IMPACTS – Interactive Monitoring using Prediction and Classification Techniques – A Review of Monitoring Tools and Datasets Relating to Freshwater Environments.

R&D Technical Report E1-090/TR

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A review of monitoring tools and datasets relating to freshwater environments

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EXECUTIVE SUMMARY

Background

This review examines the monitoring systems that utilise information on the state and quality of biological communities and environmental parameters across the functions of the Environment Agency. The review takes account of the future need to adopt broader measures for assessing pressures and their environmental impacts.

Review Activities

A workshop (July 2000) was organised to provide an up-to-date account of the current monitoring tools and data held within the Agency. The workshop participants defined the degree to which these sources are yielding the key information on environmental quality within the Environment Agency.

The content of two monitoring reviews were assessed ("Bridging the Gap",1998; "Monitoring for What?", 1999), also information gaps were assessed that related to implementation of the forthcoming European Water Framework Directive. Other sources of information considered in this review include: the Agency R & D CD-ROM (June 2000); a guide to 9 databases (issued by the Performance Monitoring Group); the PREMIS Technical Manual (a Water Quality Sampling database providing a pre-archive management information system); an Access database recording the Year-2000 compliance/non-compliance status of Environment Agency software and datasets.

Main Conclusions and Recommendations

- Widespread format incompatibility between datasets and databases is encountered, both within and outside the Environment Agency.
- There is scope for greater awareness of datasets/monitoring tools and their potential to inform decisions throughout the Environment Agency, at all levels.
- There is a need to deliver information in different ways to fulfil both national and local requirements within the Environment Agency.
- The review failed to access and compare the charateristics of Environment Agency databases to the extent anticipated in the project aims.
- There is scope for an improvement in cross-comparisons of datasets and information retrieval mechanisms within the Environment Agency.
- Accessible and compatible data formats are required to improve the effectiveness of using datasets and monitoring tools in a cross-function context within the Environment Agency.
- From the outset, software/database design requires close collaboration of software writers/database managers and end-users.

1. INTRODUCTION

1.1 The Purpose and Scope of this Review

The overall purpose of the project is to review the monitoring systems that utilise information on the state and quality of biological communities and environmental parameters across the functions of the Environment Agency, focussing mainly on freshwater environments. Future Agency needs will include the adoption of broader measures of environmental impact assessment and more sophisticated 'state of the environment' indicators. This review concentrates on current and developing monitoring systems, their extent and degree of compatibility.

1.2 Monitoring Requirements within the Environment Agency

The assessment of environmental quality by the Environment Agency continues to develop. The Agency requires reliable methods to measure and monitor the status of key environmental conditions. The current status and any changes detected are interpreted within the concept of 'pressure-state-response'. Future requirements will include the need to assess ecological impacts in broader contexts than at present, eg diffuse pollution, degraded habitats, and will need to take account of sustainable development whilst promoting and maintaining biodiversity (Environment Agency strategic review “Monitoring For What?”, 1999). In addition the demands of monitoring for Integrated Catchment Management, EC Directives and the forthcoming Water Framework Directive, will need to be incorporated whilst maintaining continuity with past data sets.

The monitoring and investigative techniques include indices and performance indicators that provide site-specific measures of quality and changes in quality over time, focusing on biological communities or chemical/physical attributes in a series of independent exercises.

1.3 Future Monitoring Requirements

Future monitoring priorities were reviewed within the Environment Agency at the beginning of 1999. The review considered R & D strategies to develop and improve monitoring and assessment techniques that describe the state of the environment in England and Wales (Research and Development Strategy, 1998). The Agency also supports and provides input to European initiatives such as the Framework Directives within the European Union. In this context the Agency commissioned WRc to review research gaps in underpinning science relating to the monitoring of ecological quality. The main conclusions identified: a general commonality of approach within the UK and France; the requirement to compare techniques and interpretations on pilot catchments in both France and the UK; the benefits of implementing monitoring activities which lead to effective actions that protect and enhance ecological quality.

These findings imply a need for a more holistic view of the environment incorporating indicators to view problems from a number of different directions at the same time.

At the present time further reviews and recommendations on monitoring are ongoing, both within the Agency and for the Agency (eg, Alternative Methods for the Biological Classification of Rivers, Technical Report E57). Proposed changes to the General Quality Assessment (GQA) programme and development of the forthcoming Catchment Abstraction Management Strategy (CAMS) provide opportunities to co-ordinate data collection that will address issues common to both programmes.

In the context of river basin management, the potential for integrated approaches has been recognised (Raven *et al*, 1998), whilst Wright *et al* (1998) indicated ways in which RIVPACS, RHS and SERCON may provide complementary data to improve quality diagnostics. Wright and co-authors also considered the possible future combination of these techniques: as surrogate measures of biodiversity, to quantify success in river rehabilitation schemes and to aid the selection and assess the status of new and current riverine SSSIs.

1.4 Objectives

The overall objective of the project is to review the monitoring systems that utilise information on the state and quality of biological communities and environmental parameters across the functions of the Environment Agency. The review takes account of the future need to adopt broader measures for assessing pressures and their environmental impacts, also the cross-functional requirement for monitoring tools and strategies by environmental planners.

The review has the following specific aims:

- Identify complementary features of current monitoring/investigative systems with the potential to further enhance assessments of environmental quality and assist in setting targets.
- Identify knowledge gaps that inhibit both the use of current methods and the development of new tools to assess environmental quality, particularly the links between pressures and states.
- Identify mechanisms to improve the understanding of the key pressures influencing ‘quality’ and the reasons for status change.
- Identify ways to standardise commonly recorded variables in different monitoring systems, increasing harmonisation of Agency sample collection, recording, data archiving and retrieval, with a view to reducing the cost of data acquisition and analysis.
- Identify and eliminate redundant data collection.

1.5 Sequence of Review Activities

- Identify outstanding questions/uncertainties in environmental quality assessment – that need to be addressed.
- Identify new monitoring techniques that are at an early stage of development.
- Identify new science/technology that can improve monitoring capabilites.
- Identify complementary and contrasting quality predictions/results generated by the current monitoring techniques (utilising available data).
- Identify potentially useful new combined techniques.
- Design procedures for testing new techniques and how they can be used to relate environmental impacts to ecological change.
- Identify where there is potential for reducing data acquisition.

The output targets:

- increase understanding of 'pressure-state-response' in terms of quality changes.
- identify methods, which increase the precision and accuracy of monitoring environmental quality.
- increase predictive capabilities, incorporating particularly the ability to test management options in different environmental scenarios.

2. METHODS

2.1 Review Activities

At the start of the review process the topics that needed to be addressed were assessed against the backdrop of the project aims.

(1) The agenda and format for the planned Workshop and other project activities were discussed and agreed with the Project Board. Workshop participants from within the Environment Agency were invited to attend by the Project Manager. Certain staff from CEH Dorset (formerly IFE River Laboratory) were invited to attend the Workshop by the Review Co-ordinator.

(2) The Workshop (July 2000) focused on providing an up-to-date account of the current monitoring tools and data sources that are yielding the key information on environmental quality within the Environment Agency. The participants also discussed future options and needs in relation to the practical difficulties encountered when accessing and cross-referencing environmental data.

(3) The contents of two Environment Agency documents (Bridging the Gap, 1998 and Monitoring for What?, 1999) were examined and related to the Workshop conclusions in the present review.

(4) A CD-ROM containing the titles and summary outputs of 2,146 Environment Agency R & D reports (June 2002) were examined. Selected information was retrieved from reports that referred to databases and/or monitoring and an account of the readily available information are presented as part of this review. In addition, the titles of current and planned R & D projects were accessed.

(5) An account of relevant information from a 2-day Workshop on the Water Framework Directive (31st Nov & 1st Dec, 2000) is presented.

3. WORKSHOP

3.1 Workshop Background

The one-day Workshop (Kings Meadow House, Reading, 20th July 2000) considered a preliminary listing of monitoring techniques, in the context of the future priorities within the Environment Agency:

- monitoring aquatic environments and adjacent habitats.
- new monitoring methods, currently at the development stage.
- related underpinning science and development of interpretative techniques.
- predictive systems/techniques which should be explored in depth.

The Workshop participants were asked to consider the relationships between monitoring techniques, in terms of the approaches, outputs, compatibility and potential for the combination of monitoring activities currently used and being developed by the Environment Agency. The methods reviewed include both broad techniques (eg, RIVPACS, RHS, SERCON, MTR, PLANTPACS, PHABSIM, and HABSCORE and more focused techniques (eg, the developing indices and models, eg, Trophic Diatom Index, LIFE (invertebrate-based flow index), Community Conservation Index, CPET (Chironomid Pupal Exuviae, species assemblages) and PROTECH (Phytoplankton Responses to Environmental Control).

The participants were also asked to consider the questions that need to be addressed in order to improve our understanding of the links between 'pressures' and 'states' in the environment and, in so doing, strengthen monitoring capabilities and the interpretation of results. Also to identify any additional potential benefits in terms of the management of biological, chemical and physical systems within the aquatic environment.

It was anticipated that Workshop participants would include both a broad representation of the Agency functions that utilise information from environmental monitoring and a range of specialists with expertise in relevant monitoring techniques. The potential for omission of key monitoring techniques/datasets was recognised, in the light of the under-representation of hydrologists, engineers and chemists at the Workshop.

The contributions from Workshop participants and subsequent feedback resulting from circulation of the account of the Workshop formed a major basis for the assessment of new applications for monitoring tools, the knowledge gaps and the interpretation of monitoring techniques in this review.

3.2 Workshop Proceedings

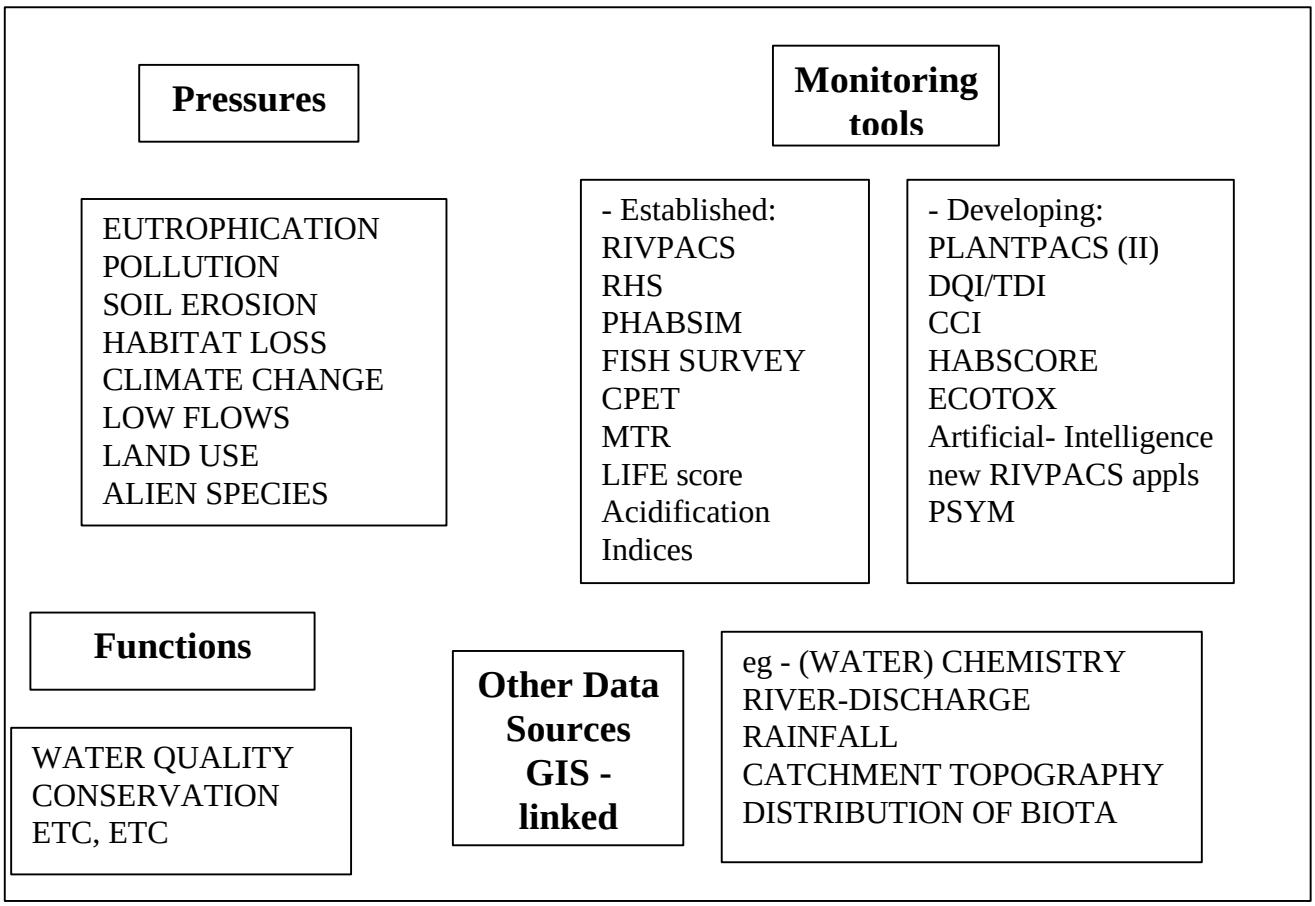
Following an introduction to the aims of the IMPACTS review project, the participants split into three **Breakout Groups**. The participants were assigned to groups in a manner to maximise the breadth of experience in each group. Biological expertise was strongly represented in all groups.

The **Breakout Groups** each discussed three **Tasks** designed to elucidate current and future applications for datasets and monitoring tools within the Environment Agency. These

included datasets and monitoring tools currently used by the Agency and those potentially available from other organisations.

A summariser from each group presented a combination of answers, opinions and conclusions, following the completion of each Workshop task.

To assist these discussions a series of overheads were displayed; these illustrated the preliminary assessment of monitoring tools and databases currently in use and under development. The overheads included a context table, presented below. Acronyms for monitoring tools, datasets and associated titles are listed in Appendix I.



Workshop Participants

Review Co-ordinator: Jon Bass (CEH Dorset)

Environment Agency staff:

Keith Atkinson	(North West)
Richard Chadd	(Anglian)
Martin Christmas	(North East)
Chris Extence	(Anglian)
Jim Flory	(South West)
Richard Hemsworth	(Wales)
Shelley Howard	(Midlands)
Ed Mycock	(North West)
Graeme Storey	(National Centre for Environmental Data & Surveillance)
Ron Thomas	(National Centre for Environmental Data & Surveillance)
Tim Webb	(Thames Region)
Karen Williams	(North West)
Doug Wilson	(Thames Region)

CEH Dorset staff:

Ralph Clarke	(statistician)
Hugh Dawson	(aquatic plants, MTR, RHS)
Mike Furse	(RIVPACS/headwaters/CS2000)
John Hilton	(water chemistry)
Anton Ibbotson	(fish)

Subsequent discussion and additional input (CEH Dorset) were provided by:

Patrick Armitage	(macroinvertebrate ecology and mesohabitats)
John Wright	(RIVPACS)

3.3 Workshop Outputs

3.3.1 Task 1

Question: **Which sets of information used by the Agency are currently separate but can be combined to yield fast answers to new questions?**

Guide*: Start by identifying datasets or tools/classification systems already being combined, then debate and agree a list of practical, new and desirable combinations).*

Responses:

Group 1

The Group listed datasets and monitoring tools that could be usefully combined, but recognised that currently most lack automated links to assist cross-referencing and selective analysis. They highlighted that the choice of traditional sampling sites has been driven by legislative requirements. This has resulted in a downstream bias in the distribution of monitoring sites in catchments - a situation not ideally suited for the effective monitoring of environmental variables and taxa in the upper reaches of catchments. The Group specifically

mentioned the following datasets and monitoring tools that are currently (or could in the future be) usefully cross-referenced. They are listed in random order:

- Macroinvertebrates (RIVPACS) - water chemistry - water temperature
- River Habitat Survey - GQA site characteristics - RIVPACS
- NGR - Hydrological Code (link required)
- LIFE scores - Hydrological data - RIVPACS data
- Marine biodiversity (macroinvertebrates) - water chemistry
- Microbiological data - water chemistry
- Biodiversity indicators/data - water chemistry
- CCI/River Habitat Survey - macroinvertebrates - fish (diversity/biomass)
- Predictive System for Multimetrics (PSYM - biological data) - lakes/ponds/canals

Group 2

This Group raised the lack of commonality (format incompatibility) between datasets and monitoring tools. They also felt that there was a limited awareness of particular datasets and monitoring tools, which could discourage the initial exploration and development of new monitoring approaches. The Group specifically mentioned the following datasets and monitoring tools, listed in random order:

- Geographic Information Systems (using Map Explorer/ArcView) - include external links to data
- Diatoms - acidification status - specific pollutant indicators - Mean Trophic Ranking
- Biology (macroinvertebrates/macrophytes/fish) - WIMS (water chemistry) and HYDROLOG (flow monitoring) - predicting site/reach vulnerability.
- Remotely sensed data - CASI/LIDAR - delineating/quantifying habitats and buffer zones.
- SSSI/cSAC - habitat/species inventories - define status (at local, national, international scales).
- Urban environments - systems to classify sites, incorporating a downgrade of site quality 'expectation' - to provide useful tools for between-site comparisons.

Some additional information sources, external to the Environment Agency, were identified:

Terrestrial/marine data sources -
Landcover Map, Registry of Contaminated Land, Coliform data, Groundwater abstraction rates (licensed and utilised quantities), human population census, Soil Survey data, Agrochemical inputs (by catchment)

Group 3

This Group also raised the lack of commonality (format incompatibility) between datasets and monitoring tools, arising from the gradual evolution of the Environment Agency function-specific requirements for new data. They considered there should be a unifying dataset, at least for physical data (as is available for water chemistry). They stressed that the collection of long-term data was recognised to be potentially valuable but that adequate funding and support for this activity was often difficult to maintain in the context of changing priorities within the Environment Agency.

The Group queried the appropriateness of some monitoring sites - where data were gathered for specific purposes (water chemistry, RIVPACS) - some are from closely adjacent but subtly different localities and thwarted viable comparisons and extrapolations. They identified that external (to the Agency) data sources were frequently in incompatible formats and incurred access charges, discouraging further investigation and exploitation. They commented that some information requirements for conservation monitoring fit uncomfortably alongside data needed to assess water quality status.

3.3.2 Task 2

Question: **On which spatial scales are datasets and monitoring tools most usefully cross-referenced?**

Context*: eg - point source location, habitat, river reach, sub-catchment, catchment, area/region, national (other)? Prioritise the spatial scales in order of information need (within the Agency or for external use) - then identify which (if any) scales can be extrapolated to answer queries at a different scale (give examples).*

Responses:

Group 1

This Group listed desirable attributes, in relation to the scale at which data are available:

Cross-referencing of datasets and monitoring tools should apply at the lowest or smallest scale - with the facility to coarsen or broaden the scale of comparison. Effective surveillance requires that the data analysis tools are compatible with monitored data. The capability to change from monitoring for one purpose to multi-tasking operations.

This was illustrated by the GQA - a Nationally driven process - which has the potential to address local-scale questions. In this context, RIVPACS and water chemistry are used for summarising 'performance' measures nationally but, along with species level data, they inform proactive management locally.

Group 2

The Group identified that information needs and analyses operate at a broad range of scales. The following points illustrated these:

- GQA data are required at only a limited number of primary sites.
- For secondary sites, river reaches, point-source inputs the cross-referral between data on river reach and point source inputs needs to be easier.
- There is an increased need for data relating to Special Areas of Conservation and the data are frequently scattered and difficult to access and identify information gaps.
- It is desirable to have the facility to assess site and reach data over varying timescales.
- There is a conflict between National and Local priorities within the Agency on scale perspective.
- Established GQA sites are not universally useful (non-representative for certain parameters and attributes)

Group 3

The Group identified a list of general issues:

- There is the need for accurate and representative data that is clearly defined.
- Site impacts (local investigations) may require access to information at a range of spatial/temporal scales.
- The scale at which combined datasets and monitoring tools are interpreted is often restricted to the coarsest scale of available datasets and monitoring tools.

The Group summarised by emphasising the importance of access to data at a wide range of scales.

3.3.3 Task 3

Question: What are the datasets and monitoring tools - unique to different functions, describe (briefly) their potential relevance to other Agency functions?

Context*: Cross-Function add-ons: Agency departments have their own priorities/duties - with monitoring tools and datasets for specific purposes. Consider 'new' opportunities, expanding on Task 1.*

Responses:

Group 1

Desirable links were identified and new opportunities considered, they are listed in no specific order:

- River Habitat Survey data - attributes of wetlands - RIVPACS - HABSCORE
- Flood defence (survey map/levels data) - weedcutting protocols/effects
- Flood defence data/site conservation status (already strong connections)
- Fish kill data - public reports/complaints
- Pollution Register (currently regarded as difficult to utilise)
- CDC ('community' dominated) - cross-refer to species data
- LQI - (RIVPACS) BMWP/ASPT
- 'Dirty Water' RIVPACS - categorising gradients in lower quality watercourses
- SOILPACS (recently explored, full development costs noted as very high)
- Bioassays - ecotoxicological methods (listed elsewhere) - establish field relevance
- Forecasting freshwater biological community change - in response to pollution/habitat management

Group 2

The Group identified new opportunities and listed them in no specific order:
[Note: they frequently involve collaboration between the different Agency functions.]

- Eutrophication strategy - Land data - Water data (including groundwater data)
- Mean Trophic Ranking (plants) - Conservation interpretation/priorities
- Flow (discharge) - wider uses possible than at present
- Waste management - leachate data

- Diatoms (indicator systems) - potential to expand from eutrophication (eg metals)
- Invertebrates (indicator taxa/communities) - potential to expand (eg habitat quality)
- Invertebrates - fish (population diversity, biomass, and protected species)
- Fisheries data (biomass, species) - aquatic plant data (habitat requirements)
- Recharge/infiltration data - contaminated land - water chemistry (including groundwater)
- Historical maps (eg Agency Survey Section data) - contaminated land register - GIS overlays
- Inputs from airborne contaminants (eg, dioxins) - vulnerable sites/freshwater communities
- Flood defence (survey data) - RHS (+ River Corridor Survey data?)
- Hydrological data - time-of -travel (watercourse-specific)
- Endocrine disruptors (eg oestrogens/oestrogen-mimics) - expand from fish to freshwater invertebrates
- Legislative information - invertebrates, plants, fish (eg protected species)
- Algal toxicity - microcystin Test

Group 3

This Group identified the following 'new' opportunities, they are listed in no specific order:

- RIVPACS - many cross-related uses - eg, RHS - possibilities for developing an 'aesthetic' GQA system (lacks a statutory 'driver', at present).
- PHABSIM/fish surveys - water resources - fishery status
- MTR/PLANTPACS (to develop)/CPET - (chemical) water quality/land-use
- Acidification indicators - biotic/abiotic
- DQI/DTI - tools for predicting climate change scenarios
- Influences of pesticides on non-target organisms/communities (eg sheep-dip/crop sprays)
- Relationship between (chemical) water quality assessment - impact assessment of - specific developments at species/taxa/communities levels.
- Navigation pressures - environmental effects
- Artificial Intelligence (pattern detection) - scope for identifying redundant data collection.
- Micro Low Flows - flows at ungauged sites

3.3.4 Synthesis of additional information from the workshop participants.

Following circulation of the draft account of the Workshop some additional datasets and monitoring tools were identified by individuals from the Breakout Groups, these were:

- SERCON - A system for evaluating rivers for conservation
- FEH - Flood Estimation Handbook, a CD-ROM produced by CEH-Wallingford
- LIFE Index (macroinvertebrates responding to flow conditions)
- CCI - Community Conservation Index (Anglian Region) - cumulative scores of taxa present - based on regional/national rarity and conservation status.
- BAPs - Biodiversity Action Plans - summary information on particular species and habitats of high conservation status

- cSAC - candidate Special Areas of Conservation (includes designated rivers), with consequences for monitoring priorities (concentration of monitoring resources at these sites).
- CS 2000 - Countryside Survey (x 1km squares surveyed, including y 1km squares with watercourses - range of biological, chemical and physical data obtained) - an environment audit.
- SOILPACS - development proceeding (connections with CS 2000, Agency contact: Malcolm Lythgo)
- CASI/LIDAR - remotely sensed data (landform, habitat distribution, and specific impact signatures) - ground-truthing critical for some applications.
- Landcover Map (remotely sensed data - electronic format) - CEH Monks Wood
- Biological Records Centre - CEH Monks Wood - range of species data, variable completeness, format and accessibility.
- WIMS (Water Information Management System)
- PREMIS Pre-Archive Management Information System (Water Quality Sampling database)
- HYDROLOG (database system for all hydrological data)
- RIVPACS - GQA data set - family level; plus reference dataset (>600 GB sites) and - National Invertebrate Database at species level (held at CEH - Dorset)
- Acidification Index (macroinvertebrates) - land-use change - climate change - critical loads
- PHABSIM - describes habitat characteristics at different flows - initially developed to assess habitat quality for trout in the USA
- HABSCORE - categorising system for habitat quality for a defined species (fish)
- ERS - Exposed Riverine Sediment - dataset - (associated semi-terrestrial fauna, including species of high conservation status).
- PSYM - Predictive System for Multimetrics - applied to classifying the quality of ponds and canals
- Harmonised Monitoring sites - focuses on chemical water quality
- POPPIE - model of pesticide run-off
- BACTISAMPLE - Coliform data
- Phosphatase activity (enzyme assay system)
- Soil Survey Data
- Population Census (human)
- Registry of Contaminated Land

A series of additional combinations of datasets and monitoring tools were identified for consideration:

- RHS - Wetlands/Bankside habitat
- GQA - MTR - RHS
- LIFE Score - biological data - wetland management/protection
- HYDROLOG - WIMS
- Urban run-off - 'Dirty RIVPACS' - macroinvertebrate community response to modified flow regimes and inputs of heavy metals
- Soil Survey Data - surface run-off - used to model phosphate movement
- HABSCORE - RHS - RIVPACS

Observations on scales of monitoring

Data need to be accurately spatially referenced - eg -

Chemistry	-	single point sample (instantaneous)
Macroinvertebrates	-	over a few meters (sentinel monitors)
Mean Trophic Rank	-	100m reach surveys for macrophytes
River Habitat Survey	-	500m watercourse reaches (long/medium term channel modification).
SERCON	-	at a broader scale than RHS - a system for evaluating rivers for conservation (measure of current status)

Spatial interpretation

National statistics from routine point-samples can provide representative summary statistics, but in most cases it is not valid to extrapolate back to a local scale using the national statistics.

Temporal interpretation

Changes in environmental variables and potential impacts cannot be assessed effectively unless key long-term datasets are maintained and adequately resourced.

Questions and observations that arose following the Workshop

There is a recognised need to classify the number of determinands and descriptors which are stored in accessible and compatible formats, with the facility to cross-reference them in terms of the distribution of restricted and multi-use monitoring sites.

How do we interpret the consequences of subtle changes within biological communities? (Eg - loss of particular species - in response to pollution, invasive species, habitat/site management changes). Biological 'quality' is assessed in terms of high 'scores'/high community diversity/the presence of rare species - and equated to current views on 'desirable to conserve'. However, the majority of communities/habitats are characterised by a low diversity of abundant species. These abundant species interact with the 'desirable to conserve' communities/species. How do we interpret and manage the status of rare communities/species/habitats without understanding their interactions with abundant species?

4. CONSULTATION

The consultation exercise combined conclusions from the Workshop participants and their colleagues within the Agency, plus advice from the Project Board. Three Project Board meetings were held (July and October 2000, April 2001) to ensure the review activities were correctly focused.

5. REVIEW

5.1 Conclusions from the Workshop

Question 1: **Which sets of information used by the Environment Agency are currently separate but can be combined to yield fast answers to new questions?**

Two of the three Breakout Groups listed a total of around 23 datasets and monitoring tools that are, or could be, usefully cross-referenced. The third Group concentrated on describing the difficulties of combining data sources.

The second and third Groups raised the lack of commonality (format incompatibility) between datasets and monitoring tools. Attributing this to changing software capabilities and the gradual evolution of Agency function-specific requirements for new data.

Question 2: **On which spatial scales are datasets and monitoring tools most usefully cross-referenced?**

All Breakout Groups concluded that information is required at a broad range of scales within environmental monitoring. They also concluded that it is desirable for cross-referencing to operate over the range of scales (temporal and spatial). One Group suggested that cross-referencing should be undertaken at the shortest/lowest/smallest scale, with the facility to broaden the scale of comparison.

One Group stressed the need for accurate and representative data that is clearly defined.

No Groups actually defined the most desirable spatial scales for cross-referencing datasets and monitoring tools, as they reasoned that this is dictated by the varied information requirements.

Question 3: **What are the datasets/monitoring tools - unique to different functions, describe (briefly) their potential relevance to other Agency functions?**

All Breakout Groups suggested lists of desirable new(?) links between monitoring tools. These suggestions generally covered two datasets and monitoring tools (19 combinations), but they also included the linking of three or more datasets and monitoring tools (7 combinations).

Following the circulation of an account of the Workshop some further points were raised:

Question 1
Additional information was provided on 11 datasets and monitoring tools, whilst a further 16 previously overlooked datasets and monitoring tools were listed.

A further 7 potentially useful combinations of datasets and monitoring tools were suggested.

Question 2
There is the need to confirm the accuracy of monitoring data and its spatial reference, whilst useful cross-comparisons of data depend on the continuous maintenance of long-term monitoring and effective data archiving.

General points raised:
Accessible and compatible data formats are required to improve the effectiveness of using datasets and monitoring tools in a cross-function context within the Environment Agency. This would both: (1) facilitate site-specific investigations, providing a route to the types of information available for that site; (2) promote faster cross-correlation of that data.

5.2 Previous Reviews of Monitoring

5.2.1 Bridging the Gap

An international 3-day conference was held in London (June 1998) to discuss the environmental information "demand and supply cycle". The brief account of the conference ("Bridging the Gap") was disseminated by the Environment Agency.

Report scope
Four main questions were addressed:
- What are the current and prospective priorities for environmental information to meet policy and environmental management needs?
- To what extent are the existing information needs already being met and where are the perceived gaps?
- How can future information needs be met most efficiently and what frameworks are needed to optimise environmental monitoring and modelling?
- How can the information be most effectively put to use to meet the demands placed on it by policy makers and the public?

Main conclusions
The information gap was perceived to be between the recognised information needs and current delivery systems. The state of the environment should be conveyed via suitable indicators and agreed targets.

There is a pressing need to update and rationalise monitoring and the transfer of information on the environment, aiming to develop a system to serve the needs of many different stakeholders.

Recommendations
The essence of the conference recommendations centred on:
- Improvements in the dialogue between information suppliers and users must continue.
- The state of the environment should be expressed using indicators that mirror the approach used with accepted economic indicators.
- We must capitalise on new developments in monitoring techniques, whilst streamlining and prioritising the information gathering activities.

Critique
The conference concentrated on policy requirements and highlighted the changing needs of monitoring information and desirable improvements in its ease of transfer between organisations and the public. These factors are very pertinent to the UK Environment Agency. However, there was no acknowledgement of (1) the practical difficulties and cost implications of updating and changing monitoring programmes; (2) the current lack of mechanisms to deliver monitoring policy changes underpinned by sound science.

5.2.2 Monitoring for what?

A Strategic review of the Agency's environmental information needs and monitoring programmes (Anon) was undertaken by the Environment Agency's Environmental Strategy Directorate and presented at an internal meeting in February 1999.

Report scope
The review provides a comprehensive account of the Agency's information needs and the monitoring activities currently carried out. Information gaps and redundancy of monitoring effort are highlighted, within the context of the UK's environmental monitoring programme as a whole and the changing legislation requirements (eg, the 1995 Environment Act; the proposed European Water Framework Directive).

Main conclusions
The report sets out sixty action points to address information gaps in monitoring data. It identifies a series of further improvements that can be made in efficiency and effectiveness, also five priority areas that require management decisions to implement the recommended changes. It notes some evidence of redundancy in data collection that provides the opportunity to re-allocate monitoring effort resources.

Recommendations
The recommended further improvements in efficiency and effectiveness of monitoring were:
- Make better use of available information
- Place more emphasis on defining priorities in information needs
- Improve collaborative partnerships with others
- Improve the overall management of monitoring processes and programmes
- Utilise existing tools and predictive models for better targeting of sampling effort
- Capitalise to a greater extent upon instrumentation and new developments in surveillance technologies
- Re-examine the charging basis for monitoring processes

Critique
This wide-ranging review provides a large volume of information on the environmental monitoring activities across the Regions and within the Environment Agency, as a whole. Inevitably, the main focus of the review is on the currently perceived future usefulness of monitoring information, with priorities driven by legislative requirements and limited by funding constraints. The identification of 'redundant data' and 'redundant monitoring activities' does not clearly distinguish duplication of information from unnecessary or outdated information gathering. There appears to be no clear policy or mechanism in place for deciding when to reduce or terminate monitoring for particular pollutants, ie, manufactured compounds withdrawn from distribution that are no longer detected in the wider environment. Such a

mechanism would be contentious because it highlights the difficulties associated with perceived long-term risk and deciding what not to monitor in an expanding range of compounds and detection systems.

5.3 Water Framework Directive

The following notes summarise future monitoring and highlight gaps recognised during a 2-day Workshop. The Workshop included representatives from the Environment Agency, SEPA, CCW, government departments and NERC and was held at CEH Wallingford (December 2000).

Gaps in future UK freshwater environmental monitoring requirements were discussed and form the second part of this account. Comments expanding these notes are labelled (*NOTE) and reflect additions/contradictions following the wider circulation of the workshop account.

The drafting of the EU Water Framework Directive has been strongly influenced by the UK Agencies. Despite this steer some new assessment tools/data will be needed.

The Directive will operate on a 15-year delivery cycle. The only statutory requirement of the directive appears to be that River Basin Management Plans are drawn up. These plans should include, amongst other things, present status, defined targets and performance indicators.

Information is needed at the catchment and regional scale. The DETR representative present indicated that eight plans were envisaged for England and Wales based on the eight Environment Agency Regions but slightly modified in the case of Midlands and Welsh Region to allow catchment boundaries to over-ride national boundaries.

The timetable for implementation of the plan is:

Define basins, appoint “Competent Authorities”	2003
Analyse basin, review human impact	2004
Commence monitoring programmes	2006
State issues and objectives	2007
Derive measures; consult on draft plan	2008
Enact plan	2009-2012
Review plan	2013-2015
New plans for next cycle	2015+

Note: in England & Wales, Scotland & N. Ireland - there are contrasting waterbodies and varying associated gaps in information/monitoring activities.

Review of information gaps:

Environmental data

Two forms of classification of water body types are set out in the Directive, Types A and B. Type B classification is likely to be adopted in UK. For all water body types some classificatory variables are obligatory and many more are optional. Problems include:

How to categorise geology?
How to weight the importance of the obligatory and optional variables?
How many end-group river types required?

Chemistry and hydrology

The necessary monitoring data is considered to be mostly available (if not easily accessed). Research to establish chemical reference states is underway at CEH Wallingford and at CEH Dorset.

Microbiology

Microbiology was not covered in the workshop

Phytoplankton

Rivers – no standard procedures or reference states. Phytoplankton is only likely to be relevant in a few large rivers*.

[*NOTE: Phytoplankton are probably relevant to *any* large or medium-sized watercourse (inc. drains, canals, etc.) and Regional standard procedures/reference states are available (Anglian Region, Jan Krokowski, Bill Brierley or Broads Research Team (Jo-Anne Pitt).]

Lakes - detailed information is available for very few (water abstraction-related). No reference states developed*.

[*NOTE: phytoplankton responses to environmental control (PROTECH) have been examined in some lakes.]

Benthic and epipytic algae (diatoms)

Rivers - expanding range of data available + developing monitoring tools (principally TDI – Trophic Diatom Index). This technique is still not widely used and there are relatively few taxonomically capable people. No reference states developed.

Lakes - detailed information on phytoplankton is available for very few lakes (water abstraction-related). No reference states developed*. NOTE, see above.

Macrophytes

Rivers - some concern that 'morphological types', used for defining habitat extent and quality, may not be sufficient in the present context (with more comprehensive species data needed). MTR (Mean Trophic Ranking) is a standard technique but its use is normally confined to the implementation of the Urban Waste Water Directive. RHS (River Habitat Survey) data "morphological types" – see above. No reference states developed.

Lakes - a general discussion suggested there are major information gaps*.

[*Note Anglian Region have a developing methodology for defining lake types (Ian Cappitt, Bill Brierley.]

Ponds - new data (Pond Action) is becoming available.

Note that most ponds are below the one-hectare minimum size to which the directive applies and thus peripheral to its implementation.

Macroinvertebrates

Rivers - extensive coverage (probably sufficient)* is available relating to quality assessment. RIVPACS provides reference states and error rates. Possibly, separate systems are required to assess the separate impacts of low flow and acidification.

[*NOTE: Possibly, separate systems are required to assess the separate impacts of low flow and acidification. There may be some crossover, but separation of the two issues is *definitely* necessary. A review of the current sampling network is essential to address the latter.]

Lakes - detailed data confined to a few locations - queried the value of measuring lake quality/status using benthic macroinvertebrates. All records are likely to be littoral*. No widely used deep-water methodology*. No reference states developed.

[*NOTE: lake water quality and macroinvertebrates communities have been compared within Anglian Region and deep-water methodologies established.]

Ponds - new data (Pond Action) are becoming available. However, most ponds are below the one-hectare minimum size to which the Water Framework Directive will apply and thus peripheral to its implementation.

Fish

This is a recognised problem area - regarding population status and survey practicalities.

The WFD will require species distribution status and some measure of abundance in order to gauge status and future change and maintenance of species status.

Context:

There was no reference to Environment Agency's rolling programme of fish population assessment in rivers (spp/size/age class distribution). The Agency’s Coarse Fish Centre may feel they have suitable tools already? No reference states developed? HABSCORE - currently only applies to salmonids.

Lakes and ponds - no systematic widescale surveys. No reference states developed. A method is under development to assess invertebrate status using a multimetric approach (PSYM)

Canals - British Waterways undertake surveys. No reference states developed.

Habitat quality

Rivers – River Habitat Survey (RHS) and Rvier Corridor Survey (RCS) data are available. These systems are less developed in terms of the provision of reference states and error statistics (than RIVPACS)

Lakes – No equivalent procedures are thought to be operating.

Ponds – Pond Action provide a standard technique but most ponds are too small to be covered by the Water Framework Directive. Pond methods may be applicable to lake shores?

General biological issues that need to be addressed

- Is there a need or requirement to assess all taxonomic groups for each site?
- If not, which are the most appropriate groups for which type of waterbody?
- How are the five categories of ecological status defined and how are their value ranges determined?
- How does the separate information from each taxonomic group get integrated into a single measure of ecological status?
- How are ecological, chemical and hydrological status integrated to give an overall site assessment?

5.4 Account of Environment Agency R & D Output (June 2000)

Titles and summary abstracts from research projects funded by the Environment Agency were searched for references to environmental monitoring and data holdings that related to freshwater environments.

R & D output content

There were 2,146 R & D projects listed on the CD- ROM spanning the period 1985-2000. Just over half the report abstracts (1,110) had no reference to the year of publication (or in the case of 6 it was obviously incorrect). The distribution by year of the reports with dates documented (Table 1) illustrates the accelerating report production by the Environment Agency in the mid-1990s. (Note: output from year 2000 is incomplete). Approximately thirty additional R & D projects covering monitoring themes and/or datasets are classed as Active, Awaiting Completion or Budget Delegated in the current Environment Agency R & D programme (autumn 2000).

The R & D project report abstracts (CD-ROM, June 2000) with specific referrals to environmental monitoring and data holdings relating to freshwater topics were surprisingly small (27 out of 2,146). This probably reflects both the inadequacy of some abstracts and the selection of key words used to search the CD contents. Despite these limitations, the information from the 27 abstracts (together with summary information on RIVPACS and RHS) was analysed using a questionnaire designed to show the range of topics covered. The results indicate the poor level of accessibility of this type of information and identify very limited references to links between different monitoring tools and datsets.

Table 1. Environment Agency R & D Reports Catalogue (CD): Number of reports for each calender year.

Year	Number
1981	1
1982	6
1983	21
1984	6
1985	23
1986	37
1987	32
1988	17
1989	47
1990	53
1991	40
1992	32
1993	53
1994	60
1995	63
1996	112
1997	133
1998	114
1999	143
2000	43 *
Total	**1,036**

* Records for year 2000 are incomplete

Summarised information from the reports shortlisted using the keywords: "monitoring" and "data*" (* - to include datasets) in the CD search facility.

Abstracts with specific referrals to environmental monitoring and data holdings:
(out of 2,146 reports): **29**

Geographic coverage:
National **20**
Regional **4**
Catchment-specific **3**
International **2**
(In the case of national coverage, whether data are in a consistent format is unknown)

General topics (not exclusive) covered in the reports:
Biological **19**
Physical **24**
Chemical **15**

Data (where specified):
GIS layer **2**
Sample point based **2**
River reach based **1**

Data verification status:
(eg, raw data/all error data flagged/duplicate data eliminated):
Data verification process used **3**

Is the data actively used in other contexts?
combined with other datasets **3**

Software/storage format (Access, Excel, ASCII, Agency-specific package):
storage format specified **6**

Accessibility (specify restrictions applying - or intranet/web-based/CD, etc):
'Open **5**
'Regional' **3**
Directly comparable with other datasets:
(eg matching site codes)? **6**

Run of data?
(Periodicity - annual, monthly, 15-minute, etc):
one-off studies **23**
annual **3**
quinquenial **2**

Data volume specified? (kilo-bytes/mega-bytes):
data volume noted **3**

Approximate number of records/samples/sites specified?:
number of records noted **3**

Main conclusions

Without recourse to the individual research reports, conclusions on the relationships between datasets are constrained by the limited level of detail provided in research report abstracts. The most obvious common theme is the insular nature of report abstracts. Few abstracts provide technical details of the data examined or its relationship to other data holdings or related activities within the Environment Agency.

Addendum:

Within the current Environment Agency R & D programme list (autumn 2000) there are around 30 new projects that appear to be related to datasets and monitoring tools relevant to freshwater monitoring. Further analysis will be possible when the project reports are generated.

6. CONCLUSIONS

6.1 General Conclusions

The review failed to access and compare the characteristics of Environment Agency databases to the extent anticipated in the project aims. The review conclusions clarify the main problems encountered.

- Widespread format incompatibility occurs between Agency datasets and between databases.
- There is scope for greater awareness of datasets/monitoring tools and their potential to inform decisions throughout the Agency, at all levels.
- There is a need to deliver information in different ways to fulfil both national and local requirements within the Agency.

6.2 Specific Conclusions

- Some Agency datasets and monitoring tools can be usefully combined but most lack automated links to assist cross-referencing and selective analysis.
- There is a requirement for data access at a wide range of spatial scales.
- No precise definition of the most desirable spatial scales for cross-referencing datasets and monitoring tools is feasible as this is dictated by the varied information requirements within the Agency.
- There is a need for a unifying dataset for physical data, as is available for water chemistry.
- Data sources are frequently in incompatible formats, they can become rapidly outdated and external data (to the Environment Agency) may incur access charges: all these factors discourage data investigation and exploitation.
- Effective surveillance requires that the data analysis tools are compatible with monitored data.
- Established GQA sites are not universally useful, as they are often non-representative for certain parameters and attributes.
- There is a recognised need to confirm the accuracy of monitoring data and its spatial reference.
- Useful cross-comparisons of data depends on the continuous maintenance of long-term monitoring and effective data archiving.
- In retrospect, the review process would have benefited from a period of staff secondment to the Agency during the review, providing direct access to key information on datasets and monitoring tools.

6.3 Review Activities

The Workshop (July 2000) focused on providing an up-to-date account of the current monitoring tools and data sources that are yielding the key information on environmental quality within the Environment Agency. The participants also discussed future options and needs in relation to the practical difficulties encountered when accessing and cross-referencing environmental data.

The Workshop identified some additional points:

- the need for clearly defined, accurate and representative data (adopt national QA procedures for all new data, prior to archiving).
- there is a limited awareness of particular datasets and monitoring tools, which could be discouraging the initial exploration and development of new monitoring approaches.
- there is frequently a lack of format compatibility between datasets and monitoring tools. This was attributed to changing software capabilities and gradual evolution of Agency function-specific requirements for new data.
- effective surveillance requires that the data analysis tools are compatible with monitored data.
- established GQA sites are not universally useful (non-representative for certain parameters and attributes).

The Workshop also emphasised the importance of access to data at a wide range of scales. It concluded that information is required at a broad range of scales within environmental monitoring and that it is desirable for cross-referencing to operate over the range of scales (temporal and spatial). Cross-referencing should be undertaken at the shortest/lowest/smallest scale, with the facility to broaden the scale of comparison. No precise definition of the most desirable spatial scales for cross-referencing datasets and monitoring tools is feasible as this is dictated by the varied information requirements within the Agency.

Following the circulation of an account of the Workshop some further points were raised:

- Cross-comparisons of data depend on the continuous maintenance of long-term monitoring and effective data archiving.
- Accessible and compatible data formats are required to improve the effectiveness of using datasets and monitoring tools in a cross-function context within the Environment Agency. This wills both: (1) facilitate site-specific investigations, providing a route to the types of information available for that site; (2) promote faster cross-correlation of that data.
- The Network Review of biological data collection, in parallel with the CAMS process, provides the opportunity for a more effective integration of monitoring activities, data recording and cross-referencing facilities.

Previous monitoring reviews, "Bridging the Gap" (1998) and "Monitoring for What?" (1999) recommend the way forward for the Environment Agency. "Bridging the Gap" failed to mention either (1) the practical difficulties and cost implications of updating and changing monitoring programmes; or (2) the current lack of mechanisms to deliver monitoring policy changes underpinned by sound science. "Monitoring for What?" promotes a policy to re-focus monitoring activity but fails to define a mechanism for deciding when to reduce or terminate monitoring for particular pollutants (eg, manufactured compounds withdrawn from distribution that are no longer detected in the wider environment). Such a mechanism would be contentious because it highlights the difficulties associated with perceived long-term risk.

The Agency policy switch to monitoring pressures, rather than specific pollutants, will drive the decision process.

The Agency R & D CD-ROM (June 2002) with titles and summary outputs of 2,146 reports, provided little detail with which to assess database format, purpose and compatibility between

databases and monitoring tools. The titles of current and planned (Autumn 2000) R & D projects indicate databases and monitoring tools feature increasing frequently within the R & D programme.

A 2-day Workshop on the Water Framework Directive (31st Nov & 1st Dec, 2000), held at CEH Wallingford, outlined the anticipated WFD requirements and attempted to identify the information gaps. Inevitably, some regional monitoring activities were overlooked leading to an over-pessimistic account of the information gaps, but reflecting the national (devolved) coverage of monitoring activities.

Addendum

Two guides for new and existing databases in the Agency were made available at the end of the review process, also the output from a review of Year-2000 compliance within the Agency software and datasets. The Y2K compliance/non-compliance review included 2,900 entries, with supplementary information on the software/data holdings, data field 'Roles' lists Agency region and Agency staff contact point.

1) The Performance Monitoring Group (for internal Agency circulation) produced a guide listing 9 databases (list to be updated electronically). These were:

IPCIS - collectively known as the Integrated Pollution Control Information System;
BIF-Business Information System;
PI - Pollution Inventory;
NED-National Enforcement's Database;
NIRS - National Incident Reporting System; Pollution Prevention Database;
SWaT - Special Waste Tracking Database;
WIMS - Water Information Management System;
REGIS - Regulation Information for Waste Management.

2) The PREMIS Technical Manual - a Water Quality Sampling database provides a pre-archive management information system - with an overview of the application and its uses.

3) The Y2K compliance review included around 300 databases, of which approximately 50 are considered to be directly or indirectly connected with water quality monitoring. This Access database could be regularly updated to provide a more comprehensive cross-referencing index of Agency datasets and their characteristics.

7. RECOMMENDATIONS

The conclusions from the Workshop and review activities indicate that:

- There is scope for an improvement in cross-comparisons of datasets and information retrieval mechanisms within the Environment Agency.
- Accessible and compatible data formats are required to improve the effectiveness of using datasets and monitoring tools in a cross-function context within the Environment Agency.
- From the outset, database design requires close collaboration between software writers and end-users.

Such an approach will:

- facilitate site-specific investigations, providing staff with the types of information available for that site,
- promote faster cross-correlation of that data,
- Facilitate data retrieval and analysis for generating national and regional statistics.
- There is the need to confirm the accuracy of monitoring data and its spatial reference.
- Useful cross-comparisons of data also dependent on the continuous maintenance of key long-term monitoring programmes and efficient data archiving.

The Performance Monitoring Group guide, listing 9 Environment Agency databases, could be usefully expanded and incorporate the relevant subset of database descriptors that were gathered for the Y2K compliance/non-compliance review of Agency software.

REFERENCES

Environment Agency (1998) Research and Development Strategy

Environment Agency (1999) "Bridging the Gap" - summary leaflet of the international conference held in London (June 1998), 12pp.

Environment Agency (1999) "Monitoring for What?" - summary findings of a review of the environmental information needs and monitoring programmes that are needed to meet them. Unpublished report (Environment Agency), 174pp

Environment Agency (1999) Alternative Methods for the Biological Classification of Rivers, R & D Technical Report E57

Environment Agency (2000) Catalogue of Environment Agency R & D Outputs, CD ROM

Raven, P.J., Boon, P.J., Dawson F.H. & Ferguson A.J.D. (1998) Towards an integrated approach to classifying and evaluating rivers in the UK. Special issue: The application of classification and assessment methods to river management in the UK, Aquatic Conservation: Marine & Freshwater Ecosystems 8 (4) 383-393

Wright, J.F., Furse, M.T. and Moss, D. (1998) River Classification using Invertebrates: RIVPACS Applications. Aquatic Conservation. 8, 617-631

APPENDIX I:

Index of Acronyms

BAP - Biodiversity Action Plan
CAMS - Catchment management abstraction strategy
CASI - Compact Airborne Spectrographic Imager
CCI - Community Conservation Index (Anglian Region)
CEH - Centre for Ecology and Hydrology
CPET - Chironomid Pupal Exuviae (species assemblages)
CI - Conservation Index
CS 2000 - Countryside Survey (2000)
cSAC - candidate Special Area of Conservation
DQI - Diatom Quality Index
DTI - Diatom Trophic Index
ERS - Exposed Riverine Sediment (habitat with characteristic macro-invertebrates)
FEH - Flood Estimation Handbook
GIS - Geographic Information Systems
GQA - General Quality Audit
HABSCORE - Habitat Score
HYDROLOG - database for storing river flow data (managed by CEH Wallingford)
IFE - Institute of Freshwater Ecology
IMPACTS - Integrated Monitoring using Prediction And Classification TechniqueS
LIDAR - Light Direction and Ranging Instrument (remote sensing)
LIFE - Lotic-invertebrate Index for Flow Evaluation
LQI – Lincoln Quality Index
MTR - Mean Trophic Ranking (aquatic macrophyte community based)
NGR - National Grid Reference
PHABSIM - Physical HABitat SIMulation
PLANTPACS - (aquatic) PLANT - Prediction And Classification System
POPPIE - model of pesticide run-off
PREMIS - Pre-Archive Management Information System (Water Quality Sampling database)
PROTECH - Phytoplankton Responses to Environmental Control
PSYM - Predictive System for Multi-metrics
RCS - River Corridor Survey
RHS - River Habitat Survey
RIVPACS - River Invertebrate Prediction And Classification System
SERCON - System for Evaluating Rivers for Conservation
SOILPACS - SOIL (flora/fauna) - Prediction And Classification System
SSSIs - Sites of Special Scientific Interest
TDI - Trophic Diatom Index
WIMS - Water Information Management System