concerned with those areas which require further research and development. These are included under the table heading *'Requirement'*. This may be in relation to specific aspects of current methods such as the need for improved sampling procedures. Alternatively, 'gaps' may be where there is an obvious need for a method. Requirements may include the need for a scoping study to determine if an actual need for particular method development exists. Furthermore, method requirement could be in the form of guidance documents. Methods are presented in relation to business needs of the Environment Agency.

The following sections present concluding remarks and recommendations. These include general and specific comments relating to each section in Chapter 4.

5.2 General

5.2.1 Contractors

Many Environment Agency staff have expressed concern with regard to inconsistencies between contracted biological work. There is an apparent need for a national agreed protocol for contractor specifications. This would include guidelines for the management of contractors involved in biological work. An essential component of this would be strict quality assurance procedures to ensure that work was undertaken to a desired and consistent standard.

All contractors performing work on behalf of the Agency should have to follow any proposed QA and QC procedures. The National Centre for Ecotoxicology and Hazardous Substances intends to develop a register of approved laboratories for all labs performing ecotoxicology testing for regulatory use.

5.2.2 Quality assurance

Effective quality assurance is essential to the production of high quality data. Whilst having a standard method is an important first step, quality assurance procedures are required for two reasons:

- to ensure that the method is being followed properly;
- to ensure that the required levels of accuracy and precision are being achieved at each step in the process of sampling, processing, data generation, interpretation and archiving.

Quality assurance is of particular importance in situations where data may be exposed to legal challenge, or where intra-Agency, inter-agency or international comparisons of monitoring results are required.

The application of general quality assurance and analytical quality control is more widespread and comprehensive within the Agency for chemical methods than for biological ones, although it is of equal importance for both disciplines. However, the Agency is well aware of this point and the introduction of quality assurance procedures into its biological activities is underway. Standard AQC procedures have been introduced covering macroinvertebrate procedures for RIVPACS and are being built into new standard methods such as the RHS. However, formal procedures appear to be generally lacking within conservation and fisheries functions. The notable exception is the Brampton fish laboratory, which has introduced a standard analytical quality control procedure for its fish ageing operation.

An important objective for the Agency must be the introduction of good quality assurance throughout the full range of its biological activities. Quality assurance should be built in to all new biological methods before they are introduced. At its most basic, this should take the form of a predetermined level of random repeat surveys, analyses, measurements or identifications (as appropriate to the individual method), with a pre-set action level for disparity. Training provision, inter-laboratory calibration exercises and accreditation schemes for individual methods should all be considered in the overall planning of quality assurance.

5.2.3 Data handling, databases and data archiving

There is a need for the development of comprehensive, efficient biological data archiving systems and databases within the Agency.

Currently some data systems used throughout the Agency are not compatible, preventing easy manipulation and use of information. For example, the Biolean system, which archives Regional biological data, is incompatible to some statistical packages, thereby hindering detailed data analysis. A promising approach is the marine UNICORN 2 database developed in North East Region which has the capacity to store a whole suite of biological and chemical data parameters, which have the potential to be integrated with a GIS. The aim of such a system is eventually to incorporate various datasets from other sections of the Agency, such as conservation. This should be the way forward and such systems should be introduced but on a much greater scale in the Agency. Such a system could be facilitated by multi-functional data collection throughout the Agency and therefore the potential and feasibility of multi-functional data collection should be considered. Some Regions have much better computer systems and facilities than others. This may impose some delays in developing nationally compatible data handling systems and databases.

The Environment Agency archiving system stemmed from interests developed within Regions. Consequently a vast amount of information exists unknown to many staff. Data storage within the eight Regions is diverse and is present in different formats and different locations, variably centralised within Areas or Regions. The Environment Agency should review its procedures for archiving its reports and other data inputs. The role of the New National Data and Surveillance Centre will be to create and hold databases in conjunction with locating raw data. An obvious way forward is for the Environment Agency to develop a multi-platform-accessible database which could hold all data ranging from national monitoring and R&D down to one-off surveys. It is important that the Environment Agency maintains and shares its information base. Currently information is lost when staff move or old reports are confined to a box-file management system held regionally.

Databases capable of receiving data in a wide variety of descriptive forms are becoming increasingly well developed. The European Environment Agency, for example, is making considerable strides in this direction through its powerful and flexible GELOS system. Ideally Environment Agency data and reports should be available and exportable in electronic format to the EC and beyond; conversely, datasets and information should be importable from other UK environmental organisations and ministries both in the UK and from overseas. It seems inevitable that the Agency will have to consider this in the near future. A particular case in point is State of the Environment reporting, where the Agency will need to collate, assess and review environmental data gathered by a variety of organisations. It will have to decide whether it is logistically better to set up its own comprehensive IT division, or use a model similar to that being developed by the European Environment Agency which will comprise a home-based 'core' system with a range of databases distributed at expert centres around the country.

Ultimately an easily accessible system to be used by all fully trained staff, which rapidly outputs data requests in standard comprehensive format from a number of relevant organisations, is desirable.

Other issues were flagged up during the consultation process of this project. Biologists feel they lack trained expertise in systems such Geographical Positioning Systems (GPS) and Geographical Information Systems (GIS) and also statistical packages, particularly multivariate analysis. Furthermore, it would be beneficial if environmental modelling incorporated a greater biological input.

5.3 Freshwater macroinvertebrates

The use of freshwater macroinvertebrates in water quality investigations is probably the most established, advanced and standardised approach available within the Environment Agency. Standard methods exist in the form of GQA and RIVPACS along with detailed quality assurance procedures. Within the water quality function, however, certain shortfalls and recommendations have been highlighted.

- There is an inconsistency between Regions in the approach to macroinvertebrate monitoring between quinquennial GQA surveys. Operational river quality monitoring should be standardised and should feature within Local Environment Agency Plans (LEAPS) where appropriate.
- Some Agency biologists would prefer not to be limited to the existing GQA monitoring sites but feel regular sampling of a wide range of freshwater habitats would provide a better indication of environmental change.
- Certain Regions would like to see a refinement of the RIVPACS system on a local basis.
- Standardisation of sample handling and preservation is required.

- Although comprehensive quality assurance procedures exist for macroinvertebrates, quality assurance procedures should be initiated at the sampling stage, as variation between sampling effort in the field is common.
- Sampling in deep waters, canals and headwaters require development, aspects of which are currently under Environment Agency R&D.
- Other aquatic habitats which have been neglected include temporary streams, winterbournes, artificial watercourses and tidal rivers.
- The potential for adaptation of Regional methods, including quality assurance procedures, on a national basis needs to be assessed.
- Long-term post pollution incident monitoring would be useful.
- There is a requirement for further standardisation of biological investigation methods of pollution incidents to ensure certain standards are met which uphold in court.
- The potential use of macroinvertebrates in the biological assessment of aquatic pollution from contaminated land should be investigated further.
- The inclusion of macroinvertebrate standards in discharge consents should be considered further.

The wealth of experience in the Environment Agency with regard to macroinvertebrates places them in a good position for adaptation to other existing and future business needs, for example:

- macroinvertebrate data (GQA) has been used in the setting of draft Biological Quality Objectives (BQOs) - research in this area should continue;
- some work has focused on the relationships between macroinvertebrate communities and flow regime but further research is necessary;
- a feasibility study of using macroinvertebrates for general assessments of conservation value and studies of rehabilitation should be undertaken and the applicability of RIVPACS in this respect should be assessed;
- the use of macroinvertebrates in the assessment of ecological integrity should be assessed further;
- formalisation of Environmental Change Network (ECN) monitoring and application of the data generated is necessary;
- the inclusion of biological GQA component in State of the Environment Reporting would be appropriate.

5.4 Freshwater macrophytes

It has become increasingly apparent that macrophytes fulfil aspects of water quality assessment not addressed by macroinvertebrate groups. It is recognised that macrophytes are important in the distinction between organic and nutrient pollution.

Macrophyte methods for the evaluation of eutrophication are well underway and some of the limitations are being addressed via national R&D. The UWWTD method has not been fully tried and tested and it will take several years before the method is fully robust. Macrophytes are not as amenable to traditional quality control procedures as macroinvertebrates or diatoms and quality control remains an inherent shortfall of the method. The adoption of the

UWWTD methods and MTR for general eutrophication studies and other needs should be assessed. Inclusion of UWWTD macrophyte data in 'status of the catchment' sections of LEAPS may be useful.

A drawback of using macrophytes is that they cannot be used reactively throughout the year in the same way that invertebrates can. The group may be more appropriate as a long-term strategic tool, for example in annual comparative studies. Furthermore, macrophyte expertise is less widespread within the Agency than for macroinvertebrates and good national baseline data is scarce.

Aquatic plant communities play a fundamental role in the assessment of conservation value and in freshwater classification systems. It would be useful if macrophyte data was collected by different Environment Agency functions in a comparable manner. This would increase datasets and allow intercomparisons to be made. However in many cases this may prove too difficult. Aquatic macrophytes may also have a role in post project appraisal monitoring.

Other business needs such as water resources could potentially be addressed using macrophytes and further work in this area is required. The current North East Region Surface Water Abstraction Licensing Procedure (SWALP) concept uses macrophyte information as part of the environmental weighting determination used in the abstraction licensing review process. The use of standard macrophyte methods, in association with other biological assemblages to overcome their strong seasonality disadvantage, is recognised as significant in still water quality assessments.

Formalisation of Environmental Change Network (ECN) macrophyte methods are required, along with data applications and quality assurance procedures.

5.5 Freshwater epilithic algae

Epilithic algae have assumed a greater role within the Agency over recent years since they have been used in the assessment of nutrient status. A national standard method for UWWTD monitoring is in operation but is still under R&D.

Algae are useful for UWWTD compliance monitoring because they are less restricted than macrophytes in the range of habitats which they can occupy, and do not show severe seasonal fluctuations in biomass. However, the use of macrophytes and epilithic diatoms in tandem for UWWTD purposes is a more holistic approach. The main concern of Agency biologists was the capacity of the current quality audit system to cope with increasing numbers of samples. As for macrophytes, the adoption of TDI and DQI by the Agency for general eutrophication monitoring should be considered.

Epilithic algae (and epiphytic, epipelic etc.) have received little attention for other purposes, although they have potential to provide a range of useful information, for example in water resources. The future use of algae greatly depends on the ongoing stillwaters R&D programme that is evaluating the use of diatoms against other groups (e.g. fish in canals, macrophytes in ponds). If algae are not used in this context their role is not likely to expand within the remit of the Agency.

Formalisation of ECN methods is necessary. Identification of samples and data analysis should be undertaken because this may provide hints to improving the methodology.

5.6 Freshwater plankton

Both phytoplankton and zooplankton receive little attention within the Agency. Exceptions are one-off studies, such as the study of zooplankton in Lake Bala, monitoring of potentially toxic cyanobacteria and trophic studies in the River Thames (Bass *et al.*, 1997). In addition they have been used extensively in toxicity testing (e.g. *Daphnia*). They are also monitored as part of the ECN programme but as with other freshwater biological groups, methods require formalisation.

The lack of attention towards plankton is largely because plankton do not readily lend themselves to environmental monitoring. They are not as well studied as other groups of freshwater organisms, and still waters have historically received less attention than running waters. However, the general opinion among Agency staff, particularly biologists, is that plankton are not currently being used to their full potential.

The plankton are an important component of lentic ecosystems and need to be taken into account if lakes and other still waters are to be fully understood. Plankton are important food for fish and have a role in trophic investigations and biomanipulation studies in lake systems.

The biological assessment of still waters is currently being addressed in an Agency R&D project (Phase 2 under way) and the future use of plankton will greatly depend on the outcome of this research.

The main concern of the Agency regarding plankton is the identification of potentially toxic blooms. The Agency does not routinely monitor algal blooms but investigates reports from field officers and the public. Toxic blue-green algae and other algal blooms are included in the Agency's State of the Environment reporting.

5.7 Freshwater fish

5.7.1 Future developments in analytical and reporting software

There is a clear need for a standard suite of programmes for the analysis and presentation of fisheries data. The software should offer a variety of presentation formats appropriate to the various customer groups.

5.7.2 Regional/national fish archives and availability of fishery data

There is a clear need for fisheries data to be held in comprehensive Regional computer archives, as is the norm for routine physicochemical data. At present, much potentially valuable information is scattered throughout local offices in hard-copy reports. It is therefore difficult to abstract the data, which is potentially wasted. Where centralised databases are held (for example the National Fish Laboratory holds records of all fish it has aged), then these can be potentially used for a variety of purposes, e.g. the production of a comprehensive set of standard national growth curves or comparative studies of river systems.

5.7.3 Quality assurance

Sampling data must be of known and sufficient quality to achieve the sampling objectives. Introduction of the fisheries classification scheme will require standardisation and the application of more quality assurance (QA) procedures. The form which a QA system should take requires careful consideration and poses a number of potential difficulties.

Each fish survey site must be individually assessed and the most appropriate survey method selected on the basis of experienced judgement and available resources. With the exception of 0+ juveniles, fish identification is very straightforward and identification errors are very unlikely. The one area where a formal AQC system is clearly appropriate is for fish ageing from scales or other bony elements. The National Fisheries Laboratory at Brampton has introduced its own AQC system for scale reading which involves independent re-reading of a proportion of scales with a defined permissible level of disagreement beyond which remedial action is implemented.

The current state of Environment Agency QA for fish surveying methods varies from Region to Region and is somewhat ad-hoc and informal but tends to follow a general pattern. The most important requirement for any fish capture survey method is to ensure constancy of capture efficiency. This is fundamental to catch depletion population estimates and essential for meaningful comparisons between semi-quantitative surveys. In order to meet this requirement, it is common practice for each member of a survey to undertake the same task at each site in a survey, thus at least ensuring constancy of effort.

5.7.4 Standardisation of fish and fisheries methods

Survey methods are particularly well developed for small to medium sized running waters but even here there is little standardisation of methods and approaches between Agency Regions. Survey methods are less well developed for large rivers, lakes, estuaries and coastal waters. Standard protocols for fisheries methods for the Agency as a whole are generally lacking, in particular the required level of precision in fish survey methods has not been specified. Past and current national R&D programmes are beginning to address the need for standardised methodologies in fisheries assessment. Whilst there is a clear case for a suite of national standard methods, these should not be overly prescriptive as survey methods must be sufficiently flexible to accommodate a wide range of individual site characteristics.

Furthermore, there is a requirement to introduce a standardised approach to habitat data collection associated with fisheries surveys.

5.7.5 Use of fishery data and integration of fisheries with other Agency functions

There appears to be considerable variation in the perceived role of fisheries units and the uses to which fisheries data are put across the Agency Regions. This variation would appear to stem from the clearly defined stand-alone fisheries role and the historic separation of fisheries functions from those of water quality and biology, which have always been more closely integrated. The extent to which fisheries functions and data uses have now become integrated is highly variable. In some Regions, e.g. Southern and North West, the fisheries role is still largely confined to stock-assessment and management and there appears to be little formal use of fisheries data within water quality and biology sections to provide an overall environmental assessment. In other Regions, fisheries units are more closely integrated with other functions. This more holistic approach is most developed in Welsh Region, where the water quality, biology and fisheries scientific sections are combined into 'Environmental Appraisal Units', where the interrelatedness of chemical, biological and fisheries information is fully recognised in the overall assessment and management of environmental quality.

Throughout the Regions and at Headquarters, there is a widely held, though not universal, view that there could and should be a much more widespread use of fishery data, and that the potential role of fish in biological monitoring is currently largely unrealised. Although the high mobility and avoidance reactions of fish are sometimes seen as disadvantages in their use as biomonitors, many biologists and fisheries scientists see particular benefits in the use of fish. In particular:

- fish are recognised as being the first and often only means by which some of the effects of poor water quality and some pollution incidents can be identified;
- fish are perhaps the best indicators of the level of habitat degradation caused by land use and development, flood defence works and abstraction, and their financial value aids in their protection;
- fish are especially valuable in monitoring long term effects, e.g. of chronic pollution, oestrogenic substances, acidification and through bioaccumulation studies, and the impact of trace pollutants such as metals and pesticides;
- fish data are and should continue to contribute significantly to the Agency's 'State of the Environment' reporting;
- a more integrated reconciliation between fisheries and other ecological duties may be appropriate, particularly if new approaches such as ecological integrity assessment of waterbodies is introduced.

5.7.6 The Fisheries Classification Scheme

The current development and introduction of the national Fisheries Classification Scheme (FCS) provides a potential opportunity to harmonise fisheries data collection and use across the Regions and the potential to introduce a formal fisheries 'window' into the GQA.

There is currently a growing trend towards the collection of semi-quantitative fish survey data in a high proportion of the Agency Regions, as this is seen to represent a more cost-effective deployment of available resources. The FCS, however, requires quantitative data. The resolution of this conflict is an obvious priority.

5.8 Marine/Estuarine

Marine and estuarine habitats have received considerably less attention than freshwaters, although there is a clear need for the Agency to monitor these habitats to fulfil various commitments. Often methods are available within the Agency, although formalisation and standardisation are typically required. The Marine Biology Group is addressing the issue of standardisation and formalisation of methods and is considered to be fulfilling a very useful role in this context by Agency staff. There is a perceived lack of marine biologists in the Agency and this is considered a major limiting factor on the amount of work carried out. There are several areas requiring development which were identified by Agency staff and these are given below:

- formalisation and standardisation of marine and estuarine protocols;
- development of a method for sampling rocky intertidal areas;
- investigations into the relative merits of different levels of taxonomy for the study of macrobenthos, particularly in estuaries;
- development of marine and estuarine classification schemes;
- possible inclusion of marine taxa into the algal image database to help with the identification of marine taxa;

- production of guidelines for the management of contractors involved in marine work (including quality control);
- expand the use of UNICORN database, which stores biological and chemical data, so that data requests can be produced quickly and in a standard format;
- there is a need to review the need for specific marine conservation protocols, for example in the monitoring of SACs;
- standard sampling should be prescriptive enough to ensure methods are adhered to but should incorporate flexibility for one off investigations.

5.9 Conservation

Although the Environment Agency has no direct role in site designation, it is likely to have a significant role in their management and monitoring, particularly in the case of river and wetland SSSIs and SACs, marine SACs, Ramsar sites and SPAs.

Most of the Agency's conservation work is to evaluate the conservation value of a site not for designation but to elucidate human impacts upon the conservation value, gauge the success of ameliorative activities, determine the feasibility of rehabilitation, and perhaps assess the total area which is available to wildlife.

Despite the relatively high profile of wildlife conservation within the overall remit of the Agency, it is currently relatively poorly equipped with standard methods for assessing conservation value.

The following actions are necessary:

- a more detailed review of conservation needs for standard methods coupled with a critical assessment of methods developed by UK conservation bodies in order to facilitate immediate or rapid adoption by the Agency;
- further development of methods for monitoring the marine environment;
- development of methods for assessing ecological integrity in order to meet the requirements of the forthcoming Water Framework Directive;
- further investigation and development of quantitative models for relating physical habitat to carrying capacity and/or biodiversity, to determine their validity, limitations and applicability;
- methods for the assessment of rare species may need to be developed.

A further major shortfall, clearly felt by Agency conservation staff, relates to the availability of (as distinct from the existence of) biological and conservation data. A huge amount of data is being and has been collected by a wide range of conservation and related organisations (including the Agency itself). Much of this information is held in electronic format but in many different databases. Major UK databases include the Biological Records Centre run by ITE, BTO database, Botanical Society of the British Isles (BSBI) database, Wildfowl and Wetlands Trust database and County Biological Records Centres. All of this information can be accessed, but this is a complex and protracted undertaking. It would therefore be of great value to bring the disparate conservation organisations together and to establish access links between the various data sources. Ideally it would be possible for Agency conservation staff to access the existing records relating to any species or taxon for any site or area anywhere in the UK in a simple and straightforward manner. This should be an achievable goal. The benefits of a unified approach by organisations involved in conservation are recognised by the

Environment Agency (Environment Agency, 1996c). It is recommended that a feasibility study of the potential for inter-agency linking established biological databases should be undertaken.

5.10 Whole sample ecotoxicity testing (DTA)

The Agency structure which deals with ecotoxicity and hazardous substances issues is currently undergoing a period of significant change and development, as the National Centre for Direct Toxicity Assessment and National Centre for Toxic and Persistent Substances are being merged, along with the Chemical Assessment Unit of the Department of Environment, to form a National Centre for Ecotoxicology and Hazardous Substances.

The new National Centre aims to introduce a nationally consistent approach to whole sample (DTA) testing. It will be responsible for relevant policy, training, research and for the accreditation of commercial ecotoxicity test laboratories performing regulatory work. Agency staff at the Regional and Area levels will require advice on how ecotoxicity tests may be applied to water quality issues in their Region or Area, the subsequent interpretation of data and the use and management of contractors. A Regional and Area representative may be useful in this context.

Whole sample (DTA) ecotoxicity methods may have a role in contaminated land and waste assessment and in landfill leachate monitoring.

5.11 Bioaccumulation

An extensive review of the need for bioaccumulation in marine and freshwater studies within the Agency would be useful. This would have to assess the value of bioaccumulation work to the Environment Agency on top of existing ecological work or in isolation. This could be achieved by establishing what current and future business needs may be fulfilled by bioaccumulation work.

Several studies have been carried out by regulatory bodies in the UK including the Ministry of Agriculture Fisheries and Food (MAFF), Department of the Environment (DoE) and the Environment Agency. A wealth of literature on bioaccumulation studies and levels of contaminants in organisms exists. This is useful in determining trends and identifying hot spots, but further research is required in relation to the actual levels which cause effects and the extent of damage on individuals, populations and communities (i.e. dose responses). Links between concentrations of contaminants in water and body burdens need to be defined, as do links between burdens and impacts. Appropriate interpretation of data is necessary if bioaccumulation work is to be used operationally within the Agency. Standard methods exist in terms of which species to use, tissue preparation and analytical procedures. These have been defined by the Agency and are well established in the literature. Therefore production of a formal, refined standard method manual would not be difficult. The creation of a database has also been recommended which could be used to assess significant increases in contamination against background levels.

5.12 Other methods

The Waste Regulatory Management and IPC functions of the Environment Agency stemmed from previous organisations with no tradition of biological monitoring. However, the Environment Agency has an objective to *'adopt across all its functions, an integrated* *approach to environmental protection and enhancement which considers impacts of substances and activities on all environment media and on natural resources'.*

Currently, biological methods are not utilised within the waste regulatory and integrated pollution control needs of the Environment Agency. This reflects history and biological method development in these areas. However, another reason for there being little apparent usage of biological methods by either function is that many issues overlap with Water Quality responsibilities, such as consented leachate discharges or authorised discharges to controlled waters. Consequently most of the biological requirements for dealing with issues are met by the Water Quality function. Another contributory factor is that for both Waste and IPC functions, much of the onus is on the producer or discharger to undertake monitoring and carry out assessments. This has meant that their direct application of methods has been fairly limited.

IPC staff in some Regions use toxicity tests for monitoring of effluents (mainly microtox) and some request that the discharger provides toxicity data for their effluents where necessary. There are plans to include (if appropriate) conditions in authorisations requiring a biological impact assessment to be undertaken by the discharger in the vicinity of the discharge point. This could be a two phase assessment which would look at the initial status of biota and then have a follow up study to assess any changes after an alteration in the discharge. However, although this may be initiated by the Agency, the onus would be on the discharger to carry out the survey. It is also highly likely that Water Quality staff, possibly in consultation with IPC colleagues, would undertake the auditing of these surveys.

Terrestrial biology expertise within the Agency is limited. This is of consequence with respect to air pollution, contaminated land and radioactivity assessment. Potential biological methods of use to the Agency were outlined in Section 4.9. Of these methods, air quality assessments using plants is the most widely recognised nationally and internationally.

The value of plants in air pollution studies is evident. The response of plants to elevated concentrations of air contaminants is modified by other environmental factors and by the physiological status of the plant. Monitoring the plants directly assesses the integrated effects of these factors and contamination. Tingey (1989) emphasised that *'there is no better indicator of the status of a species or a system than the species or system itself'*.

Physical and chemical methods do not provide sufficient information on the risk of an exposure, whereas biological methods allow direct assessment of risk from an exposure. Biological data can be used to estimate the environmental impact and potential impact on other organisms including humans. Furthermore, continuous biological data collection is often not necessary and can be performed periodically. Biological monitoring of air contamination is generally less expensive than other methods in that it favours long-term monitoring over large areas without deploying sophisticated and high maintenance equipment.

For specific duties of IPC, the use of plants in aerial emission assessment/monitoring is more appropriate. On regional, urban and point source scale, methods vary in terms of monitoring design and data analysis. Development of standard methods on this scale may be problematic since most cases would be site specific. Additionally, biological monitoring of air quality will in many instances not provide actual pollutant levels. However, the data would provide a relative picture of contamination impact. Method protocols could be designed to be prescriptive enough to ensure the method is adhered to but should incorporate flexibility for site variations.

Plants have been used extensively in assessing air pollution sources and burdens over larger areas, on the regional, national and multi-national scale. Standard national and international documents have been produced for the latter purpose. Larger-scale, long-term monitoring data could be useful to the Agency in its State of the Environment reporting and in its new role of integrated pollution control.

In summary, a combination of physiochemical and biological monitoring is advocated if a holistic picture is to be represented.

Contaminated land issues are gaining profile throughout the Agency. Specialised expertise exists in the form of a National Policy Group in Land Quality Function and the National Contaminated Land and Groundwater Centre. Contaminated land issues in relation to water quality, such as leachate monitoring into receiving watercourses, should be easily tackled by the Agency. This stems from its aquatic expertise gained under the auspices of the National Rivers Authority. These aspects are by no means under control but the Agency does have the in-house expertise to potentially deal with the problems.

However, the Agency may be lacking in terrestrial ecology expertise, which may be required if contaminated land/soil biological methods are to be adopted. There is a future for biological monitoring in land management and remediation with respect to process monitoring and validation of land bioremediation technologies, assessing the ecotoxicity of soils, conservation assessment and environmental impact assessments. Biologically-based tests are often more appropriate, particularly toxicity testing, and allow a holistic analysis, capable of detecting effects of compounds not assessed or detectable chemically. Proposed future Environment Agency R&D is concentrated on microbiological and ecotoxicity methods.

Not only the Environment Agency but the UK as a whole has limited expertise in biological assessment of radioactivity. In the near future, the onus will probably be placed on measuring the effects and tolerances of radioactivity on biological parameters. Current R&D is focusing on this area of research. Outputs from this may provide information which will aid the development of bioindication and biomonitoring of radioactivity.

Biomarkers offer enormous potential in meeting pollution control and conservation needs of the Agency, but a lot of research is required within and outside the Agency before their use in future pollution control and monitoring strategies is considered. Their use is currently being investigated as part of the Agency's R&D programme.

In summary, a stand alone comprehensive review and scoping study of the requirements of IPC and Waste Regulatory functions for biological methods is essential. This could take the approach of looking at the aims and scope of existing non-biological monitoring. The review should identify:

- areas of deficiency in current monitoring regimes e.g. process of identifying potential impacts of waste management activities is needed;
- areas where existing biological methods could realistically replace or complement traditional techniques;
- situations where biological methods would offer a better mechanism of determining environmental threat or impact;
- existing biological methods which may be applicable or easily adapted;
- potential for development of novel biological monitoring methods to meet present or future business needs;
- whether the Agency has existing capability or if expertise from external organisations needs to be sought;

- priority list of actions;
- highlight further areas of research.

Standardisation of such biological methods can only be regarded as a long-term goal, the implementation of which will depend on substantial fundamental research. Even if the Agency choose not to undertake such monitoring themselves, development and familiarity of methods is necessary in their advisory and guidance roles.

5.13 Implementation of R&D

The Environment Agency carries out substantial research in the form of their national R&D programme. Many existing standard biological methods including quality assurance developments have been investigated, piloted and implemented via Environment Agency R&D. R&D work is therefore fundamental to biological method development. However, it appeared from the consultation and review process of this project that a substantial amount of R&D undertaken by the Agency and its contractors is not fully assessed and fails to reach the implementation stage. One proposed objective of the newly established National Coarse Fish Centre at Kidderminster is to review all relevant past R&D. This critical assessment should establish priority areas to determine what work should be progressed and eventually implemented and what should be rejected. This will provide focus and guidelines for future R&D work. The Agency should consider undertaking an appraisal of all past and future R&D in a manner similar to that proposed above. The various specialists centres currently being established would provide a potential mechanism for achieving this.

5.14 The development of a Manual for Biological Methods

In view of the large number of biological methods currently in use within the Agency, the inevitable future introduction of substantial numbers of new biological methods and the desirability of standardisation of method use, especially in relation to aspects such as quality assurance, there is a clear case for the production of a unified Manual for Biological Methods. Such a manual would be a substantial and ambitious publication that would require regular review and updating. The manual would therefore need to be structured in a manner that facilitated its progressive development and introduction and that allowed for individual method revisions without the need for complete manual re-issue.

A proposed format and strategy for development of a Manual for Biological Methods is presented in Chapter 6.

5.15 The development of new biological methods

In some areas of activity and in relation to some business needs, biological methods are relatively well developed and in some cases largely standardised within the Agency. In other areas, for example conservation, there is a significant shortfall in standard method availability. In functions such as IPC and waste management and in relation to business needs such as the assessment of ecosystem health, established Agency biological methods are almost entirely lacking. There is therefore a wide ranging need to develop and/or adapt additional biological methods and to standardise these for Agency use.

A proposed strategy for biological method development is presented and discussed in Chapter 7.

Table 5.1 Matrix of Environment Agency needs and biological methods

Method status	Business need							
	Waste Regulatory	IPC	Water quality	Water resources	Flood defence	Conservation	Fisheries	Recreation and navigation
Agency National			1. Standard biological methods for GQA. 2. Standard methods for UWWTD. 3. Dangerous Substances Directive. 4. UK National Monitoring Plan (NMP).			1. River Corridor Survey (RCS). 2. River Habitat Survey (RHS).	1. National fisheries classification scheme. 2. HABSCORE	
Agency Regional			1. Acidification assessment. 2. Ferruginous minewaters. 3. Rapid biological appraisal keys (RBAKs). 4. Chironomid pupal exuviae technique (CPET). 5. Bankside assessment 6. Sheep dip assessment 7. Lincoln Quality Index (LQI).	1. Regional guidelines on monitoring of water resource projects. 2. Surface Water Abstraction licensing Policy (SWALP). 3. Invertebrate Flow Index (IFI).		1. Community conservation index		
Agency Current/Proposed/ recent R&D	1. Development of microbiological and ecotoxicological test methods. 2. Feasibility of SOILPACS.	1. Potential impact of radioactive discharges on non-human species. 2. Toxicity based criteria for assessing water quality. 3. Toxicity based consents.	1. Still waters GQA and classification. 2. RIVPACS Phase 3 - deep waters and canals. 3. Water quality of headwaters. 4. Macrophyte methodology. 5. Diatom methodology. 6. PLANTPACS. 7. Blue-green algal identification database. 8. Biomanipulation of eutrophic water. 9. Toxicity based criteria for assessing water quality. 10. Toxicity based consents. 11. Impact of pesticides on river ecology. 12. Ecotoxicological quality assessment procedures. 13. Alternative methods of biological classification of rivers. 14. Acid Waters monitoring. 15. Analysis of 1995 biological survey data. 16. Endocrine disruption - effects on invertebrates. 17. Endocrine disruption - monitoring in marine and coastal waters.	1. RIVPACS and low flows. 2. PHABSIM Category 2 habitat suitability curves. 3. Ecologically Acceptable Flow Regimes (EAFRs). 4. River flow needs for the control of algae.	1. Vegetation management of raised embankments. 2. River monitoring of channel response to modification. 3. Implications of Habitats directive on shoreline management plans. 4. Flood defence management practices and habitat creation. 5. Saltmarsh management for flood defence.	1. SERCON. 2. RHS developments. 3. Rehabilitation of degraded habitats. 4. Standard post-project appraisal methods. 5. Otter biodiversity action plan. 6. Methods for assessing ecological health of the environment including biomarkers. 7. Use of diatoms to monitor river characteristics. 8. Techniques to assess biological stocks for biodiversity action plans. 9. Integrated environmental assessments of the aquatic environment. 10. Environmental indicators. 11. Conservation assessment techniques for ponds. 12. Waterways Bird Survey. 13. Conservation input to IPC and waste regulation management. 14. Species management. 15. Invertebrates on exposed riverside sediments. 16. Environmental assessment undertaken by external developers - Phase 3 &4. 17. Faunal richness of headwater streams. 18. Mechanisms for protecting and enhancing headwater s.	1. Semi-quantitative electric fishing methods. 2. Survey method for assessment of fisheries in headwater streams. 3. Fisheries habitat inventory. 4. Habitat rehabilitation methods for coarse fish in still waters. 5. Design and implementation of fisheries survey. 6. Fisheries classification scheme. 7. PHABSIM.	1. Impact of recreation on wildlife.
Selected external	1. Some methods available in literature in relation to the assessment of contaminated land (Section 4.10.3).	1. Standard international methods for use of lichens, mosses, algae and trees in air contamination monitoring (UNECE, 1993). 2. Variety of air quality monitoring methods in literature (Section 4.10.3). 3. Limited methods of biological assessment of radioactive discharges in literature (Section 4.10.3).				1. EN Phase 1 Survey. 2. NVC. 3. NCC Lake classifications. 4. Countryside Information System. 5. Habitat Evaluation Procedure (HEP). 6. Habitat Evaluation System. 7. Common Bird Census. 8. Breeding Birds of Wet Meadows. 9. Wetland Bird Survey. 10. National Low Tide Counts.	1. Rapid assessment protocols for lotic systems (US EPA, Section 4.5.3).	
Requirement	1. Biological input into waste site EIAs and exemption decisions. 2. Landfill restoration/ contaminated land remediation. 3. Conservation input to IPC and waste regulation management.	1. Biological measures of harm. 2. Impact assessment of air pollution/acid rain on protected sites. 3. Assessment of the sensitivity and tolerances of organisms to radioactive substances. 4. Potential biological input in State of the Environment reporting. 5. Conservation input to IPC and waste regulation management.	1. Standardisation of sample handling and identification. 2. Quality assurance of macroinvertebrate sampling procedures. 3. Value of quantitative macroinvertebrate work.. 4. Guidance on statistical analyses particularly multivariate. 5. Incorporation of biological aspect in discharge consents. 6. Further work with respect to temporary streams, artificial watercourses, tidal rivers and groundwaters. 7. Estuaries and coastal water GQA. 8. Standard procedures for coastal algae monitoring. 9. Further work with respect to pollution incidents. 10. Research into the potential of extension of the use of regional methods. 11. Aquatic pollution from contaminated land. 12. Feasibility of specific methods for urban runoff assessment. 13. Assessment of future water quality problems. 14. Development of bioaccumulation methods. 15. Potential of multimetric methods. 16. Improved databases. 17. Other adaptations of UWWTD methods. 18. *Cladophora* methodology. 18. Potential of multi-functional data collection and integrated approaches. 19. Potential in State of the Environment reporting. 20. National standardisation of marine methods.	1. Development or modification of existing methods for the assessment of low flows. 2. Urgent need for standard methods. 3. Methods for prediction of low flows.	1. Requirement for greater and standardised biological and conservation input. 2. Feasibility study of potential of soft engineering alternatives. 3. Standard EIAs procedures.	1. A more detailed review of conservation needs for standard methods coupled with a critical assessment of methods developed by UK conservation bodies in order to facilitate immediate or rapid adoption by the Agency. 2. Further development of methods for monitoring the marine environment. 3. Development of methods for assessing ecological integrity in order to meet the requirements of the forthcoming Water Framework Directive. 4. Further investigation and development of quantitative models for relating physical habitat to carrying capacity and/or biodiversity, to determine their validity, limitations and applicability. 5. Methods for the assessment of rare species may need to be developed. 6. A feasibility study of the potential for linking established biological databases so that existing information relating to sites and areas can be more readily accessed.	1. More integrated reconciliation between fisheries and other ecological duties. 2. Review of the potential role of fish in biological monitoring. 3. Feasibility of introducing a formal fisheries 'window' into the GQA. 4. Urgent need for standardised consistent approaches to fisheries surveying, data collection, data analysis and reporting. 5. Standardisation of habitat data associated with fisheries surveys. 6. Need for centralised and comprehensive data archiving system. 7. Urgent need for formal, standardised quality assurance system. 8. Feasibility study of adaptation of similar HABSCORE system for coarse fish.	1. More integrated approach between recreation, navigation and ecological needs.

6. DOCUMENTATION FOR A MANUAL FOR BIOLOGICAL METHODS

6.1 Introduction

The Agency's ultimate aim, of which this report forms Phase 1, is to produce a manual of national standard biological methods, to be used by all relevant staff in all Regions. It is assumed that a biological methods manual(s) would be managed by the Operations Directorate in a manner comparable to that for the Environmental Monitoring and Sampling manuals. There is an ongoing review of Agency methods documentation by the Operations Directorate which covers all aspects of the structure and management of Agency Documents. The documentation review not withstanding, the current report considers and makes independent recommendations for the structure and management of a Manual for Biological Methods.

6.2 The need for a Manual for Biological Methods and its scope

The manual should address all biological methods approved for use within the Agency in meeting its own business needs. The manual should also address identified business needs for which standard biological methods are lacking, or existing methods not yet fully validated, providing information on current or planned R&D and the time-scale over which methods may become available.

Ideally, the biological methods manual should also include methods which meet the biological survey, monitoring and assessment needs of other organisations in those situations where the Agency has a direct interest in the outcome of such work. For example, the Agency has a wide involvement in EIA through its role as statutory consultee for almost any type of development project. The Agency should have a reasonable expectation that EIAs carried out by developers or their consultants have been undertaken to acceptable standards using established methods. When consulted at an early (scoping) stage of a project, the Agency should be in a position to advise, both on key issues to be addressed and on the methods to be used for their investigation.

In the case of Agency functions such as IPC and Waste Regulatory Management, there is considerable, although currently largely unrealised, scope for the use of biological methods. Within both of these Agency functions, much of the onus is on the producer or discharger to carry out assessments, undertake monitoring or provide toxicity data. The Agency's role is to instigate and audit these activities, but to do this effectively it must be able to stipulate both the data requirements and the methods for their collection. The Agency therefore needs to be at the forefront of method development in these fields.

In common with many organisations, there is a growing trend across all functions within the Agency, including biology and biologically related activities, to contract out work. It is not only the quantity, but also the diversity of work contracted out that is increasing and this trend is unlikely to diminish in the foreseeable future. A considerable number of Agency staff expressed concern regarding the variable quality of contracted biological work. It is clear therefore, that a biological methods manual should also be aimed at contractors. In the case of contractors, particular attention will need to be paid to quality assurance procedures, in order to ensure that external work is carried out to a desired and consistent standard.

One of the Agency's duties under the Environment Act 1995 is to compile information for State of the Environment reporting in order for it to form an opinion on the general state of the environment. This will require a national environmental monitoring and assessment framework (Environment Agency, 1996a) with biological input required for, *inter alia*:

- measurement of the status of key biological populations and communities;
- monitoring with respect to environmental quality standards;
- measurement of the health of the environment.

A substantial component of the data used for these activities will not be collected by the Agency itself but will be drawn from a wide range of national and local organisations. How these data are collected, and their consequent reliability, will therefore be an important Agency concern.

It is apparent from the foregoing that a Manual for Biological Methods should not be seen solely as a guidebook for Agency staff use, but should be directed at a much larger target audience. The manual should encompass both what the Agency does itself, and what it expects, or would like to see, in the work of others. The Agency's Manual for Biological Methods should be seen as a key vehicle for influencing and directing the collection and assessment of biological monitoring data throughout the UK. In this respect, the Environment Agency has a pivotal role and is in a unique position to take a lead.

6.3 The format of a Manual for Biological Methods, Parts 1 - 4

In proposing a format for an Agency biological methods manual, it is necessary to consider a number of points:

- Due to the necessary length of detailed method descriptions, a single volume manual for biological methods would be very large, unwieldy and very expensive to produce. Probably the best example of an all-embracing methods manual is the APHA-AWWA-WPCF Standard Methods for the Examination of Water and Wastewater. 'Standard Methods' is the product of a very large number of editorial task forces overseeing the individual chapters on specific subject areas. Whilst the output is technically excellent, it is also prohibitively expensive, not just once, but every five years. Furthermore, most users will only ever directly use a few small sections of the overall publication.
- Production of a unified all-embracing biological methods manual would be a very time consuming undertaking. Conversely, there is a considerable range of methods that are widely used and already largely standardised within the Agency. Method manuals for these could be produced quite quickly and easily, whereas definitive method manuals for others may not be possible without substantial additional R&D. The 'Blue Book' manuals produced by the Standing Committee of Analysts (SCA) provides a very effective mechanism for addressing individual methods or areas. A topical need can be identified, an expert panel assembled and a state-of-the-art guidance manual produced within a realistic time frame and the cost per volume makes the Blue Books very accessible. The main drawback of the SCA approach is the lack of overall coherence and the absence of a unified overview.
- The Manual for Biological Methods will grow and evolve continuously over time, it will never therefore be complete.

With the foregoing points in mind, it is proposed that the Manual should consist of a series of volumes grouped together into four parts; namely:

- **Part 1**
  Part 1 would comprise the parent document for the Manual for Biological Methods and would act as a first reference point for the use of biological methods. Part 1 would be, in essence, a single volume annotated index to the manual as a whole. This volume should introduce the various biological methods, describe the methods in outline and indicate the scope of the various methods, defining the situations in which they are appropriate (issue of concern, habitat of interest etc.), particularly with reference to the business needs of the Agency.

- **Part 2**
  Part 2 would comprise a series of general volumes covering topics common to many biological methods. Potential topics for inclusion in Part 2 are discussed in Section 6.5 below.

- **Part 3**
  Part 3 of the manual would address individual methods in detail. Each method (or group of similar methods, or a common aspect of several methods) should have a detailed procedural volume of its own, the individual Method Handbooks. Standard Agency methods would have been thoroughly researched and evaluated. Therefore the scope and use of each method can be clearly defined in the handbook, and the methodology can be appropriately prescriptive and detailed. Within these detailed instructions, it would be important to indicate where instructions are definitive and where given alternatives are permitted, and circumstances in which an alternative method might be more appropriate.

- **Part 4**
  Part 4 would be a current awareness bulletin.

Suggested formats and contents for Parts 1-4 are discussed in Sections 6.4 - 6.7 below.

6.4 Proposed structure for Part 1 - Manual for Biological Methods

Part 1, the manual directory, should be loose-leafed, as this would allow for the routine inclusion of new methods, removal of obsolete methods, modification of existing methods etc. It is envisaged that updating of Part 1 would be an ongoing process with additions or amendments to individual sections issued, as they became available. A complete revision and reissue of Part 1 would be required every few years.

It is proposed that the level of detail relating to individual methods contained in Part 1 would be broadly comparable to that contained in the current Phase 1 project report. It would therefore be possible to produce Part 1 relatively quickly, and certainly within a one year time scale. In the first instance, Part 1 would direct the reader to the existing method documentation in its various guises, i.e. existing dedicated methods manuals (e.g River Corridor Survey, National Rivers Authority, 1992), internal reports and memoranda, R&D outputs or publications in the literature as appropriate. Part 1 would be progressively updated as individual volumes of Parts 2 and 3, the definitive method statements, were issued.

6.5 Proposed contents of Part 2 - Manual for Biological Methods

It is proposed that Part 2 should comprise a series of general volumes covering topics and issues applicable to many biological methods. Titles for inclusion in Part 2 might include, *inter alia*, the following:

- **Quality assurance in biological surveys, sampling, identification and analysis**
  Although individual methods will have their own specific quality assurance requirements detailed in the Method Handbooks in Part 3 of the Manual, the general principles of quality assurance are common to all methods. A quality assurance volume would seek to encourage a climate of quality awareness, not just within the Agency, but for contractors, consultants and others whose biological data the Agency may need to use or assess.

- **A guide to biological identification**
  This should comprise a bibliography of identification keys and reference works relating to the full range of taxonomic groups together with general comments relating to the ease of use, comprehensiveness, identification level and general applicability of each work cited. For the more difficult groups, (i.e. those with which most biologists are likely to be unfamiliar, or for which identification keys are lacking) sources of assistance and recognised expertise, both within and outside the Agency, should be given.

- **A guide to the collection and preservation of biological materials**
  There are a number of situations in which it may be valuable to make reference collections of biological materials for confirmation of identification etc. General guidance on when and how this should be done would be useful.

- **The timing of field surveys**
  Many biological surveys are partially or wholly limited by seasonal constraints. Although biologists may be well aware of these constraints, their various customer groups are frequently not. General guidance on what can be done when and with what level of confidence would therefore be very useful.

- **The design and management of surveys and monitoring programmes**
  This volume should cover the basic strategies for selecting the number and location of sampling sites, frequency of sampling, choice of taxonomic group(s) or population parameter to be measured etc. These variables should be discussed in relation to the stated objectives of the proposed programme, the acceptable confidence limits, the level of change to be detected and how these requirements can be balanced against resource constraints.

- **A guide to the statistical analysis of biological samples, surveys and monitoring programmes**
  This volume should cover statistical procedures, the availability and applicability of software packages, availability of training programmes etc.

- **Health and Safety in biological field work**
  This should cover the general principles of safe working in the field and should direct the reader to individual codes of practice for specific situations where these exist, e.g. Code of Practice for Safety in Electric Fishing (Environment Agency, 1996i). Safe working practices are already well established within the Agency. However, the Agency has a potential legal liability in respect of its contractors and consultants and a moral responsibility to any third party that may wish to use one of its standard methods. A dedicated volume on safety on fieldwork is therefore an essential component of the biological methods manual.

A major part of the information suggested for inclusion in Part 2 of the Manual either already exists within the Agency, or would be essentially simple to produce. The compilation of Part 2 of the Manual for Biological Methods would therefore be a relatively straightforward and rapid exercise.

6.6 Proposed format for Part 3 - Manual for Biological Methods

6.6.1 Grouping of methods and procedures

As a general principle, it is suggested that each method should have a detailed procedural volume of its own, an individual Method Handbook, which should cover all aspects of the method from field survey/sample collection to the reporting of results. However, it is apparent that in a significant number of cases, there will be substantial elements of commonality between methods. It would therefore be logical to either group similar methods, or to produce individual stand-alone handbooks for widely used procedures, or to use both of these approaches as appropriate.

There are a number of obvious instances where grouping of procedures would be appropriate. For example, a substantial number of methods require the collection of freshwater macroinvertebrate samples and in many cases, the same method of sampling is stipulated. It is therefore logical to have a 'Procedures for Invertebrate Sampling Methods' Handbook that would be a companion volume to any of the individual invertebrate method Handbooks. Likewise with fish survey and assessment work, procedures for the computation of population statistics are essentially common to any capture technique. In this case also, it would be logical to produce a specific 'Fish Population Statistics' Handbook separate from the Handbooks describing the individual capture techniques.

The 'grouping of methods and procedures' approach would offer the major advantage of avoiding multiple repetition of large quantities of material. However, if this approach is taken for Part 3 of the Manual, then any requirement for companion volumes must be explicitly stated in Part 1. This will avoid user frustration on the discovery that, having finally acquired the desired method Handbook, two other volumes are required to go with it.

6.6.2 Proposed format for individual Method Handbooks

It is proposed that, as a general rule, individual Method Handbooks should follow a standard format with information grouped under the following general topics or headings. It must be recognised however that for some methods, additional headings may be required, or that some standard headings may be redundant.

Scope of method

It is vital that the scope of the method is clearly defined. The scope of a method will be given in a parent document but it should be given, in an expanded form, at the beginning of its specific Method Handbook. This section should describe the circumstances in which the method is appropriate and may refer to other methods which are more useful in certain other situations.

The aim of the method, the habitats in which it can be used, the type of information which it produces and the business needs which can be addressed should all be discussed in this section.

Current status and history

This section should give a succinct account of the main stages in development of the method through external and/or Agency R&D and planned/potential future developments. Key references should be cited. The status of the method within the Agency, e.g. Regional or National standard method, currently under evaluation etc., should be stated. The status within other organisations should also be given. The latter should cover adoption by national and international standardisation organisations such as British Standards Institute (BSI), European Committee for Standardisation (CEN) and International Standards Organisation (ISO) and the use of the method outside the Agency (by MAFF, SEPA, English Nature etc.).

Contact point

No matter how thoroughly validated a method might be, it is inevitable that unexpected problems will arise, or that there will be situations in which the method falls short of expectation. The most effective way of identifying shortcomings and limitations, potential for improvement or extension, novel applications etc. is through user experience and ideas. A key Agency Contact should therefore be identified for each method so that user comments can be collated and the need for, and scope of, additional R&D identified.

Scientific rationale

This section should explain the underlying scientific principles on which the method is based. For a method to be applied appropriately and effectively, it is important that users understand the rationale of what they are doing, rather than simply follow a recipe.

Resources

The resources required to implement the method should be clearly defined and cover equipment and manpower. There may also be minimum training requirements for personnel and this should be clearly stated. If there are different equipment and/or manpower requirements for various stages of the method (e.g. field sampling, identification in the laboratory) these should be defined.

Methodology

Detailed instructions are required for all stages of method implementation and the issues given below should be addressed where they are applicable to the method in question. In some instances particular steps in the procedure or other issues relating to the method would be dealt with by cross-reference to other volumes in Part 2 or Part 3 of the Manual.

a) Sampling and field procedures

- location and number of sampling sites;
- number of samples required at each site;
- frequency of sampling;
- date (season) of sampling;
- health and safety considerations;
- specifications of sampling equipment;
- operation of equipment and sampling procedure;
- recording of relevant additional information (e.g. NGR, stream depth and width);
- sample handling, labelling, fixing (if necessary) and transportation.

b) Handling in laboratory and identification

- sample treatment procedures;
- minimum required level of identification;
- use of identification keys (recommendations for relevant identification literature) or other tools (e.g. algal image data base);
- preservation and long-term storage (if required).

c) Data analysis

- calculation of scores or indices;
- reporting and presentation of results;
- data handling and storage.

d) Quality assurance

- equipment records;
- adherence to methods;
- sampling variability;
- environmental data variability;
- sample handling;
- identification variability;
- data handling errors;
- audit of identification;
- quality control of score/index calculation;
- training requirements and records;
- details of AQC schemes and audits.

e) Additional information

- glossary of terms;
- references;
- list of suitable identification keys.

6.7 Proposed format for Part 4 - Manual for Biological Methods - Current Awareness

Part 4 would comprise a current awareness bulletin. This would provide up to date information on topics such as:

- methods under development through the Agency's R&D programme;
- methods being developed, reviewed or introduced by other UK organisations;
- methods introduced in Europe, the USA and other parts of the world;
- abstracts of papers on methods published in the literature;
- reviews of new books on biological methods, biological monitoring and other relevant topics;
- reports of novel applications for established methods.

Part 4 would be of considerable potential value and interest to practitioners in the Regions but would only be a realistic proposition if the Manual were to be produced in electronic format (discussed in Section 6.8 below).

6.8 The Manual for Biological Methods in electronic format

It is strongly recommended that serious consideration should be given to production of the Manual for Biological Methods in electronic format so that it is freely available on-line. There are a number of advantages that the Agency would gain from such an approach.

- It would allow regular updating (even minor updating) of existing methods and the inclusion of new methods without the need for new print runs of major sections of the Manual.
- In particular, electronic format would provide a very cost-effective mechanism for the Agency to ensure that Part 1 (the index and applications section) was always up to date (Part 1 will evolve continuously as the Manual as a whole evolves).
- Electronic format provides the only practical vehicle for Part 4 of the Manual (the Current Awareness Bulletin).
- Potential users would be able to scan the methods available, select those relevant to their particular needs and download the instructions for those methods only. Copies of the downloaded methods could then be taken into the field, which would not be appropriate for a large printed manual.
- Inclusion of a 'keyword search' facility would enable users, unaware of which method to use, to access their desired topic area directly.
- Incorporation of a hypertext link (e.g. push button link which automates email process) with each method would provide a very effective pathway for method users to send in comments and experiences and for these to be collated.
- An electronic format manual would allow for the inclusion of action clips, for example of operators undertaking particular activities such as sampling (the Agency has already produced training videos for invertebrate sampling, and others, such as marine macrobenthic field methods, are planned).
- As indicated in Section 6.2, there are compelling reasons for targeting the Manual at a much wider UK audience than the confines of the Agency itself. An electronic manual, accessible via the Environment Agency Web Site, would provide the simplest and most cost effective mechanism for achieving this objective.
- If the Agency views itself as a world leader in its fields of activity, and as a consequence regards European or wider international recognition and adoption of its strategies, approaches and methods as a desirable goal, then the free availability of material such as the proposed Manual for Biological Methods via the Internet provides an extremely effective shop window.

For the reasons listed above, electronic format would significantly enhance the proposed manuals user-value. Whilst initially the objective should be to produce a basic methods manual, electronic format would ultimately allow the Manual to be developed well beyond its current concept. In particular, Part 4 lends itself to longer-term expansion and development on an interactive basis with links to Agency and other specialist topic centres and the incorporation of a searchable database of information sources. In this way the Manual for Biological Methods becomes an invaluable guide to best practice for key areas of environmental technique and gains a wide, potentially international, readership.

Whilst all of the benefits discussed above become readily available if the manual is published in electronic format, many of the benefits are denied or curtailed if publication is restricted to hard copy only. In contrast, restriction to hard copy offers no obvious benefits but it is recognised that Information Technology (IT) resources are currently limited within the Agency and the adoption of the proposed electronic format would require additional IT expertise to create and maintain facilities.

6.9 Summary of proposals and proposed programme and timescales for implementation

The proposed Manual for Biological Methods should be seen as a vehicle for disseminating awareness and good practice in the application of biological methods, aimed at a broad audience within the Agency and amongst those with whom the Agency interacts. It is proposed that the Manual should be produced in electronic format, as this would provide the most cost-effective mechanism for developing and updating the Manual, and for keeping Manual users appraised of the latest method developments within the Agency.

It is further proposed that the Manual should be produced in four Parts, where Part 1 provides an overview and guide to the Manual, Part 2 consists of a series of volumes on general topics, Part 3 comprises the individual Method Handbooks and Part 4 is a current awareness bulletin.

The proposed manual format has been selected for two primary reasons:

- it provides a simple and logical framework which can be readily updated and expanded;
- it allows for the stepwise production of the Manual and permits maximum interim use to be made of existing documentation.

Stage One of manual production would entail the compilation of the first working edition of Part 1 and its catalogue and review of existing methods and documentation. Parts 2 and 3 would consist of the collected existing documentation in its currently diverse styles and levels of detail. Much of the groundwork for Stage One of manual production has already been undertaken in Phase 1 of the project. It should thus be possible to have a prototype, albeit somewhat disjointed and skeletal, version of the Manual in place for review within one year. Ideally this would include a specimen volume of Parts 2 and 3 to allow some concrete criticism at this early stage.

Stage Two of manual production would be to collate, edit, reformat (and where necessary expand) the collected method documentation and material into the definitive Part 2 and Part 3 formats. It should be possible within the second year to have fully incorporated the majority of currently well established methods into the Manual and to have revised Part 1 accordingly. Thus a realistic target would be to have a recognisable and functional product in use within a time frame of some two years.

Manual development would then move into Stage Three, an extension phase, where new and more peripheral methods are brought into the overall framework and into Stage Four, a maintenance phase, where established parts of the manual are monitored and updated as required.

7. APPROACH TO NEW METHOD DEVELOPMENT

7.1 Introduction

The development of new biological methods needs to be undertaken in a logical and coherent manner. A useful initial step is to identify needs at a macro-level, that is to identify broad areas where biological methods are currently poorly developed and which should thus form the focus for new method development, perhaps through specialist topic centres or topic groups.

Gross pollution in Western Europe is now largely controlled, or at least in the process of being controlled, and, with a few notable exceptions, rapidly ceasing to be a major issue in most areas. The need to devise biological monitoring methods that parallel or mirror basic chemical monitoring is no longer the main priority. Firstly, this monitoring need is largely met by existing methods and secondly, the need is receding. Although problems of acute toxicity/pollution still persist.

The need now is for methods orientated towards the conservation/biodiversity/biotic integrity/ecosystem health spectrum. Within this spectrum, several priority areas where methods are not currently well developed, or are not currently adopted as Agency or National Standards can be identified. These areas include the following:

- an ecological window in general quality assessment i.e. biotic integrity/biodiversity/key species and habitats;
- methods for toxicity based consent/controls;
- development of biomarker methods (particularly for early warning systems, i.e., to detect ecosystem stress at the organism level);
- methods of determining critical loads of pollutants and monitoring exceedance in sensitive habitats (e.g. aquatic eutrophication, airborne pollutants on terrestrial habitats).

The Environment Agency has a very broad environmental management/monitoring remit and cannot address this in isolation. There needs to be a unified national approach to monitoring strategy and monitoring method development involving all of the key statutory agencies and perhaps some of the major voluntary organisations. The parochial approach is no longer viable or desirable. Current issues affect all media and are often not readily compartmentalised between agencies. In practice, current and future key issues are trans-boundary and pan-European, if not global. The Agency therefore needs to work with its counterparts in other EU countries, with EEA topic centres and the European Commission, ISO, CEN etc. in order to formulate unified European monitoring strategies and methods. Ultimately, the European environment must be managed as an entity, which requires that data from different agencies and different countries is directly comparable. Therefore the move must be towards international standardisation of data collection. The roles of the various national and international standards organisations in this respect are outlined in Section 7.4 below.

7.2 Management of biological method development

The establishment of a Biological Methods Development Group would provide the most logical mechanism for managing the development of new biological methods. The principal remit of the Group would be to identify and prioritise needs for new biological methods and feed proposals into the Agency's R&D programme. The Agency's Development Group should include representatives from key-player UK organisations involved in biological monitoring. These organisations could include, *inter alia*, MAFF; SEPA; EN/CCW/SNH; NERC (ITE, IFE); NETCEN; Forestry Authority; WWT; BTO. The Group should have clearly identified contact points within the Agency so that it can receive and consider bottom-up proposals. The Group should also contain representatives from, be represented on, or establish links with, relevant European bodies.

The Agency has already proposed the establishment of a *Collaborative Forum* (Environment Agency 1996a) with the objective of developing inter-agency harmonisation of environmental monitoring within a unified UK strategy. The suggested Biological Methods Development Group could operate within the framework of the Collaborative Forum. Within the Biological Methods Development Group, specialised groups will be responsible for the development of their areas of expertise, for example the marine group will develop marine methods.

7.3 Procedure for biological method development

The development of new methods should follow a sequence of logical steps as follows.

7.3.1 Definition of need for method

The definition of need should address several issues. It should define the problem that the method is seeking to address. It should define the performance targets of the method, i.e. its required information output. It should identify the priority for developing the method whereby:

- *Priority 1*: the method is needed to meet statutory obligations;
- *Priority 2*: the method is needed for fulfilling established strategy, policy or programme requirements;
- *Priority 3*: the method would be a useful adjunct to current statutory or non-statutory activities, or it is recognised as a probable future requirement.

7.3.2 Initial scoping study

The scoping study should address two principal issues.

- *Who should develop the method*? Should the Agency be developing the method alone, should it be one of the other UK agencies, should the method be developed jointly with other UK agencies or internationally? For example, if a method is likely to be used by MAFF or EN on a regular basis but only occasionally by the Agency, then it should fall to one of those organisations to develop it. If several agencies need a method then they should develop it together rather than duplicate effort. If method development is in response to an international need and that ISO or CEN recognition is the ultimate aim, then method development on a multinational basis would be the logical route to follow. This idealised division of labour not withstanding, for Agency Priority 1 methods, where time may be of the essence, expediency may dictate that the Agency undertakes the method R&D on a unilateral basis.
- *On what principles should the method be based*? This should review methods in use in other countries or published in the literature to identify methods with potential for adaptation or development. If it is necessary to start from first principles, these principles should be defined.

The scoping study therefore defines the remit and requirements of the main R&D programme.

7.3.3 Method development

Develop one or more methods to the draft method stage. This should involve limited method testing, e.g. within one Agency Region or on a selected set of UK or European rivers etc. The outcome should be a Draft Method Protocol. Quality assurance requirements should be considered at all stages of this process.

7.3.4 National validation and calibration

The Draft Method Protocol should be taken forward through a national testing exercise. The method protocol can then be modified if required and a final protocol produced for introduction as an Agency or National Standard. If the method is being developed as a replacement for an existing method, then it should be calibrated against the old method. Failure to calibrate may mean that temporal trend analysis is compromised. To take an example from urban air pollution monitoring, this first measured black smoke, then measured total particulates, and now measures PM_{10} and $PM_{2.5}$. Trend analysis is now difficult because both the methods of measurement and the principal sources of pollution have changed.

7.3.5 Introduction as an Agency or National Standard Method

Introduction of a new standard method will require two key actions:

- introduction of a Standard Method Handbook;
- provision of training programmes if the method involves novel systems of data collection or analysis.

7.3.6 International standardisation

Once adopted nationally, methods should be put forward to ISO, CEN etc. for consideration as international standards.

7.4 National and international standardisation organisations

7.4.1 Introduction

There are several national and international organisations involved in the production of standard biological methods, which are relevant to the Agency's business needs. Standardisation ensures a basic level of methodological quality and allows for comparisons between workers. Such comparisons are important in the light of European Directives. Future Directives may require more standardisation of methods used within Europe and, therefore, it is vital that the Agency is extensively involved in the proposal of international standard methods. The involvement of the Agency with these standardisation organisations is similar to that of the NRA, which is described in Logan (1993).

7.4.2 The Standing Committee of Analysts

The Standing Committee of Analysts (SCA) was incorporated into the Environment Agency in 1996. Previously it had been involved in the production of 'Standard Methods for the Quality Control of the Water Cycle' (Standing Committee of Analysts, 1993) but its remit is now expanded to cover air and soil, including contaminated land (Standing Committee of Analysts, 1996). SCA is responsible for the familiar 'blue books' which have dealt with a wide range of biological methods including those dealing with macroinvertebrates (Standing Committee of Analysts, 1978, 1980, 1983a, 1983b) algae (Standing Committee of Analysts, 1982, 1990, 1993), macrophytes (Standing Committee of Analysts, 1985, 1986, 1991) and fish (Standing Committee of Analysts, 1983c).

7.4.3 British Standard Institute (BSI)

The British Standards Institute (BSI) is an independent organisation involved in the production of standards. Relevant standards are developed by the Technical Committee EPC/44-. Water quality and biological methods are dealt with by subcommittee EPC/44/5-. The Environment Agency is represented on this subcommittee by Roger Sweeting and Paul Logan, both based in Thames Region.

7.4.4 International Standards Organisation (ISO)

The International Standards Organisation (ISO) committee, which deals with water quality, is ISO/TC 147. Over 60 countries participate in this committee and currently about 120 water quality standards are available (Logan, 1993), although most of these deal with water chemistry. Many of the ISO methods dealing with biological methods are guidelines rather than prescriptive methods. ISO methods are reviewed every five years.

7.4.5 European Committee for Standardisation (CEN)

The European Committee for Standardisation (CEN) covers the countries of the EC and the European Free Trade Area. The CEN technical committee CEN/TC 230 'Water Analysis' has a similar remit to ISO/TC 147 described above. Methods covered by CEN are frequently driven by European Directives, particularly if suitable ISO methods are not available. If ISO methods are available they are typically adopted by CEN without modification. CEN methods do not undergo review at present.

7.4.6 Relationships between these organisations

Agency methods can become national standards via their adoption by SCA or BSI. Only when established as national standards can methods go on to be considered as international standards. Furthermore, BSI standards must not be in conflict with international standards. Both CEN and ISO have a relatively lengthy review and voting process for the determination of new standards.

7.4.7 Future developments

There are several standards in the development stage which are of interest to the Agency. ISO and CEN are jointly involved in the development of a set of standards relating to the biological classification of rivers using macroinvertebrates. This is in three parts, the first of which discusses systems of classification and guidance on the development of classification systems. The second part deals with the presentation of results, for example maps. The third part is being developed by CEN only and relates to the interpretation of classifications. A CEN working group is just starting to address algal and macrophyte methods and the Agency is being represented by Martin Kelly. CEN are also involved in the development of standard fish sampling methods and will be addressing habitat surveys of rivers in the near future.

7.4.8 Conclusions

Methods tend to be well established before they are adopted as national or international standards and therefore they are not likely to be unfamiliar to the Agency. In fact they may be derived from methods which are well defined within the Agency (e.g. three-minute kick sample). Therefore, national and international standards are not likely to be useful in fulfilling the immediate needs of the Agency for new methods. However, it is vital that the Agency maintains a high profile in the development of both the international and national standards so that its methods receive adequate attention. In the future this may become more important if standard methods are to be adopted throughout Europe.

8. SUMMARY OF KEY POINTS FROM PHASE 1 STUDY

The following key points have emerged from Phase 1 of the Manual for Biological Methods R&D project.

- In order to fulfil its many and varied functions and business needs, the Environment Agency will require a comprehensive suite of tested and standardised biological methods, each of which is fully documented and backed by appropriate quality assurance procedures.
- There is a clear need for a comprehensive Manual for Biological Methods that should be progressively expanded and updated as new methods become available. It is proposed that the Manual should consist of four parts, namely:
  Part 1 - the parent document - a guide to manual and the availability and applicability of biological methods;
  Part 2 - a series of general volumes on issues common to many methods;
  Part 3 - a set of Method Handbooks, each of which addresses an individual method in detail;
  Part 4 - a current awareness bulletin.
- The development of new biological methods should be managed within the framework of the Agency's proposed unified national approach to monitoring strategy. A Biological Methods Development Group, comprising representatives from key-player UK organisations involved with biomonitoring, should be established to identify and prioritise needs for new biological methods and feed proposals into the Agency's R&D programme.
- There is an urgent need for the development of a comprehensive, efficient and unified biological (including fisheries and conservation) data archiving system within the Agency to replace the current disparate arrangements. Ideally, unification and linking of data storage and retrieval should extend to all major UK government departments, agencies and organisations involved in environmental monitoring.
- Currently, biological methods are not used within the Waste Regulatory and IPC functions of the Agency. A stand-alone comprehensive review of the potential requirements of these functions for biological methods is essential.
- Despite being central to all Agency functions, wildlife conservation largely lacks standard methods. There is a clear need for a stand-alone review of conservation method needs coupled with a critical assessment of methods developed by UK conservation bodies.
- Methods for fishery assessment are generally well developed but there is little standardisation of methods and approach between Regions, or sometimes within Regions. The fisheries function also tends to stand somewhat apart from other biological activities within the Agency. There is scope for much closer integration of fisheries into the mainstream of biological and conservation activities, possibly as in Welsh Region.
- Plants and algae are not currently used to their full potential in aquatic monitoring, assessment and management, although method development is proceeding on several fronts under the current R&D programme.
- There is a need for the standardisation and consolidation of marine methods and the development of new methods is required for some situations. Standardisation is being addressed by the National Marine Group.

- The development of methods for the assessment of ecological integrity and ecosystem health, especially the use of biomarkers, should be an important growth area within the Agency.
- Methods, which relate physical habitat quality to biological carrying capacity or biodiversity, would be of major value to the Agency but there are concerns as to the underlying scientific validity of such an approach. Substantial additional R&D is required before such methods can be formally adopted.

9. REFERENCES

Agrawal, M., Singh, S.K., Singh, J. and Rao, D.N. (1991). Biomonitoring of air pollution around urban and industrial sites. *Journal of Environmental Biology* **12**, 211.

Alcock, M.R. and Palmer, M.A. (1985). *A standard method for the survey of ditch vegetation.* CST Report 37. Nature Conservancy Council, Peterborough.

Alebic-Juretic, A. and Arko-Pijevac, M. (1989). Air pollution damage to cell membranes in lichens: Results of simple biological test applied in Rijeka, Yugoslavia. *Water, Air and Soil Pollution,* **47**, 1-2, 25.

Ammann, K., Herzig, R., Liebendörfer, L. and Urech, M. (1987). Multivariate correlation of deposition data of 8 different air pollutants to lichen data in a small town in Switzerland. *Advances in aeriobiology*, **51**, 401-406.

Anglian Region (1994). *Standard methodologies: Assessment of freshwater riverine environments using macrophytes. Final Draft.* Anglian Region, National Rivers Authority.

Anglian Region (1995a). *Standard Methodologies Freshwater Phytoplankton. Final Draft.* Anglian Region, National Rivers Authority, Peterborough.

Anglian Region (1995b). *Standard Methodologies Estuarine/Marine Benthic Macroinvertebrates.* Anglian Region, National Rivers Authority, Peterborough.

Anglian Region (1996). *Standard Methodologies Freshwater Zooplankton. Final Draft.* Anglian Region, National Rivers Authority, Peterborough.

Anglian Region (1997). *The development of a macrophyte method for use in lake/reservoirs.* Northern Area, Anglian Region, Environment Agency, Peterborough.

Antonsen, P. and Folkestad, B. (1993). Contaminated land in Norway: a nation-wide survey and clean-up action plan. *UNEP industry and environment*, **16**, 3, 7-10.

Archer-Thomson, J. (1991). *Guide to rocky shore investigation.* Occasional publication of the Field Studies Council, Preston Montford, Shropshire.

Armitage, P.D., Cannan, C.A. and Symes, K.L. (1997). *Appraisal of the use of ecological information in the management of low flows in rivers.* Environment Agency R&D Technical Report W72, Bristol.

Barnard, S. and Wyatt, R.J. (1995). *A guide to HABSCORE Field Survey Methods and the Completion of Standard Forms.* National Rivers Authority R&D Note 401, Bristol.

Barnes, A.P. and Hirst, I.D. (1995). *Fish Health Indices as a Marker of Surface Water Quality.* National Rivers Authority R&D Note 383, Bristol.

Barnett, B.E. (1990). *Guidelines for a bio-accumulation programme for the monitoring of persistent contaminants in estuaries and coastal waters. Final Version.* National Rivers Authority, Peterborough.

Barnett, B.E. (1993a). *National Standard Methodology for Marine Macrofaunal Benthic Sampling. I. Intertidal Soft Sediments.* National Rivers Authority, Internal Document.

Barnett, B.E. (1993b). *National Standard Methodology for Marine Macrofaunal Benthic Sampling. III. Guidelines for Sample Pre-treatment for Marine Benthic Invertebrate Samples.* National Rivers Authority, Internal Document.

Bass, J.A.B., May, l., Esteban, G.F. and Collett, G.D. (1997). *Zooplankton interactions in the River Thames.* IFE Report, Re.: No: T04073 7/1. Environment Agency (Thames Region), Reading.

Barker, I. And Kirmond, A. (1997). *Surface Water Abstraction Licencing Procedure. Guidance for application of proposed methodology working draft Version 1.1.* Environment Agency, Bristol.

Bates, J.W., McNee, P.J. and McLeod, A.R. (1996). Effects of sulphur dioxide and ozone on lichen colonization of conifers in the Liphook Forest Fumigation Project. *New Phytologist* **132**, 4, 653-660.

Benton, J., Fuhrer, J., Skarby, L. and Sanders, G. (1995). Results from the UNECE ICP-Crops indicate the extent of exceedance of the critical levels of ozone in Europe. *Water, Air and Soil Pollution,* **85**, 3, 1473-1478.

Biological Quality Objectives Sub-Group (1997a). *Biology Quality Objectives for rivers – Version 3.* Rivers Group and Water Quality Function Group, Environment Agency, Bristol.

Biological Quality Objectives Sub-Group (1997b). *Guidelines for local variations to BQOs – Version 1.* Rivers Group and Water Quality Function Group, Environment Agency, Bristol.

Bird, G. (1993). *A biological survey of Jackson's Bay, Scarborough, to record possible ecological recovery after closure of the short sewage outfalls, July 1993.* Dales Area, Northumbria and Yorkshire Region, National Rivers Authority.

Boon, P.J., Holmes, N.T.H., Maitland, P.S., Rowell, T.A and Davies, J. (1997). A System For Evaluating Rivers For Conservation (SERCON): Development, Structure and Function. In *Freshwater Quality: Defining the Indefinable,* Boon, P.J. and Howell, D.L. (Eds), The Stationary Office, Edinburgh.

Bovee, K.D. (1982). *A guide to stream habitat analysis using the Instream Flow Instrumental Methodology.* US Fish and Wildlife Service, Instream Flow Information Paper No.12, FWS/OBS – 82/26.

Brakenhielm, S. (1996). *Impacts of air pollutants on processes in small catchments. Integrated monitoring 1982-1995 in Sweden.* Swedish Environmental Protection Agency Report 4524.

Brakenhielm, S. and Qinghong, L. (1995). Spatial and temporal variability of algal and lichen epiphytes on trees in relation to pollutant deposition in Sweden. *Water, Air and Soil Pollution,* **79**, 1-4, 61.

British Trust for Ornithology, (1992a). *Waterways Bird Survey: Instructions.* British Trust for Ornithology, Thetford.

British Trust for Ornithology, (1992b). *National Low Tide Counts: Detailed instructions.* British Trust for Ornithology, Thetford.

British Trust for Ornithology, (1993), *Common Bird Census: Instructions.* British Trust for Ornithology, Thetford.

British Trust for Ornithology, (undated a) *Instructions to counters: Breeding Birds of Wet Meadows.* British Trust for Ornithology, Thetford.

British Trust for Ornithology, (undated b) *Wetland Bird Survey: Instructions.* British Trust for Ornithology, Thetford.

Brown, M.J., Dyke, H., Wright, S.M, Wadsworth, R.A., Bull, K.R., Farmer, A., Bareham, S., Metcalfe, S.E., Whyatt, D. and Powesland,C. 1995. Estimating the impact of air pollution on environmentally valuable sites. *Water, Air and Soil Pollution*, **85**, 2589–2594.

Bull, K.R. (1991). The critical loads/levels approach to gaseous pollutant emission control. *Environmental Pollution*, **69**, 105-123.

Bullock, A., Gustard, A. and Grainger, E.S. (1991). *Instream Flow Requirements of Aquatic Ecology in Two British Rivers, Application and assessment of the Instream Flow Incremental Methodology using the PHABSIM system.* Institute of Hydrology, Report No. 115, Wallingford.

Burton, M.A.S. (1986). *Biological monitoring (plants).* MARC Report Number 32, King's College, London.

Chandler, J.R. (1970). A biological approach to water quality management. *Water Pollution Control*, **69**, 415-422.

Clarke, K.R. and Warwick, R.M. (1994). *Change in marine communities. An approach to statistical analysis and interpretation.* Natural Environment Research Council, Swindon.

Clemments, D.K. and Tofts, R.J. (1992), *Hedgerow Evaluation and Grading System (HEGS) - A Methodology for the Ecological Survey, Evaluation and Grading of Hedgerows (Test Draft).* Countryside Planning and Management, Cirencester.

Codling, I.B., Warwick, R.M., Clarke, K.R. and Ashley, S.J. (1995). *Assessment of feasibility using macrobenthic community status to describe the general quality of coastal waters and estuaries.* National Rivers Authority Project Record 469/19/HO, Bristol.

Coles, T.F., Whortley, J.S. and Noble, P. (1985). Survey methodology for fish population assessment within Anglian Water. *Journal of fish biology*, **27**, Supplement A, 175-186.

Culling S. (1992). *National Standard Methodology for Marine Macrofaunal Benthic Sampling. II. Subtidal Soft Sediments.* National Rivers Authority Internal Document.

Davies, G., Butler, D., Mills, M. and Williams, D. (1997). A survey of ferruginous minewater impacts in the welsh coalfields. *Journal of the Chartered Institute of Water and Environmental Management*, **11**, 140-146.

de Leeuw, F.A.A.M. and van Zantvoort, E.D. G. (1997). Mapping of exceedances of ozone critical levels for crops and forest trees in the Netherlands: preliminary results. *Environmental Pollution*, **96**, 1, 89-98.

Department of the Environment (1993). *Air pollution and tree health in the UK.* HMSO, London.

Department of the Environment (1994). *Biodiversity, The UK Action Plan.* HMSO, London.

Department of the Environment (1995). *Biodiversity: The UK Steering Group Report.* HMSO, London.

Dowding, P. (1994). Leafyeast survey for air pollution monitoring. In: *Biological monitoring of the environment*, Salanki, J., Jeffrey, D. and Hughes, G. M. (Eds), IUBS Methodology series CAB International, Oxon, UK.

Dowding, P. and Richardson, D. H. S. (1990). Leafyeasts as Indicators of Air Quality in Europe. *Environmental Pollution,* **66,** 3, 223-235.

Duncan, A. and Kubecka, J. (1993). *Hydroacoustic methods of fish survey.* National Rivers Authority R&D Note 196, Bristol.

Earll, R. (1992). *The SEASEARCH Habitat Guide - an identification guide to the main habitats found in the shallow seas around the British Isles.* Marine Conservation Society and Joint Nature Conservation Committee, Peterborough.

Elmes, J.P. (1996). *An investigation of the Cockle (*Cerastoderma edule L.*) population on Seal Sands and the potential of such a population for monitoring of sensitive inter-tidal areas.* North East Region, National Rivers Authority.

Environment Agency (1996a). *Viewpoints on the Environment: Developing a National Environmental Monitoring and Assessment Framework.* Environment Agency, Bristol.

Environment Agency (1996b). *The quality of rivers in England and Wales (1990 to 1995).* Environment Agency, Bristol.

Environment Agency (1996c). *The Agency's Conservation Duties.* Sustainable Development Section publication series, SD2 Environment Agency, Bristol.

Environment Agency (1996d). *Environmental assessment: scoping handbook for projects.* HMSO, London.

Environment Agency (1996e). *Introductory Guidance on the Agency's Contribution to Sustainable Development.* Sustainable Development Section publication series, SD1, Environment Agency, Bristol.

Environment Agency (1996f). *The Environment of England and Wales. A Snapshot.* Environment Agency, Bristol.

Environment Agency (1996g). *Invertebrates of exposed riverine sediments (ERS).* National Rivers Authority R&D Project Record W1/I525/1; R&D Technical Summary W43.

Environment Agency (1996h). *Methodology for the assessment of freshwater riverine macrophytes for the purposes of the Urban Waste Water Treatment Directive Version 2.* Environment Agency, Bristol.

Environment Agency (1996i). *Code of practice for safety in electric fishing operations.* Environment Agency, Bristol.

Environment Agency (1996j). *The application of toxicity-based criteria for the regulatory control of wastewater discharges.* Environment Agency Consultation Document, Bristol.

Environment Agency (1996k). *The application of toxicity-based criteria for the regulatory control of wastewater discharges.* Response Compendium Environment Agency Document No. SO/3/97/1000/AYAM. Bristol.

Environment Agency (1996l). *Certification scheme for laboratories involved in toxicity-based consent testing and monitoring.* Environment Agency Consultation Report, Bristol.

Environment Agency (1997a). *A Strategy for Implementing the Environment Agency's Contribution to the UK Biodiversity Action Plan.* Sustainable Development Section publication series, SD7. Environment Agency, Bristol.

Environment Agency (1997b). *Procedures for collecting and analysing macroinvertebrate samples.* Quality Management Systems for Environmental Monitoring: Biological Techniques, BT001. Environment Agency, Bristol.

Environment Agency (1997c). *Procedure for collecting and analysing macroinvertebrate samples for GQA surveys.* Quality Management Systems for Environmental Monitoring: Biological Techniques, BT002. Environment Agency, Bristol.

Environment Agency (1997d). *Procedure for Quality Assurance for RIVPACS compatible macroinvertebrate samples analysed to the taxonomic level needed for the BMWP-score system.* Quality Management Systems for Environmental Monitoring: Biological Techniques, BT003. Environment Agency, Bristol.

Environment Agency (1997e). *Direct toxicity assessment (DTA) demonstration programme.* Update sheets series. Environment Agency, Bristol.

Environment Agency (1997f). *A register of approved laboratories undertaking toxicity testing.* Environment Agency Draft R&D Note, Bristol.

Environmental Advisory Unit (1993a). *Impact assessment and acceptable conservation criteria: area A - conservation criteria and river flow parameters - Phase 1.* National Rivers Authority R&D Note 212, Bristol.

Environmental Advisory Unit Ltd. (1993b). *Review of Nature conservation Survey Methodologies.* National Rivers Authority R&D Note 107, Bristol.

Environmental Change Network (1997). *Environmental Change Network (ECN). Draft freshwater protocols – macrophytes.* Environmental Change Network FMA.

ERL (1993a). Mytilus edulis *as a Monitor of Red List Organochlorines in Marine Ecosystems: A method for the sampling, treatment and analysis of the mussel* Mytilus edulis *to monitor Red List organochlorines in marine ecosystems.* Final Report. National Rivers Authority, Bristol.

ERL (1993b). Fucus *and* Enteromorpha *as Monitors of Red List Organochlorines in Marine and Estuarine Ecosystems: A method for the sampling, treatment and analysis of the seaweeds* Fucus *and* Enteromorpha *to monitor Red List organochlorines in marine ecosystems.* Draft Report. National Rivers Authority, Bristol.

Extence, C. and Chadd, R. (1996). *The conservation of aquatic macroinvertebrate populations - a community based classification scheme.* Environment Agency, Anglian Region. Northern Area.

Extence, C.A., Bates, A.J., Forbes, W.J. and Barham, P.J. (1987). Biologically based water quality management. *Environmental Pollution,* **45**, 221-236.

Furse, M.T., Winder, J.M., Symes, K.L., Clarke, R.T., Gunn, R.J.M., Blackburn, J.H. and Fuller, R.M. (1993). *The faunal richness of headwater streams: Stage 2 - Catchment studies - main report.* National Rivers Authority, R&D Note 221, Bristol.

Gardiner, A.J., (1996). *Freshwater Wetlands in England, A Natural Areas Approach.* English Nature Research Reports, No.204, Peterborough.

George, D.G. (1997a). *Environmental Change Network (ECN). Draft freshwater protocols – phytoplankton.* Environmental Change Network FPP.

George, D.G. (1997b). *Environmental Change Network (ECN). Draft freshwater protocols – crustacean zooplankton.* Environmental Change Network FZP.

Gimeno, B.S., Penuelas, J., Porcuna, J.L. and Reinert, R.A. (1995). Biomonitoring ozone phytotoxicity in eastern Spain. *Water, Air and Soil Pollution,* **85**, 3, 1521-1526.

Giovani, C., Nimis, P.l., Bolognini, G., Padovani, R. and Usco, A. (1994). Bryophytes as indicators of radiocesium deposition in northeastern Italy. *Science of the Total Environment*, **157**, 1-3, 35-43.

Gnamus, A., Horvat, M. and Stegnar, P. (1995). The mercury content among deer and of browsed foliage as a means of ascertaining environmental-pollution of the mining regions Idrija - a case-study from Slovenia. *Zeitschrift Fur Jagdwissenschaft*, **41**, 3,.198-208.

Gonzalez, C.M., Casanov, as, S.S. and Pignata, M.L. (1996). Biomonitoring of air pollutants, - from traffic and industries employing *Ramalina ecklonii* (Spreng.) Mey. And Flot. In Cordoba, Argentina. *Environmental pollution*, **91**, 269-277.

Gore, J.A. and Hamilton, S.W. (1996). The comparison of flow related habitat evaluations downstream of low-head weirs on small and large fluvial ecosystems. *Regulated Rivers: Research and Management*, **12**, 459-469.

Gregson, S., Clifton, S. and Roberts, R.D. (1994). Plants as bioindicators of natural and anthropogenically derived contamination. *Applied biochemistry and biotechnology*, **48**, 15-22.

Gstoettner, E.M. and Fisher, N.S. (1997). Accumulation of cadmium, chromium, and zinc by the moss Sphagnum *Papillosum lindle*. *Water Air and Soil Pollution*, **93**, No.1-4, 321-330.

Hanninen, O., Ruuskanen, J.I. and Oksanen, J. (1993). A method for facilitating the use of algae growing on tree trunks as bioindicators of air quality. *Environmental Monitoring and Assessment*, **28**, 3, 215.

Harvey, J. and Cowx, I.G. (1995). *Electric fishing in deep rivers*. National Rivers Authority R&D Note 303, Bristol.

Hawksworth, D.L. and Rose, F. (1970). Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichen. *Nature*, **227**, 145-148.

Heggestad, H.E. (1991). Origin of Bel-W3, Bel-C and Bel-B tobacco varieties and their use as indicators of ozone. *Environmental Pollution*,**74**, 264-291.

Herzig, R. and Urech, M. (1991). Flechten als bioindikatoren, integriertes biologisches Messystem der Luftverschmutzung fur das Schweizer Mittelland. *Bibl. Lichenologica*, **43**, 1-283.

Hiley, A. (1995). *Predation in Freshwater Macroinvertebrate Samples - Project Summary*. Northumbria Area, North East Region, National Rivers Authority.

Hill, M.O. (1995). *TABLEFIT Version 1.0 - For identification of vegetation types*. Institute of Terrestrial Ecology, Huntingdon.

Hiscock, K. (1990). *Marine Nature Conservation Review: Methods*. MNCR Occasional Report MNCR/OR/05. Nature Conservancy Council, Peterborough.

Hiscock, K. (1997 draft). *Measuring biological change for the management of marine protected areas: a handbook of methods*. Draft, JNCC, Peterborough.

Holmes, N.T.H. (1983a). *Classification of British rivers according to their flora*. Focus on Nature Conservation No. 3, Nature Conservancy Council, Peterborough.

Holmes, N.T.H. (1983b). *Typing Rivers according to their macrophyte flora*. Focus on Nature Conservation No. 4, Nature Conservancy Council, Peterborough.

Holmes, N.T.H. (1995). *Macrophytes for water and other river quality assessments.* A report to Anglian Region, National Rivers Authority, Peterborough.

Holmes, N.T.H. (1996). *The use of riverine macrophytes for the assessment of trophic status: review of 1994/95 data and refinement for future use.* A report to Anglian Region, National Rivers Authority, Peterborough.

Holmes, N.T.H. and Rowell, T. (1993). *British rivers according to their flora – Update.* Research contract report to Scottish Natural Heritage, Edinburgh.

Hugget, R.J., Kimerle, R.A., Mehrle, P.M. and Bergman, H.L. (1992). *Biomarkers: Biochemical, Physiological and Histological Markers of Anthropogenic Stress.* SETAC Special Publication Series, Lewis Publishers, pp 347.

Institute of Environmental Assessment (1995). *Guidelines for Baseline Ecological Assessment.* E & F N Spon, London.

Johnes, P., Moss, B. and Philips, G. (1994). *Lakes - classification and monitoring: A strategy for the classification of lakes.* National Rivers Authority R&D Note 253, Bristol.

Johnson, I. and Vine, S. (1993). *Body Burdens in Fish.* National Rivers Authority R&D 397/5/ST, Bristol.

Johnson, I.W., Elliot, C.R.N., Gustard, A., Armitage, P.D., Ladle, M., Dawson, F.H. & Beaumont, W.R.C. (1993). *Ecologically Acceptable Flows, Assessment of Instream Flow Incremental Methodology.* National Rivers Authority R&D Note 185, Bristol.

Joint Nature Conservancy Council (1993). *Handbook for Phase 1 habitat survey: a technique for environmental audit.* Joint Nature Conservation Committee, Peterborough.

Karr, J.R. (1981). Assessment of biotic integrity using fish communities. *Fisheries*, **6**, 21-27.

Karr, J.R. and Dudley, D.R. (1981) Ecological perspective on water quality goals. *Environmental Management*, **5**, 55-68.

Kelly, M.G. (1996). *The Trophic Diatom Index: A User's Manual.* Environment Agency R&D Technical Report E2, Bristol.

Kerans, B.L. and Karr, J.R. (1994). Development and testing of a benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. *Ecological Applications*, **4**, 768-785.

Kinley, R.D. and Ellis, J.C. (1991). *The application of statistical quality control methods to macroinvertebrate sampling.* Water Research Centre Report No. C02905, Medmenham, for Thames Region, National Rivers Authority.

Leblanc, F. and DeSloover, J. (1970). Relation between industrialisation and the distribution and growth of epiphytic lichens and mosses in Montreal. *Canadian Journal of Botany*, **48**, 1485-1496.

Levin, A.G. and Pignata, M.L. (1995). Ramalina Ecklonii as a bioindicator of atmospheric-pollution in Argentina. *Canadian Journal of Botany,* **73**, 8, 1196-1202.

Logan P. (1993). *Standardisation and Biological Methods.* National Rivers Authority, Thames Region Internal Memorandum M93208, Reading.

Lopez, J., Retuerto, R. and Carballeira, A. (1997). D665/D665a index vs. frequencies as indicators of bryophyte response to physicochemical gradients. *Ecology*, **78**, No.1, 261-271.

Loppi, S. and Corsini, A. (1995). Lichens as bioindicators of air quality in Montecatini Terme (central northern Italy). *Ecologia Mediterranea,* **21**, 3-4, 87-92.

Loppi, S., Francalanci, C., Pancini, P., Marchi, G. and Caporali, B. (1996). Lichens as bioindicators of air quality in Arezzo (central Italy). *Ecologia Mediterranea*, **22**, 1-2, 11-16.

Mainstone, C.P., Barnard, S. and Wyatt, R. (1994). *The NRA National Fisheries Classification Scheme: A guide for users*. National Rivers Authority R&D Note 206, Bristol.

Marchant, J.H., Langston, R. and Gregory, R.D. (1996). *The Waterways Bird Survey: an evaluation and appraisal of its future role.* Environment Agency R&D Technical Report W22, Bristol.

Margules, C.R. and Usher, M.B. (1981). Criteria used in assessing wildlife conservation potential. *Biological Conservation*, **21**, 79-109.

Marine Pollution Monitoring Management Group (1994). *UK National Monitoring Plan.* Marine Pollution Monitoring Management Group, Monitoring Coordination Subgroup. HMIP, London.

Marmorek, D.R. and Korman, J. (1993). The use of zooplankton in a biomonitoring program to detect lake acidification and recovery. *Water, Air and Soil Pollution*, **79**, 223-241.

McCarthy J.F. and Stugart, L.R. (Eds) (1990). *Biomarkers of Environmental Contamination.* Lewis Publishers, Boca Raton, Florida.

Mignanego, L., Biondi, F. and Schenone, G. (1992). Ozone biomonitoring in northern Italy. *Environmental Monitoring and Assessment,* **21**, 2, 141.

National Marine Biology Sub Group (undated). *Environmental impact assessment requirements for new marine outfalls - biological protocol.* National Marine Biology Sub Group, National Rivers Authority.

National Rivers Authority (1992). *River Corridor Surveys; methods and procedures.* Conservation technical handbook No.1, National Rivers Authority, Bristol.

National Rivers Authority (1994). *Implementation of the EC Freshwater Fish Directive – water quality requirements for the support of fish life.* National Rivers Authority Water Quality Series, No. 20, HMSO, London.

National Rivers Authority (1995a). *Scoping guidance for the environmental assessment of projects.* National Rivers Authority, Bristol.

National Rivers Authority (1995b). *Further guidance on the environmental assessment of projects.* National Rivers Authority, Bristol.

National Rivers Authority (1995c). *Detection of organic farm pollution: the use of a biological technique for the detection and monitoring of farm pollution.* National Rivers Authority R&D Report 19, Bristol.

National Rivers Authority (1995d). *1995 River Habitat Survey. Field methodology guidance manual.* National Rivers Authority, Bristol.

National Rivers Authority (1996). *River habitats in England and Wales. A national overview.* National Rivers Authority, Bristol.

National Rivers Authority and English Nature (1995). *Memorandum of Understanding on River SSSIs.* National Rivers Authority and English Nature.

National Water Council (1981). *River quality. The 1980 survey and future outlook.* National Water Council, London.

Nature Conservancy Council (1984). *River Corridor Survey: draft methodology*. Nature Conservancy Council, Peterborough.

Nature Conservancy Council (1989). *Guidelines for selection of biological SSSIs*. Nature Conservancy Council, Peterborough.

Nature Conservancy Council (1990). *Handbook for Phase 1 habitat survey, Vols. 1 and 2.* Nature Conservancy Council, Peterborough

Newman, J.R. and Dawson, F.H. (1996). *Guidance on interpretation of the Mean Trophic Rank system for assessment of trophic status of rivers using macrophytes. Use of MTR for the purposes of the UWWTD.* Environment Agency R&D Progress Report E1/I694/03, Bristol.

Nicholson, S.A., Aprahamian, M.W., Best, P.M., Shore, R.A. and Karr, E.T. (1995). *The design and use of fish counters*. Environment Agency R&D Note 382, Bristol.

North East Region (1996a). *Guidelines for monitoring methodologies for water resources projects Volume 2.* Internal Report, North East Region, Environment Agency.

North East Region (1996b). *Migratory Salmonid Monitoring Strategy.* Internal report, North East Region, Environment Agency.

North East Region (1996c). *Regional marine centre method manual.* Environment Agency, Regional Marine Centre, Newcastle.

Palmer, C.M., Bell, S.L. and Butterfield, I. (1992). A botanical classification of standing waters in Britain: applications for conservation and monitoring. *Aquatic conservation: marine and freshwater ecosystems*, **2**, 125-143.

Paoletti, M.G., Favretto, M. R., Stinner, B. R., Purrington, F. F. and Bater J.E. (1991). Invertebrates as Bioindicators of Soil Use. *Agriculture Ecosystems and Environment*, **34**, No.1-4, 341-362.

Patrick, S.T. and Monteith, D. (1997). *Environmental Change Network (ECN). Draft freshwater protocols – epilithic diatoms*. Environmental Change Network FDT.

Peakall, D. (1995). *Animal biomarkers as pollution indicators*. Chapman and Hall, London.

Pearsall, S.H., Durham, D., Eager, D.C. (1986). Conservation evaluation methods in the USA. In: *Wildlife Conservation Evaluation*, Usher, M.B. (Ed.).

Petts, G., Crawford, C. and Clarke, R. (1996). *Determination of minimum flows.* National Rivers Authority R&D Project Record S02/7/A, Bristol.

Petts, G.E. and Bickerton, M.A. (1997). *River Wissey Investigations: Linking Hydrology and Ecology. Manual for Using Macroinvertebrates to Assess In-River Needs.* Environment Agency Project Report OI/526/3/A, Bristol.

Pickering, T. (1997). *Bankside sampling protocol.* North West Region, National Rivers Authority.

Pinder, L.C.V. (1997). *Environmental Change Network (ECN). Draft freshwater protocols – macroinvertebrates.* Environmental Change Network FIN.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K. and Hughes, R.M. (1989). *Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish.* Report no. 444/4-89-001, Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Pomfret, J. and Reaston, P. (1995). *The use of, and needs for, biological services within the NRA Water Quality function, Final report*. ENTEC Report X25D/3. National Rivers Authority, Bristol.

Postle, M. (1993). *Development of environmental economics for the NRA*. National Rivers Authority R&D Report 6, Bristol.

Puckett, K.J. (1988). Bryophytes and lichens as monitors of metal deposition. In: *Lichens, bryophytes and air quality*, T.H. Nash and V. Wirth, (Eds), J.Cramer, Berlin.

Ratcliffe, D.A., Ed. (1977). *A Nature Conservation Review*. 2 Volumes. Cambridge University Press, Cambridge.

Ratcliffe, D.A. (1986). Selection of important areas for wildlife conservation in Great Britain. The Nature Conservancy Council's approach. In: *Wildlife Conservation Evaluation*, Usher, M.B. (Ed.).

Raven, P.J., Fox, P., Everard, M., Holmes, N.T.H. and Dawson, F.H. (1996). River Habitat Survey: a new system for classifying rivers according to their habitat quality. In: *Freshwater quality: defining the indefinable,* P.J. Boon and D.L. Howell (Eds), HMSO, Edinburgh.

Richardson, D.H.S. (1988). Understanding the pollution sensitivity of lichens. *Botanical Journal of the Linnean Society,* **96**, 31-43.

Rodwell, J. (1991). *British plant communities: Volume 1, Woodland and Scrub*. Cambridge University Press, Cambridge.

Rodwell, J. (1992a). *British plant communities: Volume 2, Mires and Heaths*. Cambridge University Press, Cambridge.

Rodwell, J. (1992b). *British plant communities: Volume 3, Grassland and Montane Communities*. Cambridge University Press, Cambridge.

Rodwell, J. (1995). *British plant communities: Volume 4, Aquatic communities, swamps and tall-herb fens.* Cambridge University Press, Cambridge.

Rodwell, J. (1996). *British plant communities: Volume 5, Maritime and Weed Communities.* Cambridge University Press, Cambridge.

Ruhling, A. (1994). *Atmospheric heavy metal deposition in Europe - estimations based on moss analysis*. Nord 1994:9.

Ruse, L. (1997). *A simple key to canal water quality using a biological technique*. Environment Agency, Thames Region, Reading.

Rutt, G.P. and Mainstone, C.P. (1994). *The development of macroinvertebrate keys using TWINSPAN classification: a manual for NRA biologists*. National Rivers Authority R&D Note 302, Bristol.

Rutt, G.P., Pickering, T.D. and Reynolds, N.R.M. (1993). The impact of livestock farming on Welsh streams - the development and testing of a rapid biological method for use in the assessment and control of organic pollution in farms. *Environmental Pollution*, **81**, 217-228.

Rutt, G.P., Weatherley, N.S. and Ormerod, S.J. (1990). Relationships between physiochemistry and macroinvertebrates in British upland streams: the development of modelling and indicator systems for predicting stream fauna and detecting acidity. *Freshwater Ecology*, **24**, 463-480.

Sanders, G.E., Skarby, L., Ashmore, M.R. and Fuhrer, J. (1995). Establishing critical levels for the effects of air pollution on vegetation. *Water, Air and Soil Pollution*, **85**, 189-200.

Scott Wilson Kirkpatric (1992). *Methods for assessment of low flow conditions caused by abstraction - procedural manual.* National Rivers Authority R&D Note 45, Bristol.

Scottish Fisheries Research Service (1992*). Description of NRA tracking studies – techniques and fish counter technology.* National Rivers Authority R&D Note 33, Bristol.

Scottish Natural Heritage (1995). *Botanical survey of Scottish freshwater lochs.* Scottish Natural Heritage, Information and Advisory Note, Number 4, Edinburgh.

Seaward, M.R.D. (1995). Use and abuse of heavy metal bioassays in environmental monitoring. *Science of the Total Environment,* **176**, 129-134.

Showman, R. (1988). Mapping air quality with lichens, the North American experience. In: *Lichens, bryophytes and air quality*, Nash, T.H. and Wirth, V. (Eds), J.Cramer, Berlin.

Shtina, E.A. and Dorochova, M.F. (1994). Principles and methods of soil use for bioindication of soil pollution. In: *Biological monitoring of the environment. A manual of methods*. J. Salanki, D. Jeffrey and G.M. Hughes (Eds), IUBS Methodology Series. CAB International, Oxford.

Silberstein, L., Siegel, S.M., Keller, P., Siegel, B.Z. and Galun, M. (1990). A new method for the extraction of ATP from lichens. *Bibliotheca Lichenologica*, **38**, 411-418.

Silberstein, L., Siegel, B.Z., Siegel, S.M., Mukhtar, A., and Galun, M. (1996). Comparative studies on *Xanthoria parietina*, a pollution-resistant lichen, and *Ramalina duriaei*, a sensitive species: 1. Effects of air pollution on physiological processes. *Lichenologist,* **28**, 4, 355-365.

Sloof, J.E. and Wolterbeek, H.T. (1991). Patterns in trace elements in lichens. *Water, Air and Soil Pollution,* **57**-58, 785.

Standing Committee of Analysts (1978). *Methods of biological sampling. Handnet sampling of aquatic benthic macroinvertebrates 1978.* HMSO, London.

Standing Committee of Analysts (1980*). Quantitative samplers for benthic macroinvertebrates in shallow flowing waters 1980.* HMSO, London.

Standing Committee of Analysts (1982). *Sampling of Nonplanktonic Algae (Benthic Algae or Periphyton) 1982.* HMSO, London.

Standing Committee of Analysts (1983a). *Methods of Biological Sampling: Sampling of benthic macroinvertebrates in deep rivers 1983.* HMSO, London.

Standing Committee of Analysts (1983b). *Methods of biological sampling. A colonisation sampler for collecting macro-invertebrate indicators of water quality in lowland rivers 1983.* HMSO, London.

Standing Committee of Analysts (1983c). *Methods for sampling fish populations in shallow rivers and streams 1983.* HMSO, London.

Standing Committee of Analysts (1985). *The direct determination of biomass of aquatic macrophytes and measurement of underwater light 1985.* HMSO, London.

Standing Committee of Analysts (1987). *Methods for the use of use of aquatic macrophytes for assessing water quality 1985-86.* HMSO, London.

Standing Committee of Analysts (1990). *The Enumeration of Algae, Estimation of Cell Volume and Use in Bioassays 1990.* HMSO, London.

Standing Committee of Analysts (1991). *Use of plants to monitor heavy metals in freshwaters.* ISBN 0117523712 HMSO, London.

Standing Committee of Analysts (1993). *A review of methods for the use of epilithic diatoms for detecting and monitoring changes in river water quality 1993.* HMSO, London.

Standing Committee of Analysts (1996). *Standing Committee of Analysts - Annual Report 1996-97.* Environment Agency, London.

Steinnes, E, Rambaek, J.P. and Hanssen, J.E. (1992). Large scale multi-element survey of atmospheric deposition using naturally growing moss as a biomonitor. *Chemosphere*, **25,** 735-752.

Taylor, H.J., Ashmore, M.R. and Bell, J.N.B (1990). *Air pollution injury to vegetation.* IEHO, London.

The Biology Strategy Group (1997). *An Environment Agency policy for the use of biology in aquatic systems.* Environment Agency, Bristol.

Thorne, C., Amarasinghe, I., Gardiner, J., Perala-Gardiner, C. and Sellin. R. (1997). *Bank protection using vegetation with special reference to willows.* Engineering and Physical Sciences Research Council and Environment Agency Project Record. June 1997.

Tingey, D.T. (1989). Bioindicators in air pollution research - applications and constraints. In: *Biologic markers of air pollution stress and damage in forests.* Committee on biological markers of air pollution damage in trees. National Research Council. National Academy Press, Washington D.C. 1989.

United Nations Economic Commission for Europe (UNECE) Convention on long-range transboundary air pollution (1993). *Manual for integrated monitoring, programme phase 1993-1996.* Environmental Data Centre, National Board of Waters and the Environment, Helsinki.

Usher, M.B. (Ed.) (1986). *Wildlife Conservation Evaluation.* Chapman Hall, London

van Dijk, P.A.H. (1994). *Analytical quality control for macroinvertberate enumeration.* National Rivers Authority, R&D Note 331, Bristol.

van Dobben, H.F. and De Bakker, A.J. (1996). Re-mapping epiphytic lichen biodiversity in The Netherlands - effects of decreasing SO_2 and increasing NH_3. *Acta Botanica Neerlandica,* **45**, 1, 55-71.

von Arb, C. and Brunold, C. (1990). Lichen Physiology and Air Pollution. I. Physiological Responses of in Situ Parmelia sulcata Among Air Pollution Zones Within Biel, Switzerland *Canadian Journal of Botany*, **68**, 35-42

Ward, D., Holmes, N. and José, P. (Eds) (1994). *The new rivers and wildlife handbook.* The Royal Society for the Protection of Birds, the National Rivers Authority, The Wildlife Trusts, Bedfordshire, UK.

Water Research Centre (1996). *Direct Toxicity Assessment (DTA) Methods Guidelines.* Environment Agency R&D Note 322, Bristol.

Welsh Region (1996). *Marine Algal Monitoring Programme 1996.* Report EAN/96/03. Northern Area, Welsh Region, Environment Agency.

White S.J. (1993a). *National standard methodology for marine macrofaunal benthic sampling. V. Non biological sample collection.* National Rivers Authority Internal Document.

White S.J. (1993b). *National standard methodology for marine macrofaunal benthic sampling. IV. Laboratory treatment of biological samples.* National Rivers Authority Internal Document.

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

Wolterbeek, H.T. and Bode, P. (1995). Strategies in sampling and sample handling in the context of large-scale plant biomonitoring surveys of trace-element air pollution. *Science of the Total Environment,* **176**, 1-3, 33-43.

Woodiwiss, F.S. (1964). The biological system of stream classification used by the Trent River Board. *Chemistry and Industry*, **11**, 443-447.

Wright, J.F., Armitage, P.D., Furse, M.T. and Moss, D. (1989). Prediction of invertebrate communities using stream measurements. *Regulated Rivers: Research and Management*, **4**, 147-155.

Wyatt, R.J. and Lacey, R.F. (1994). *Guidance Notes On The Design And Analysis Of River Fishery Surveys.* National Rivers Authority R&D Note 292, Bristol.

Wyatt, R.J. and Lacey, R.F. (1995). *Fish stock assessment demonstration software – user instructions.* National Rivers Authority R&D Note 299, Bristol.

Wyatt, R.J., Barnard, S. and Lacey, R.F. (1995). *Use of Habscore V software and application to impact assessment.* National Rivers Authority R&D Note 400, Bristol.

Zaman, N. (1997). *Review of organochlorine pesticide and polychlorinated biphenyl bioaccumulation in fish and fish eating mammals.* National Centre for Toxic and Persistent Substances (TAPS) Report No. TAPS/Tox/201/00 NWZ, Peterborough.

APPENDICES A, B AND C

APPENDIX A

Questionnaire sent to Environment Agency primary contacts

A. Personal details

A1. Name

A2. What is your location? Please specify region, area etc.

A3. What is your position within the EA?

A4. What is your primary role within the EA?

B. The design of sampling regimes

B1. Do you use a standard set of criteria when designing a biological monitoring program? (Is there a written standard methodology (local, regional or national)? If so please supply a copy.)

B2. What criteria do you use for the selection of sampling sites?

B3. What criteria do you use for determining the number of samples at each site?

B4. What methods of project management do you use to ensure quality control throughout a biological monitoring program?

C. Freshwater

(i) Macroinvertebrates

C1. What role do you think biological monitoring using macroinvertebrates should fulfil within the remit of the EA and is this potential being met at present?
Please give details of any areas of short-fall.

C2. In addition to GQA, do you currently use benthic macroinvertebrates for
(a) the routine biological monitoring of water quality?
(b) specific biological monitoring investigations? (e.g. LEADS)
Yes/No, If so please answer the following questions.

C3. What methods do you use for the sampling of benthic macroinvertebrates
(a) in shallow waters? (e.g. 3 minute kick-sample)
(b) in deeper waters, such as canals and lowland rivers? (e.g. artificial substrates, dredge)

C4. What methods do you use for the handling of macroinvertebrate samples? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

C5. What methods of analysis do you use for the evaluation of macroinvertebrate data in the context of water quality? (e.g. BMWP, BMWP-ASPT, both together, ordination, RIVPACS, GQA classification)

C6. What quality control mechanisms are employed to ensure the accuracy and reliability of water quality assessments using macroinvertebrates?

C7. In what form do you present macroinvertebrate water quality data? (Is there a standard format?)

(ii) Epilithic algae

C8. What role do you think that biological monitoring using epilithic algae should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

C9. Do you currently use epilithic algae for the biological monitoring of water quality? Yes/No, If so please answer the following questions.

C10. What sampling methods do you use for the sampling of epilithic algae? (e.g. scraping /brushing from rocks, microscope slides as artificial substrates)

C11. What methods do you use for the handling of epilithic algae samples? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

C12. What methods of analysis do you use for the evaluation of epilithic algal data? (e.g. Diatom Index)

C13. What quality control mechanisms are employed to ensure the accuracy and reliability of water quality assessments using epilithic algae?

C14. In what form do you present algal water quality data? (Is there a standard format?)

(iii) Fish

C15. What role do you think that biological monitoring using fish should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

C16. Do you currently use fish for the biological monitoring of water quality? Yes/No
If so please answer the following questions.

C17. What methods do you use for the sampling of fish in
(a) streams and small rivers? (e.g. electric fishing)
(b) large rivers and lakes? (e.g. seine nets, gill nets, echo sounding)

C18. What methods do you use for the handling of fish samples? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

C19. What methods of analysis do you use for
(a) the estimation of fish populations?
(b) the evaluation of water quality using fish data? (e.g. Index of Biotic Integrity, evaluations of fish health e.g. number of fish parasitised, diseased, with fin damage or skeletal abnormalities)

C20. What quality control mechanisms are employed to ensure the accuracy and reliability of fish data?

C21. In what form do you present fisheries data? (Is there a standard format?)

(iv) Plankton

C22. What role do you think that biological monitoring using plankton should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

C23. Do you currently use plankton for the biological monitoring of water quality? Yes/No
If so please answer the following questions.

C24. What methods do you use for the sampling of
(a) phytoplankton? (nets, bottle samplers, quantitative or qualitative samples)
(b) zooplankton? (nets, bottle samplers, quantitative or qualitative samples)

C25. What methods do you use for the handling of plankton samples? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

C26. What methods of analysis do you use for the analysis of plankton data? (e.g. Chlorophyll-a, biotic indices - acidification, biotic indices - eutrophication)

C27. Do you use any palaeolimnological techniques? If so give details of sampling (e.g. coring) methods and methods of data analysis.

C28. What quality control mechanisms are employed to ensure the accuracy and reliability of plankton data?

C29. In what form do you present plankton data? (Is there a standard format?)

(v) Macrophytes

C30. What role do you think that biological monitoring using macrophytes should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

C31. Do you currently use macrophytes for the biological monitoring of water quality? Yes/No
If so please answer the following questions.

C32. What methods do you use for the sampling/observation of macrophytes in addition to the UWWTD method? (e.g. rakes, drag chains, aerial photography, remote sensing)

C33. What methods do you use for the handling of macrophyte samples? (e.g. identification in the field, transportation to the laboratory, labelling of samples, preservation).

C34. What methods of analysis do you use for the evaluation of macrophyte data? (Mean Trophic Rank, Plant Score, Plant Community Description, both together)

C35. What quality control mechanisms are employed to ensure the accuracy and reliability of macrophyte data?

C36. In what form do you present macrophyte data? (Is there a standard format?)

(vi) Integrated methods

C37. What role do you think that biological monitoring using integrated or multimetric systems should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

C38. Do you currently use any integrated or multimetric systems for the biological monitoring of water quality? Yes/No
If so please answer the following questions.

C39. Which communities do you use for such studies? (e.g. benthic macroinvertebrates, fish, plankton). Please indicate if two or more communities are used in conjunction.

C40. What methods do you use for the sampling of these communities?

C41. What methods do you use for the handling of these organisms? (e.g. fixing in the field, transportation to the laboratory, preservation).

C42. What methods of analysis do you use in integrated or multimetric assessments? (e.g. Index of Biotic Integrity type model)

C43. What quality control mechanisms are employed to ensure the accuracy and reliability of data from these studies?

C44. In what form do you present this data? (Is there a standard format?)

(vii) Freshwater habitats

C45. Do you think that the methods that you use are adequate for the biological monitoring of all types of freshwater habitat, including small streams, large rivers, canals, ponds and lakes?

D. Marine

D1. What role do you think that biological monitoring of the marine environment should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

D2. Do you currently use biological monitoring methods in the marine environment? Yes/No

If so please answer the following questions.

D3. Which communities do you use? (e.g. benthic, littoral, planktonic, fish, estuarine, meiofauna)

D4. What methods do you use for the sampling of these organisms?

D5. What methods do you use for the handling of marine organisms? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

D6. What methods of analysis do you use for the evaluation of this data?

D7. What quality control mechanisms are employed to ensure the accuracy and reliability of water quality assessments in the marine environment?

D8. In what form do you present this data? (Is there a standard format?)

E. Air

E1. What role do you think that biological monitoring of air pollution should fulfil within the remit of the EA, particularly with respect to the role of other organisations (e.g. local authorities), and is this potential being met at present? Please give details of any areas of short-fall.

E2. Do you currently use biological monitoring to assess air pollution? Yes/No

If so please answer the following questions.

E3. What organisms do you use? (e.g. lichens)

E4. What methods do you use for the sampling of these organisms?

E5. What methods do you use for the handling of these organisms? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

E6. What methods of analysis do you use for the evaluation of this data?

E7. What quality control mechanisms are employed to ensure the accuracy and reliability of assessments of air pollution?

E8. In what form do you present this data? (Is there a standard format?)

F. Soil/contaminated land

F1. What role do you think that biological monitoring of soil/contaminated land should fulfil within the remit of the EA, particularly with respect to the role of other organisations (e.g. MAFF), and is this potential being met at present? Please give details of any areas of short-fall.

F2. Do you currently use biological monitoring to assess soil pollution/contaminated land? Yes/No
If so please answer the following questions.

F3. What organisms do you use and what is the objective of this monitoring? (e.g. bacteria, fungi)

F4. What methods do you use for the sampling of these organisms?

F5. What methods do you use for the handling of these organisms? (e.g. fixing in the field, transportation to the laboratory, labelling of samples, preservation).

F6. What methods of analysis do you use for the evaluation of this data?

F7. What quality control mechanisms are employed to ensure the accuracy and reliability of such assessments?

F8. In what form do you present this data? (Is there a standard format?)

G. Bioaccumulation studies

G1. What role do you think that bioaccumulation studies should fulfil within the remit of the EA, particularly with respect to the role of other organisations (e.g. MAFF), and is this potential being met at present? Please give details of any areas of short-fall.

G2. Do you currently carry out bioaccumulation studies to assess the pollution of
(a) freshwater habitats? Yes/No
(b) marine habitats? Yes/No
(c) the soil? Yes/No
(d) the air? Yes/No
If yes please answer the following questions.

G3. Which substances do these bioaccumulation tests evaluate in
(a) freshwater habitats? (e.g. heavy metals, organic substances)
(b) marine habitats? (e.g. heavy metals)
(c) the soil?
(d) the air? (e.g. lead)

G4. What organisms do you use for bioaccumulation studies of the pollution of
(a) freshwater habitats? (e.g. Fish, macrophytes)
(b) marine habitats? (e.g. Fish, macrophytes, bivalves, cetaceans)
(c) the soil?
(d) the air? (e.g. Lichens)

G5. Please give details of the methods used in the bioaccumulation studies using these organisms. (e.g. AAS)

G6. What quality control mechanisms are employed to ensure the accuracy and reliability of bioaccumulation studies?

G7. In what form do you present bioaccumulation data? (Is there a standard format?)

H. Toxicity testing

H1. What role do you think that toxicity testing should fulfil within the remit of the EA, particularly with respect to the role of other organisations (e.g. MAFF), and is this potential being met at present? Please give details of any areas of short-fall.

H2. Do you currently carry out acute toxicity tests? If so please give details of organisms and techniques used.

H3. Do you currently carry out chronic toxicity tests? If so please give details of organisms and techniques used.

H4. Do you currently carry out multispecies toxicity tests? If so please give details of organisms and techniques used.

H5. Do you currently carry out any field screening toxicity tests? (e.g. microtox, rotifer toxkits)

H6. What quality control mechanisms are employed to ensure the accuracy and reliability of toxicity tests?

H7. In what form do you present toxicity data? (Is there a standard format?)

I. Evaluation of conservation value

I1. What role do you think that the evaluation of conservation value should fulfil within the remit of the EA, particularly with respect to the role of other organisations (e.g. English Nature), and is this potential being met at present? Please give details of any areas of short-fall.

I2. Do you currently assess the conservation value of
(a) freshwater communities? Yes/No
(b) marine communities? Yes/No
(c) terrestrial communities? Yes/No
(d) soil communities? Yes/No
If yes please answer the following questions.

I3. Which communities (e.g. fish, benthos, birds, insects, mammals, plants) do you use in each habitat?
(a) freshwater
(b) marine
(c) terrestrial
(d) soil

I4. What criteria do you use to evaluate conservation value? (e.g. Ratcliffe criteria)

I5. What quality control mechanisms are employed to ensure the accuracy and reliability of such evaluations?

I6. In what form do you present conservation data? (Is there a standard format?)

J. Radioactivity

J1. What role do you think that the biological monitoring of radioactive substances should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

J2. Do you currently use biological methods to assess radioactivity in the environment? If so please could you give details of the organisms and techniques used.

K. Early warning systems

K1. What role do you think that early warning systems should fulfil within the remit of the EA and is this potential being met at present? Please give details of any areas of short-fall.

K2. Do you currently employ any early warning systems (e.g. fish alarm systems)? If so please give details.

L. Areas requiring development

L1. What areas of biological monitoring do you think the Environment Agency performs satisfactorily at present?

L2. What areas of biological monitoring, not mentioned previously, do you think the Environment Agency fails to address adequately at present?

L3. Do you know of any techniques which are available at present, or current research to develop such techniques, which can address this short-fall? If so please give details.

APPENDIX B

Schedule of meetings and/or consultations held with KES and Environment Agency

Date	Environment Agency Region	Representatives	Position
18/2/97	Initial project meeting	**Sarah Chadd**	**Project leader**
		Martin Smalls	**R&D Management support officer**
4/4/97	Bristol, Head Office	**David Jowett**	**Senior scientist, environmental monitoring**
		Malcolm Lithgow	
11/4/97	Southern Region	**Bob Dines**	**Regional Biologist**
		Chris Lee	Fisheries Co-ordinator
		Jim Wharfe	Head of Ecotoxicology and Hazardous Substances National Centre
		Derek Tinsley	Direct toxicity Assessment Manager, Ecotoxicology and Hazardous Substances National Centre
		Keith Loy	Water Quality
22/4/97	Thames	**John Murray-Bligh**	**Senior Biologist**
7/5/97	North West	**Elaine Fisher**	**Regional Biologist**
		Tim Pickering	Ecologist
8/5/97	Welsh	**Frank Jones**	**Environmental Appraisal Officer**
		Graham Rutt	Env. Appraisal Officer (Biology)
		Rob Stonehewer	Env. Appraisal Officer (Biology)
		Nicky Smith	Env. Appraisal Officer (Biology)
		Iwan Thomas	Env. Appraisal Officer (Biology)
		Mark Scott	Env. Appraisal Officer (Fish)
		Andy Robinson	Env. Appraisal Officer (WQ)
		Gill Davies	Env. Appraisal Officer
9/5/97	Midlands	**Shelley Howard**	**Regional Biologist**
		Phil Harding	Area Biologist
		Andrew Heaton	Regional Conservation Officer
		Paul Lidgett	Regional Fisheries Officer
		Helen Webb	Assistant Biologist
		Phil Wormald	Assistant Biologist
		Garry Fretwell	Assistant Biologist
		David Hudson	IPC
		David Bliss	Waste Control Officer

12/5/97	Thames	**Roger Sweeting**	**Fisheries and Conservation Manager**
		Paul Logan	Regional Water Scientist
		Mike Owen	Water Resources Manager
		John Steel	Regional Biologist
16/5/97	North West	**Karen Rouen**	**Ecologist**
19/5/97	North East * Northumbria Area	**Anne Lewis**	**Senior Ecologist**
		Roger Proudfoot	Marine Scientist
		Jonathon Shelley	Fisheries Scientist
		Colin Blundell	Senior Ecologist (Conservation)
		Neil Smith	
21/5/97	Ridings Area	**Brian Hemsley-Flint**	**Senior Ecologist**
		Jonathan Neale	IPC
		Brian Taylor	Waste Regulation
		Pat O'Brien	Senior Fisheries Investigator
		Mark Walters	EPO
		Amanda Bird	EPO
		Andrew Mollit	EPO
		Linda Bird	Environmental Modeller (Water Resources and Quality)
		James Blackmore	Water Qaulity Co-ordinator
		Nicki Dunn	Ecologist
		Stuart Horman	Hydrologist
		Sarah Madson	Technical Assistant Water Quality
		Richard Jennings	Ecologist
		Andrea Shaftoe	Conservation
21/5/97 5/6/97	South West**	**George Green**	**Senior Biologist**
		Jeanette Collett	Senior Biologist
		Andy Hicklin	Senior Biologist
		James Flory	Biologist
		Mitch Perkins	Marine Biologist
19/5/97 20/5/97	Anglian	**Sarah Chadd**	
		Gary Murphy	Regional Conservation Officer
		Graham Wilson	Regional Water Resources Manager
		Heather Keedle	Regional Waste Regulation
		Terry Clough	Senior Biologist
		Chris Extence	Senior Biologist
		Geoff Brighty	TAPS centre
		Brian Barnett	Marine Scientist
		Julia Stansfield	Area Biologist

	North East *		
23/6/97	Dales Area	**Amanda Trevithick**	**Ecology and Sampling Principle**
		Martin Fuller	Senior Conservation Officer
		Graeme Bird	Senior Biologist
		Jacinta Reynolds	Assistant Biologist
		Jim Sahaghnewsy	Waste Regulation Section
		Steve Axford	Senior Fisheries Officer
		John Calder	Pollution (Site) Inspector
		Simon Williams	Biologist
		Isobel Austin	EPO
22/8/97	Project board meeting	Sarah Chadd	
		Martin Smalls	
		Alastair Ferguson	
		Roger Sweeting	
		Frank Jones	
		John Murray-Bligh	
4/9/97	Bristol Head Office	Alastair Ferguson	Environmental Monitoring
6/10/97	Thames Region	Paul Logan	Regional Water Scientist
11/11/97	Project board meeting	Sarah Chadd	
		Frank Jones	
		John Murray-Bligh	
		Dave Forrow	

Additional correspondence with following Environment Agency staff

Bristol Head Office	Richard Howell	Head of Conservation
	Cath Beaver	Conservation Officer
Standing Committee of Analysts (SCA) †	David Westwood	
Anglian Region	Peter Barham	Humber Strategies Manager
Welsh Region	Kate Cameron	Assistant Toxicity Scientist

Note:

Names in bold indicate key regional contacts

EPO represents Environmental Protection Officer

IPC represents Integrated Pollution Control section

* North East Region does not have a representative regional contact. As a result three individual meetings were conducted in each area.

** George Green is regional contact for biology in South West Region

† as of 1 April 1996, SCA became part of the Environment Agency

APPENDIX C

Meetings and/or responses of external organisations

Date	Organisation	Representatives
Meetings		
18/4/97	English Nature	Mary Gibson
21/5/97	Institute of Freshwater Ecology	Patrick Armitage
		John Wright
Other responses by phone fax, email or post		
	Scottish Natural Heritage (SNH)	P.J. Boon
		Andrew Taylor
		Alexander J Downie
	Scottish Environmental Protection Agency (SEPA)	Ross Doughty
	MAFF	John Goudie
	National Radiological Protection Board (NRPB)	Kelly Jones
	EEA, Iceland Focal Point	Hugi Olafsson
	EEA, Germany Focal Point	Ulrike Meyer
	EEA, Belgium Focal Point	Anne Teller
	EEA, Portugal Focal Point	Fatima Brito
	EEA, Norway Focal Point	Berit Kvaeven