Institute of Freshwater Ecology

Annual Report 1995-96

Natural Environment Research Council

Institute of Freshwater Ecology Mission Statement

The Institute's mission is:-

"To conduct research of the highest quality and to develop integrated theory for the science of fresh and estuarine waters. This research will be conducted at the species, population, community and ecosystem levels and will include investigations of the genetic, physiological and behavioural mechanisms by which organisms interact with their environment. Research will also be undertaken into the biological, chemical and physical components and processes which control aquatic ecosystems, especially the mechanisms of response to natural and anthropogenic change. The Institute will study the dynamics of interactions between terrestrial and freshwater ecosystems, and the control of the chemical composition and physical structure of water bodies and their retention and transport of soluble and particulate material. The information gained will be used to develop strategies for the sustainable management, conservation and exploitation of freshwater systems at national and global levels.

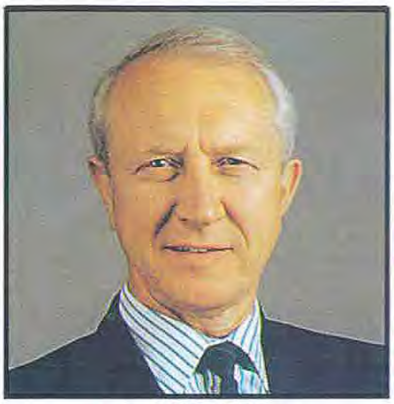
The Institute will also collect, validate and manage relevant environmental data in the furtherance of its research programme and will act as an international resource of expertise and information. It will continue to develop its programme for long-term, multidisciplinary research, undertake commissioned research on behalf of its customer base, provide training of the highest quality and maintain its international reputation. The Institute of Freshwater Ecology will collaborate with the component Institutes of the Centre for Ecology and Hydrology, the Freshwater Biological Association and other organisations to ensure achievement of these aims."

Front Cover Illustrations:
Large photograph - *River Lune, S.E. Cumbria.*
Small photographs - *IFE research underpins tropical fishery management.*
- *Lifting a perch trap, Windermere.*
- *Ice pressure ridge, Loch Leven.*
- *Bacteriophage from a freshwater lake x 85,000.*

Report of the Institute of Freshwater Ecology 1995-96

Natural Environment Research Council

Foreword



Professor W B Wilkinson
Director

Robust and timely responses to major environmental problems, such as the sustainability of natural resources, climate change, pollution etc, are only possible if based on sound interdisciplinary science.

Recognising the importance of this holistic approach, the Natural Environment Research Council restructured its activities during 1994. A major element of this re-organisation was a grouping of four NERC Institutes into the Centre for Ecology and Hydrology (CEH). Research within CEH is concerned with the land on which we live, its fresh waters and the living organisms which share the environment with us. Component Institutes of CEH are:

- Institute of Freshwater Ecology
- Institute of Hydrology
- Institute of Terrestrial Ecology
- Institute of Virology and Environmental Microbiology

CEH has some 625 staff (475 Scientists) and about 300 visiting scientists and students, well-equipped laboratories located throughout the UK (Appendix 2), and a reputation for excellence in national and international research, monitoring and data collection. As such, CEH must have one of the strongest capabilities in the world for undertaking holistic research in the terrestrial and freshwater sciences.

The CEH capability to address multidisciplinary issues has been strengthened during the past year following a full review of its research and a reshaping into ten new Research Programmes. These set the course for research over the next five years and beyond. The new Programmes have been formulated by the CEH Directors and scientists working closely with the external assessors who constitute four Programme Review Groups. In drawing together the new Research Programmes the scientists have also been cognisant of: the "wealth creation" and "quality of life" thrust in the 1993 White Paper, "Realising our Potential - a Strategy for Science and Technology"; the National Technology Foresight Programme; the UK Government's and European Union's legislation and policy; and the content of the major international science programmes.

The Institutes' activities have been further cemented by cross-Institute interdisciplinary research projects. These form part of the Integrating Science Fund which was established last year. Some seven projects were funded during 1994/95. All have made good progress. During the present year a further 6 have been approved (Appendix 3).

During 1994, the CEH Institutes were required to prepare papers and give evidence to the Office of Public Science and Services as part of the "Efficiency Survey of the Public Sector Research Establishment". The published report of the Survey left unresolved the role of many Research Council Institutes within Public Sector science. In September 1995, the Government announced that 42 Public-Sector Research establishments would be subject to further review to assess whether the "functions" of the establishments were needed and whether the Public Sector should provide these. Scope for further rationalisation was also to be examined.

CEH was subject to this so-called "Prior Options" review. CEH provided extensive documentary evidence and made a verbal presentation to the Steering Committee undertaking the NERC Prior Options review. CEH took the opportunity to highlight the major benefits that have and will continue to flow to the ecological and hydrological sciences as a result of the strong interdisciplinary focus that is now possible through CEH. The NERC Steering Committee presented its report to Government in late July 1996. Neither the recommendations of the Steering Committee nor the Government response to these are known at the time of writing.

It is to the credit of all CEH staff that the research has remained buoyant and the science outputs have been maintained at a high level during the year against this background of uncertainty and potential change.

The Institute of Freshwater Ecology has, during the year, contributed in a major way to the development of the new CEH Research Programmes and is collaborating fully with other Institutes through the Integrating Fund research projects. This Annual Report describes in some detail aspects of the year's scientific research. Under the leadership provided by the Director, Professor Alan Pickering, the science at IFE continues to flourish and I commend the report to you.

I would also take this opportunity to draw your attention to the complementary Annual Reports for 1995/96 from the other CEH Institutes and to the CEH Overview Report.

Brian Wilkinson
Director
Centre for Ecology and Hydrology

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Director's Introduction

Professor Alan Pickering
Director

The science programme has flourished at a time of great change and this report summarises some of the exciting research undertaken during the past 12 months.

The year 1995/96 has been a very positive one for the Institute of Freshwater Ecology, with major achievements in the following areas:-

- scientific advancement in the new CEH Core Strategic Programme
- collaborative work under the CEH Integrating Fund
- increased output in terms of published papers and reports
- divisional restructuring and budgetary control

The year has been dominated by the Prior Options Review of the public sector research establishments. This is a Government-led initiative to review future ownership and management options for over fifty research establishments, including those funded by NERC (CEH, CCMS, BGS) but, at the time of writing this Introduction, the Government's response has still not been released. This uncertainty follows an extended period in which the role and direction of the UK's science base has been under constant examination and reorganisation to such an extent that it has been likened to the examination of the growth of a plant by repeatedly pulling it up to examine the roots! The Institute of Freshwater Ecology is not averse to the challenge of justifying its research activities on the basis of wealth creation or the quality of life or to a sensible programme of reorganisation which has environmental science as the key beneficiary but it must be recognised that the very nature of our work, with its emphasis on a long-term, multidisciplinary approach to the understanding and solution of difficult environmental problems, requires a stability of structure and funding. It is to the credit of the staff, therefore, that the science programme has flourished at a time of such change and this report summarises some of the exciting research undertaken during the past 12 months.

The past year has been one of progress in terms of internal reorganisation at both Institute and Centre level. Within the IFE we now have a functional Divisional Structure and I am grateful to all Divisional Heads for their skill in managing each Division and for their guidance and support at the bi-monthly Divisional Heads Meetings during which scientific policy and management issues are discussed in an atmosphere of healthy debate. The newly-introduced, formal budgetary arrangements have been instrumental not only in controlling our overall recurrent expenditure but also in providing the budget holders with a degree of choice and flexibility in the way in which the Institute purchases its various goods and services, leading to a greater sense of participation and 'ownership' within the organisation. Lines of communication between the management and staff have been improved by the adoption of an Intermediate Whitley Committee to represent the views of all staff, an arrangement that is now complemented by an equivalent committee at the Centre level. The CEH Integrating Fund has done much to encourage further collaboration within CEH and I detect a greater awareness by the IFE staff of the work of our sister Institutes matched by a reciprocal awareness. This is now being translated into opportunities for commissioned research, using the complementary skills of terrestrial and freshwater ecologists, hydrologists, environmental chemists, microbiologists and environmental economists.

In response to NERC's plans for a New Funding Model, the new CEH Core Strategic Programme (see Table 1), brings together the views and plans of colleagues across the Institutes. This Annual Report is structured according to the new programme and describes

Table 1 The CEH Core Strategic Programme

Programme Area 1	Soil and Soil/Vegetation Interactions
Programme Area 2	Land Use Science
Programme Area 3	The Urban Environment
Programme Area 4	Freshwater Resources
Programme Area 5	Biodiversity and Population Processes
Programme Area 6	Pest and Disease Control and Risk Assessment for GMOs
Programme Area 7	Pollution
Programme Area 8	Environmental Risks
Programme Area 9	Global Change
Programme Area 10	Integrating Generic Science

New techniques for the automatic monitoring of salmon smolt migrations have been developed by scientists at the River Laboratory.

some of our research progress in 5 of the 10 programme areas (4, 5, 7, 9 & 10).

An important component of our work in the field of *Freshwater Resources* is the study of tropical limnology and the environmental problems facing Lake Victoria, the world's second largest freshwater lake. Closer to home, we have collaborated with the Environment Agency in the River Habitat Survey, a new system for the assessment of habitat quality of rivers and streams based on their physical structure. During the past year, drought conditions raised the focus on phytoplankton blooms in rivers and we outline some of our recent progress in the predictive modelling of potentially toxic algal blooms in rivers, taking into account the importance of "dead zones" in influencing algal growth. Weather patterns, including drought, can also have major impacts on fish populations and new techniques for the automatic monitoring of salmon smolt migrations have been developed at the River Laboratory. The links between changing weather patterns and fish populations are also explored in the analysis of long-term data on the Windermere perch.

Biodiversity is a term widely used in the context of sustainable development and environmental protection, although key questions about the functions and importance of biologically-diverse communities still remain to be answered. This Report considers the techniques needed to provide an accurate assessment of the diversity of river macroinvertebrates and demonstrates the diversity throughout the UK, the role of reference collections of living organisms and our growing awareness of the abundance and diversity of free virus particles in aquatic ecosystems. Particular problems relate to the diversity of bacteria, where the classical 'species' concept may not apply. Algal diversity across a range of Cumbrian lakes illustrates the close links between species abundance and the physicochemical environment and species diversity in riverine fish populations is also habitat-dependent.

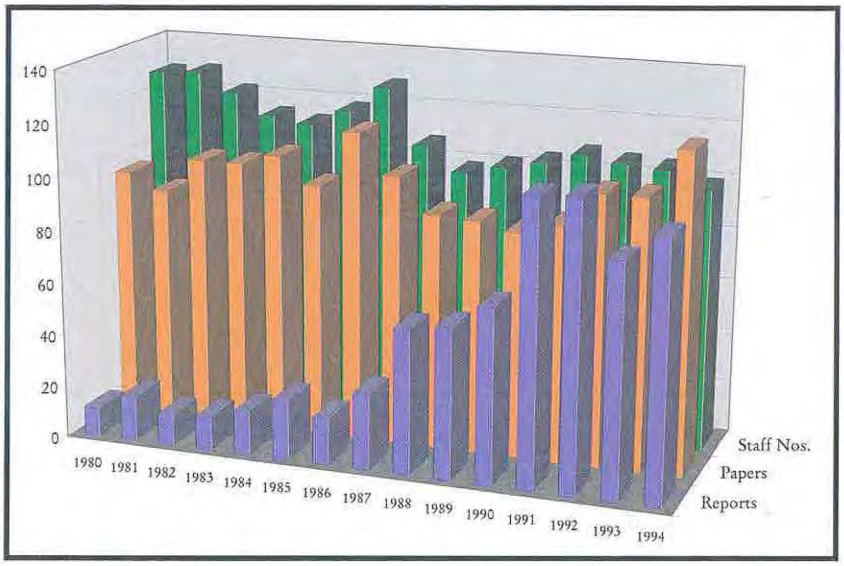
Our developing involvement with tropical limnology is also illustrated by work on Lake Tanganyika, the world's second deepest lake. With the lake under threat of *Pollution*, the IFE has been involved in designing a strategy to assess the effects of pollution on its biodiversity. Pollution also impacts on the biology of most UK rivers and a clear methodology, based on RIVPACS, is required if we are to distinguish the real effects of pollution from error and natural variation in the biological data.

Recent years have also been important for major oil tanker disasters around the UK coastline and IFE microbiologists are working with their ITE colleagues to evaluate the most effective methods of disposal of oil-contaminated beach material. Radionuclide contamination was a key environmental issue even before the Chernobyl disaster and two lines of research in this area are reported here. The growing controversy over the potential effect of oestrogenic substances in the environment has been the subject of constant media debate throughout the year and the IFE has injected a degree of scientific objectivity into the arguments through its work on the impacts of alkylphenolic compounds on freshwater fish. This work is also linked to studies at the Institute of Hydrology on the environmental stability and fate of such compounds.

The IFE's role in long-term environmental monitoring and data collection places us in a unique position to contribute to *Global Change* research. Examples are provided from the fields of insect population control, climatic reconstruction based on sediment stratigraphy, ice cover on Loch Leven and the potential impacts of increased UV-B radiation on freshwater phytoplankton.

The final programme area in this Report is the important one of *Integrating Generic Science*. By this we mean those underpinning scientific activities which are essential for research progress in the other nine areas. The three items described in this section (remote sensing to identify different algal groups, GIS modelling for the management of lake eutrophication, the design, construction and deployment of automatic water quality monitoring systems) all exploit the latest technological developments for environmental research.

All the above studies contribute to the Institute's growing list of publications and reports. However, I have some reservations about the developing fashion for the *indiscriminate* use of "Output Performance Indicators (OPIs)" and welcome NERC's move to normalise/standardise such data in order to ensure that like is compared with like. Having said that, it is interesting to examine some basic figures which illustrate how the productivity of the Institute (and the FBA before it) has changed over the past 15 years (Figure below).



Changes in staff numbers, published papers and commissioned research reports from the IFE/FBA over the past 15 years.

Since 1980, staff numbers have decreased by approximately 25% but the annual publication rate of scientific papers by the staff has increased from 95 to 120. Moreover, the number of commissioned research reports produced for our customers departments has increased from 11 per year up to the present rate of 97 per year. Thus, the productivity of the organisation has shown a real increase, at a time when staff numbers have been in decline and there is no evidence that the IFE's increased participation in commissioned research has limited our ability to publish in the refereed, scientific literature. These figures give us no information about the *quality* of the work, but a recent testimony to the quality of IFE science is our success in the first round of bids to the European Union's Framework IV. In 1995, the Institute was successful in 5 of its 15 bids for funding. This success rate of 33% compares very favourably with the EU average of 10% and confirms that, not only is the quality of our science of the highest order, but that research scientists across Europe are keen to collaborate with us.

The quality of our science is of the highest order and research scientists across Europe are keen to collaborate with us.

Although high quality environmental research is fundamental to the IFE's Mission, we also have responsibilities for the collection and management of environmental data, for the provision of training and to promote the public understanding of scientific issues. In this latter connection, IFE staff have played a full and active role in their interactions with the media and have been responsible for input into the national press, national and local radio and television. The issues during 1995 were broad-ranging and covered such subjects as the conservation of rare fish, the control of biting insects, and the impacts of droughts. The new IFE entry on the World Wide Web will act as yet another conduit to bring the Institute's science to a wider audience.

A later section of this Annual Report, *Staff and External Activities*, illustrates the Institute's involvement in training with the HEIs, with active collaboration with 32 UK and 13 overseas universities during the year. 1995/96 also witnessed discussions with the NRA/EA on the provision of training to their staff. A training workshop on scale-reading was organised (with very positive feedback from participating NRA staff) and plans are in place for a similar project on fish pass design and function. From the IFE's River Laboratory, a very successful training courses on the use of RIVPACS was hosted by Reading University and attended by members of the end-user community. Equally important is our involvement with the scientists of the next generation. The IFE has provided work experience placements for local schools, supervised projects in the BAAS schools programme, actively participated in the "Bring Your Daughters to Work" scheme and helped with the judging at the British Youth Science Fair.

Progress in developing our data management facilities has been slower than we would have liked because the response to the bid to NERC for new resources in this area has been deferred until next financial year. However, a catalogue of our data holdings, including their current state and format, has been drawn up, confirming the diversity and extent of this important resource, and the Institute's holdings of aquatic macroinvertebrate data were formalised as the National Invertebrate Database.

During the year, the IFE has continued to work closely with its founder organisation, the Freshwater Biological Association, and a synergy has developed between our respective research programmes. Since 1989, the management of the staff and the facilities of both organisations has been under an Agreement between NERC and the FBA which is now due for review. This Introduction to the IFE Annual Report is not an appropriate vehicle in which to consider the review in any detail, suffice it to say that, as Director IFE, I will do all in my power to ensure continuing close links during future years, for the mutual benefit of both organisations and for freshwater science in general. In this spirit of cooperation, we look forward to facing the exciting scientific challenges of the coming year.

Fresh water is the planet's most valuable natural resource and the challenge is to reconcile the needs for water in human activities with the requirements for healthy aquatic ecosystems. Management of this resource must be based upon the best available scientific knowledge, including the factors controlling water quantity, water quality and freshwater fisheries. All three areas interact and the IFE's research programme is directed towards understanding the key processes involved and then using this information to develop predictive models to aid the practical management of this vital, but fragile resource.

Freshwater Resources

Designing water quality monitoring and identifying research priorities

As part of a joint IFE-Institute of Hydrology project commissioned by The United Nations Food and Agricultural Organisation, IFE assisted the Lake Victoria Environmental Management Programme by preparing proposals for sustainable programmes of water quality monitoring. This focus reflects long-term concern over deterioration of the lake - due to eutrophication with agricultural fertilisers and poorly treated sewage, and traditional pollution with pesticides and industrial waste. Decreases in biodiversity including that of small fish species may also reflect

The Institute plays a major role in the assessment and management of the world's largest lakes.

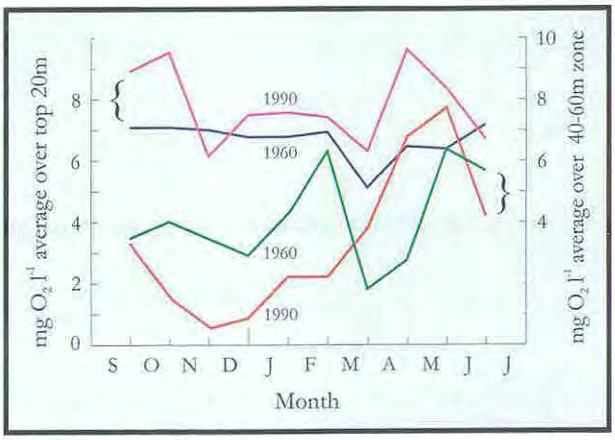


Figure 1. Eutrophication has led to increases in the photosynthetic productivity of phytoplankton (including troublesome cyanobacteria) and an overall increase in the accumulation of organic matter in the sediments. Especially during periods of thermal stratification, this has resulted in higher dissolved oxygen concentrations in the surface waters, and a greater tendency to anoxia in the deeper zones.

*Figure 2. The burgeoning of the floating Water Hyacinth (*Eichhornia crassipes*) is one of the most obvious consequences of eutrophication. The plant harbours snail vectors of* Bilharzia *disease, interferes with fishing and fish landing, and creates problems for navigation. These developments have led to increased pressures on already-limited funds for lake restoration, fishery improvement and water treatment.*

The IFE is influencing programmes designed to restore the water quality of Lake Victoria.

pollution, but 'cascade' effects of predatory Nile Perch introduced 40 years ago are also implicated. These findings emphasise the enormous impact that Man can exert on even very large waterbodies: with a surface area of 69,000 km^2 which is some 10% larger than the area of Scotland, Lake Victoria, East Africa is the world's second largest lake.

IFE's proposals build on the long involvement of our sister organisation - the Freshwater Biological Association - in tropical Africa. As an example, Dr Talling's 1960 data on oxygen levels have provided a benchmark with which Dr Bob Hecky's more recent information can be compared. A linear trend between 1960 and 1990 cannot be assumed, but nutrient enrichment has enhanced phytoplankton productivity and thus, sedimentation.

IFE has recommended a 5-year programme to monitor changes in the biota in the water column as well as the sediments, and the physical and chemical factors determining shifts in species composition and abundance. Priority research investigations overlying the basic limnological surveillances include predictive modelling of eutrophication and its effects on the lake; water circulation; food-webs and trophic interactions; sediment characterisation and sedimentation rate; and pilot-scale management projects on the effects of eutrophication control.

River Habitat Survey (RHS)

River Habitat Survey is a new system for assessing the habitat quality of rivers and streams based on their physical structure. It has been developed by a technical group of specialists for the National Rivers Authority (Environment Agency), in response to the need for a nationally applicable classification of rivers based on their habitat quality. River management in all its forms can identify, type, quantify and then take full account of the need to protect highly valued sites, implement appropriate measures to enhance degraded reaches, or to identify relevant mitigation needs where development proceeds.

Currently RHS provides:

(i) a standard field survey method with a protocol for training and accreditation of surveyors to ensure consistent recording of information and refined by extensive trials and with feedback from subsequent analysis of data.

(ii) a computerised database including a national reference network based on 10 by 10 km National Grid Reference squares with 3 sites per square in England and Wales (4,560), 2 sites per square in Northern Ireland (270) and 1 site per square in Scotland (780).

(iii) a classification of river types based on a predictive model of basic physical structure which includes background data from maps.

(iv) a preliminary scheme for assessing modification and habitat quality by providing an objective database for a classification of river types and comparison of observed features for any 500m stretch with a national or regional 'norm'.

Data collection is based on a standard 500m length of river and features are recorded at sites which relate to the channel, banks and riparian corridor to 50m either side of the river. Features that broadly characterise the site (e.g. valley form, and adjacent land use), such as bankfull and water-widths and heights and their ratios, provide information about geomorphological processes acting on the site. Attributes such as channel substrate type, presence of key habitat features, aquatic vegetation types, complexity of bank vegetation structure and type are

Figure 3. The occurrence of dippers in 1994 and 1995.

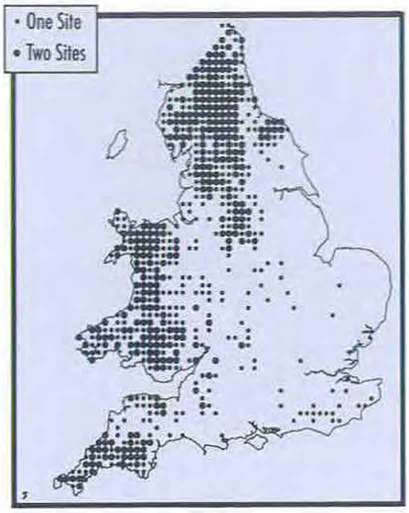


Figure 4. The distribution of exposed boulders in 1994 and 1995.

considered. In addition a *sweep-up* checklist within the 500m length ensures that the presence of features occurring between the spot checks are included, such as the actual number of selected key geomorphological features (e.g. riffles, point bars).

Overall characteristics of rivers and streams show the bulk of watercourses are small streams, with more than 50% less than 10m wide. Most are short and gently-sloping. The altitude range closely reflects the topography of England and Wales. Only 10% of reference sites were completely free of modification to the channel or banks and a further 20% of 'semi-natural' streams were very slightly modified. The influence of artificial modifications is considerable and broadly distributed throughout Britain. See 'River Habitats in England and Wales. A National Overview'. National Rivers Authority 1996.

Surveys of the physical habitats of the rivers of Britain on a structured basis over three successive years, give a powerful framework for the assessment of their quality and modification and a better understanding of their functioning.

Figure 5. The distribution of 'semi-natural' RHS sites surveyed in 1994 and 1995.

Figure 6. River Severn July 1995.

Phytoplankton blooms in rivers

An area of growing concern is the development of dense populations of algae in the nation's larger rivers and the deterioration in quality of a major freshwater resource. Usually, such "blooms" are attributed to the high concentrations of plant nutrients reaching lowland rivers. These come from the twin sources of agriculture and the effluent of sewage treatment plants. There is no disputing the fact that our rivers are overly fertile but the development of algal blooms in rivers the world over is strongly associated with periods of drought. An important relationship exists between high algal production and low river flows.

The relationship has been researched extensively by Institute scientists in recent years. One of the most remarkable discoveries was that the heterogeneous flow structure of rivers - and the existence of non-flowing "dead zones", in particular - delays the flow of enough water sufficiently to increase significantly the residence time of the algal population in the river. With algae doubling their mass with each division, a doubling of the residence time can result in a quadrupling of the mass of suspended algae. However, deeper investigation has shown that the variability in mean velocities of rivers is much smaller than the variability in discharge and that the reaches affected by algal growth are so by virtue of the greater relative volumes they hold in store. In this way, the vulnerability of a river to algal blooms is strongly consequential upon its natural (pools, meanders, side-arms) and artificial (weirs, dams) water-retaining structures. Measurements indicate that, in most rivers, between 10 and 40% of total reach volume may be in store. Using these quantities, Institute models are able to explain fully the apparent enhancement of algal recruitment up to the equivalent of one extra doubling of mass in as little as 10 km of river!

How rivers flow determines their susceptibility to algal blooms.

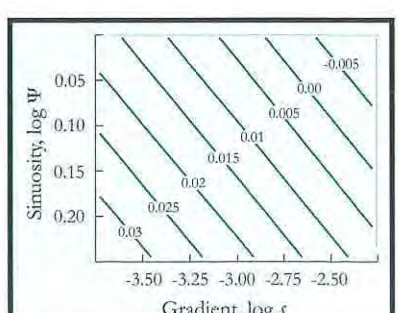


Figure 7. Graph of sinuosity v gradient and enhancement contours

The most recent work has been directed to predicting the susceptibility of major rivers to this kind of growth enhancement. A survey of river plankton in 18 major British rivers, at 70 sites delimiting 50 reaches, has been undertaken. Estimation of the downstream increase in algae in each reach, and in each of three seasons of the year, yielded data not merely on what and how much alga was present but how great was the growth enhancement over the time of travel calculated from the mean discharge through the channel.

The mathematical relationship that was detected shows that the enhancement of downstream algal increase is likely to be greatest in channels of least gradient and maximum sinuosity. This almost always means meandering, lowland rivers. Of course, these tend also to be more subject to enrichment from human settlement and agriculture. The approaches adopted in this study could now be linked to generate a bloom forecast and risk assessment model to assist with quality predictions concomitant upon river-resource management.

Smolt counting on the River Frome

Declining Salmon Stocks

The IFE has monitored the runs of adult salmon (*Salmo salar* L.) in the Dorset Frome, a major chalk stream, for over 20 years. In that time the run has declined, a situation mirrored in salmon rivers throughout the UK, from the long term average of 2500 to 1000 in recent years. The production of a stock: recruitment relationship is now vital to establish whether the decline is due to factors which operate in the marine or freshwater phase of the life history.

Smolt counting

Methods for counting smolts are far from satisfactory. Netting and trapping, the only two widely used approaches, require a great deal of manpower, can cause excessive mortality of these delicate fish and generally sample only a small fraction of the smolt run.

An exciting alternative designed to count smolts accurately and automatically without the need for trapping and handling has been developed as a result of a joint IFE/EA project to assess the efficacy of acoustic bubble screens to deflect smolts. This only became feasible following an agreement with Fish Guidance Systems Ltd (FGS) to use IFE controlled watercourses and IFE expertise to field test their screens.

Figure 8. Acoustic bubble screen directing smolts from the main river into the millstream.

An acoustic bubble screen diverts smolts from the main river into the millstream where a further screen diverts fish through one of two channels, in which smolts swim freely through a vertical series of horizontal tubes each containing electrodes connected to a counter. The fish are simultaneously recorded on videotape. Thus both the accuracy of the electronic counters and the efficiency of the acoustic bubble screen can be assessed.

Estimating the smolt run

In 1995, the first year of operation, over 4000 salmon smolts were counted over approximately half the days of the smolt run. The estimated run, given the calculated high efficiency of the acoustic bubble screen, for the whole river was 9-10,000 fish.

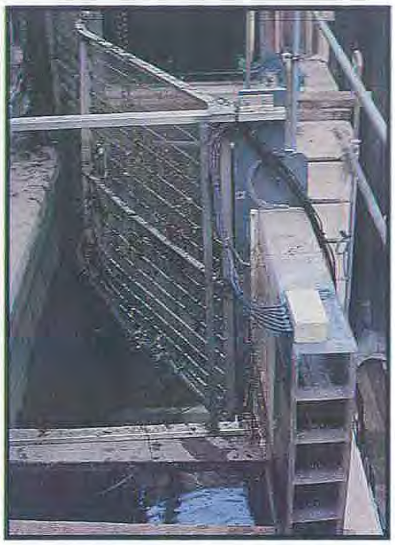


Figure 9. Counting structure before being lowered into the water showing tubes through which smolts pass.

Research into the causes of the decline in salmon.

Environmental influences on the underyearling perch of Windermere

Studies of fish population dynamics require long-term data sets, few of which have been obtained from lakes resulting in little exploration of the effects of environmental factors on many lacustrine species. A 50+ year study of the perch (*Perca fluviatilis*) in Windermere in the English Lake District offers the rare opportunity to investigate such influences, including those of the position of the Gulf Stream which has previously been linked to features of the lower trophic levels of Windermere. The key parameters of underyearling perch recruitment and growth, which are important for the exploitation of this significant freshwater resource in many parts of Europe, have been studied in particular detail.

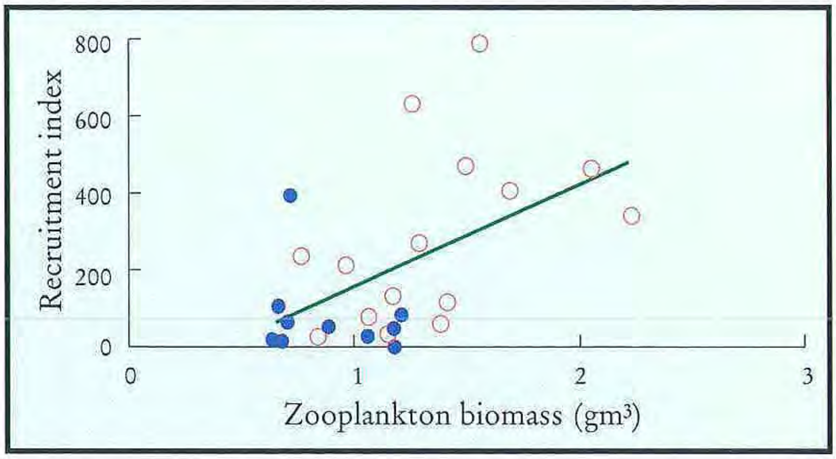


Figure 10. The recruitment of underyearling perch in Windermere is positively correlated with mean summer zooplankton biomass. Data from before (1966 to 1975) and after the outbreak of perch disease (1976 to 1990) are shown as closed and open circles, respectively.

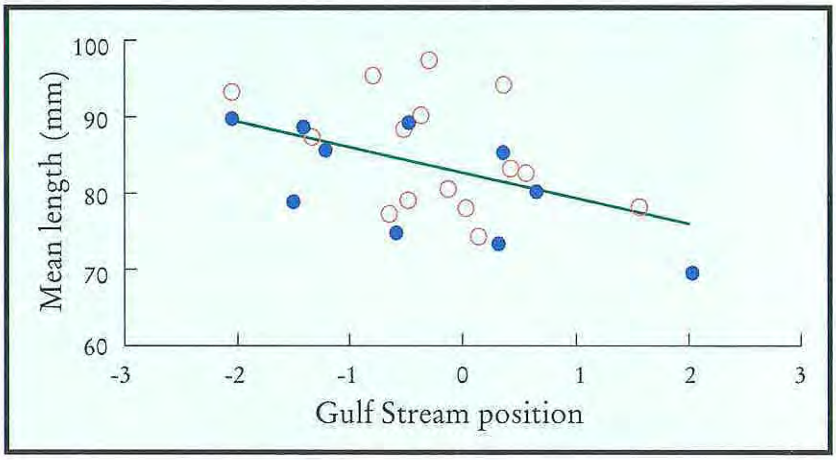


Figure 11. The mean length of underyearling perch in Windermere is negatively correlated with an index of the northerliness of the Gulf Stream position. Data from before (1966 to 1975) and after the outbreak of perch disease (1976 to 1990) are shown as closed and open circles, respectively.

Perch recruitment and growth are influenced by lower levels of the bottom-up structured Windermere food web.

Between 1966 and 1990 (a period for which the most complete suite of environmental data is currently available), perch recruitment varied considerably but also showed a significant increase since 1976 when an outbreak of disease killed many adults. Underyearling growth showed less variation and no significant overall trend. There were no significant relationships between recruitment and water temperature or the position of the Gulf Stream (data provided by Plymouth Marine Laboratory), but a significant positive relationship existed with zooplankton biomass. There was no significant relationship between underyearling growth and zooplankton biomass, but there were significant positive and negative relationships with water temperature and Gulf Stream northerliness, respectively.

The positive relationship observed between zooplankton biomass and perch recruitment suggests that the latter is controlled by the former, rather than the converse, and constitutes strong evidence that the Windermere food web is structured primarily by bottom-up rather than top-down forces. The mechanism of the Gulf Stream influence remains unknown, but it may operate through effects on the timing of stratification and thus plankton development.

Biodiversity, the natural biological capital of the Earth, embraces genetic diversity, species diversity and ecosystem diversity. Its preservation and wise utilisation are ultimately linked to the healthy functioning of natural and semi-natural ecosystems, to the quality of life and to wealth creation. Work in this programme area aims to characterise freshwater biodiversity, to understand the population processes responsible for such diversity, to investigate how biodiversity influences ecosystem function and to use this knowledge for the conservation and restoration of aquatic ecosystems.

Biodiversity

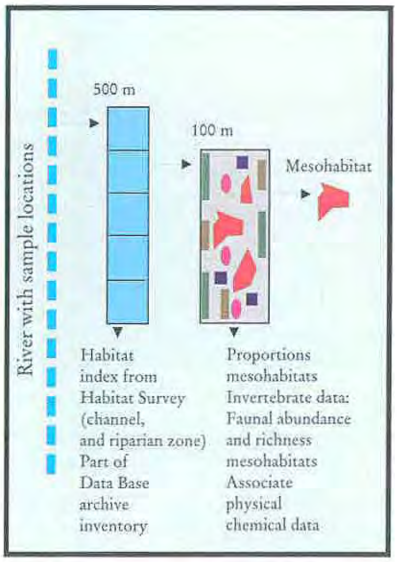


Figure 12. The sampling regime

Nested studies - multi-scale perspective on faunal distribution

Most surveys of river systems which use macroinvertebrates for biological assessment of water quality are based on the point sampling approach. Such restricted sampling regimes even if repeated at intervals along a river will only provide a 'snap-shot' of conditions and will not identify the true extent of any impact. This is particularly evident where anthropogenic activities affect the stream habitat.

A nested approach incorporating both fine and coarse scales has been used to examine the relationship between point samples and the characteristics of the River Frome at fifteen sites from source to mouth, (Figure 12). Physical/botanical features were recorded for every 500m

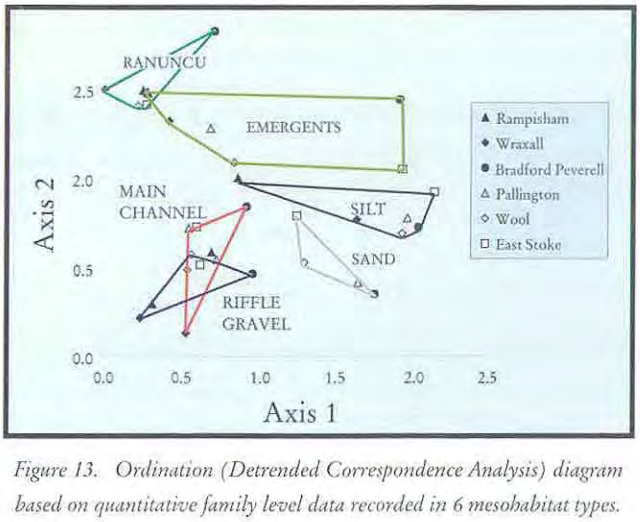


Figure 13. Ordination (Detrended Correspondence Analysis) diagram based on quantitative family level data recorded in 6 mesohabitat types.

reach and a representative 100m section was mapped to provide information on the distribution and proportion of mesohabitats (visually distinct areas of habitat on the stream bottom). Macroinvertebrates were sampled in six main mesohabitat types.

Preliminary results from summer samples from 6 sites distributed from source to mouth indicate that the faunal assemblages of mesohabitats are fairly consistent throughout the length of the Frome (Figure 13). The chief exception was emergent vegetation which shows considerable variation with distance downstream. The river may be described in terms of its mesohabitat composition thereby providing much more extensive data than point samples. Mesohabitat proportions will be sensitive to flow regulation and channel maintenance and provide a convenient method of assessing change following these activities. The nested study will compare the information obtained from surveys ranging in scale from individual mesohabitats, through to the broader River Habitat Survey and will help answer questions relating to typicality or uniqueness of a section, with application in conservation studies.

CCAP is the largest collection of algae and protozoa in Europe.

Culture Collection of Algae and Protozoa

Ex situ Conservation of Biodiversity

The CCAP is the UK service culture collection for algae and free-living non-pathogenic protozoa. One important role of service collections is the *ex situ* conservation of microbial biodiversity, in accordance with Article 9 of the Convention on Biological Diversity (Rio Convention). At present a relatively small proportion of the 80,000 described species of algae and protozoa have been successfully maintained under laboratory conditions. However, CCAP arguably contains one of the most diverse collections of these microorganisms. At present, examples of approximately 50% of the algal and 25% of protozoan species maintained in major microbial culture collections, are retained in CCAP.

Figure 14. V. sessilis *CCAP 745/1C prior to freezing. The alga has a normal appearance, with obvious cell membrane in the bud.*

Cryopreservation

A key component of the remit of CCAP is to maintain a wide variety of organisms *ex situ*. At present approximately 35% of the collection has been cryopreserved (frozen and maintained at an ultra-low temperature, -196°C), with >20% of the strains in the collection being preserved by this method alone. Many of the remaining strains are apparently recalcitrant to this form of preservation, with no post-thaw survival of frozen material. A joint research project with the University of Abertay Dundee is currently investigating the fundamental mechanisms of freeze-induced damage in algae. One organism under investigation is the multinucleate alga *Vaucheria sessilis*. In this organism conventional cryopreservation protocols can result in excessive, non-recoverable, dehydration of the filament. In addition, on freezing intra- and extracellular ice formation result in considerable cell damage.

Figure 15. V. sessilis *CCAP 745/1C post-thaw after freezing to -30°C at 1°C min^{-1} in the presence of cryoprotectant. The alga has been severely damaged by the freeze/thaw cycle. Damage to the cell wall can be seen at the tip of the bud. In addition, the cell membrane has been ruptured and there is gross disruption of the intra-cellular architecture.*

This includes distortion of the filament cell wall and intracellular architecture, including rupturing of the cell membrane (Figure 15).

For *Vaucheria* conventional cryopreservation approaches are unlikely to be successful. However, novel techniques including encapsulation dehydration and vitrification are currently under development and show some potential as alternative methods of cryopreservation.

Aquatic free-virus diversity

In any volume of natural water, viruses can constitute the largest concentration of (quasi-)living organisms, orders of magnitude greater than the bacteria upon which many depend for their replication. Little is known of their ecological role, especially within the microbial commmunity and, until recently, their population numbers have been vastly underestimated.

We are presently using electron microscopy to categorise and enumerate the variety of free-viruses in Priest Pot, a small hyper-eutrophic lake in the English Lake District. More than 50 virus morphotypes have been recorded so far including some that are apparently new to science. Total free-virus concentrations have often exceeded 10^9 per ml, making them by far the most numerous class of living particles in the water column. Natural fluctuations in the virus community are being studied and, as all viruses are obligate parasites, selected virus/microbial-host relationships are being examined. The survey forms part of a continuing IFE/IVEM collaborative study.

Aquatic free-virus concentrations exceed 10^9 per ml.

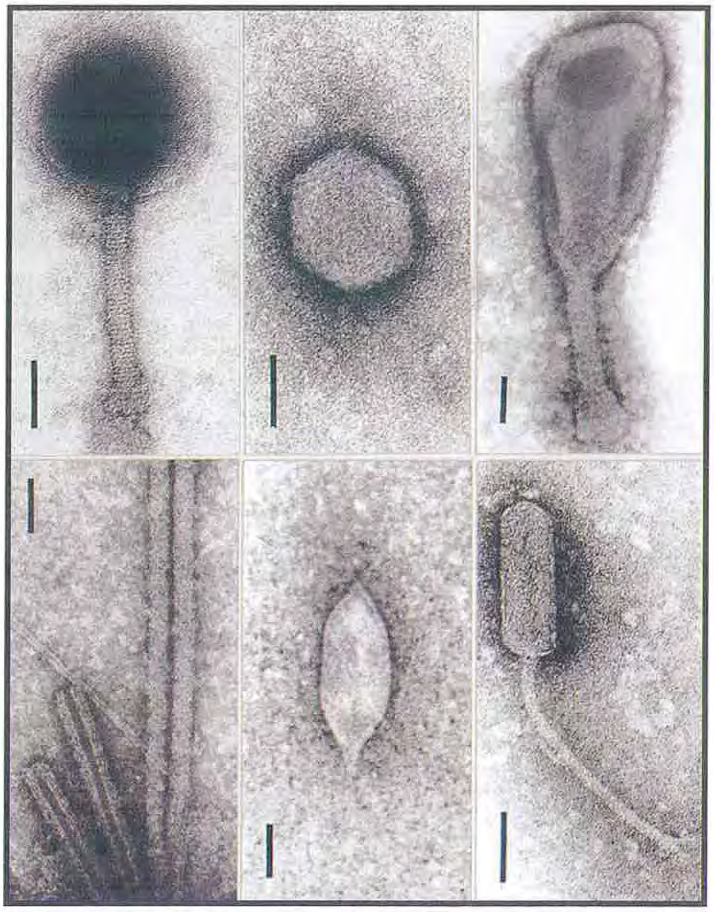


Figure 16. Examples from the wide range of free-viruses found in a small freshwater lake in the English Lake District. Bar = 50nm.

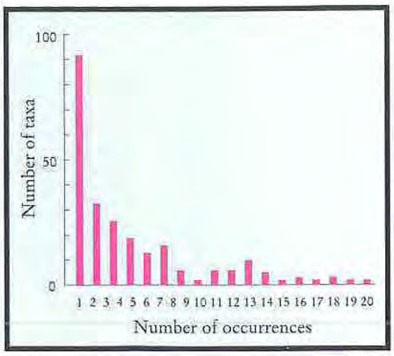


Figure 17. Lake District lakes ordered according to diatom diversity

Biodiversity in the larger Lake District lakes

These lakes range from oligotrophic to slightly eutrophic in water quality (with phosphorus levels of 5-139 μg l^{-1}), even though they lie within a 20 mile radius. As part of a British National Park, their mainly upland catchments are free from intensive agriculture and heavy industrial pollution. The difference in water chemistry is thus governed by a varied geology and land-use, with additional enrichments or pollution from small towns, villages and old mining areas. There is, surprisingly, a considerable algal diversity and the silica remains of some 240 diatom taxa were found in a brief survey, identifying just 500 specimens in just one surface sediment sample from each lake basin in 1995. Many more are to be found in the smaller tarns and pools of the area, or in older sediments.

The number of taxa (species and varieties) found in each sample ranged from 30 in Haweswater to 70 in Elterwater (Figure 17). These belong to some 35 genera (conservatively excluding recent subdivisions). Over half the taxa were found at levels less than 1% in any sample (Figure 18) while 17 dominate assemblages at >5% (Figure 19), 12 of these being >10% in at least one sample. The diatom taxa vary in size from <5 μm to over 200 μm.

The plankton forms *Asterionella formosa* and *Cyclotella comensis*, and the attached *Achnanthes minutissima* occur most frequently in this survey (Figure 19), with maxima of 57, 64 and 35% respectively; the higher percentages of *Asterionella* or *Cylotella* indicating respectively more, or less, enrichment. *A. minutissima* and *Fragilaria vaucheriae* are the only taxa to occur in all the samples, while many taxa are indicative of the gradient in nutrient level between lakes. The succession of different plankters as nutrient levels increase (Figure 18) includes certain taxa present and thriving in just one or two sites, eg. *Aulacoseira ambigua* in Bassenthwaite (21%) and Elterwater (<1%). Rare taxa may have more specific ecological habitats and their distributions reflect the complex combination of conditions. The natural order is further complicated by additional enrichment or pollution from industrial or domestic wastes, such as the effluent from a sewage treatment works into Elterwater and elevated phosphorus levels in Brotherswater.

The English Lake District lakes presently support a high diatom diversity.

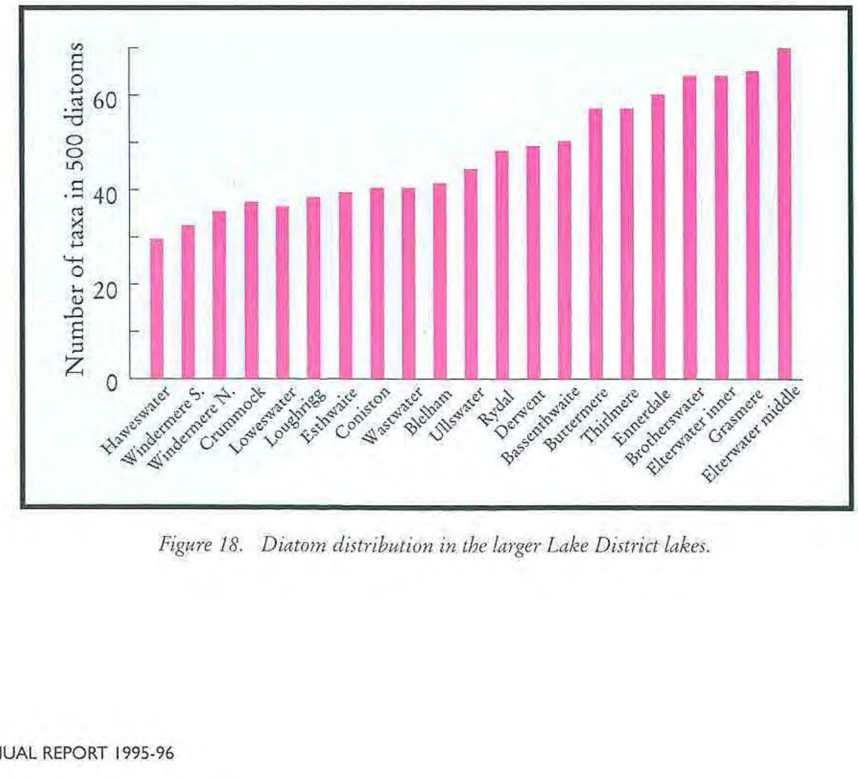


Figure 18. Diatom distribution in the larger Lake District lakes.

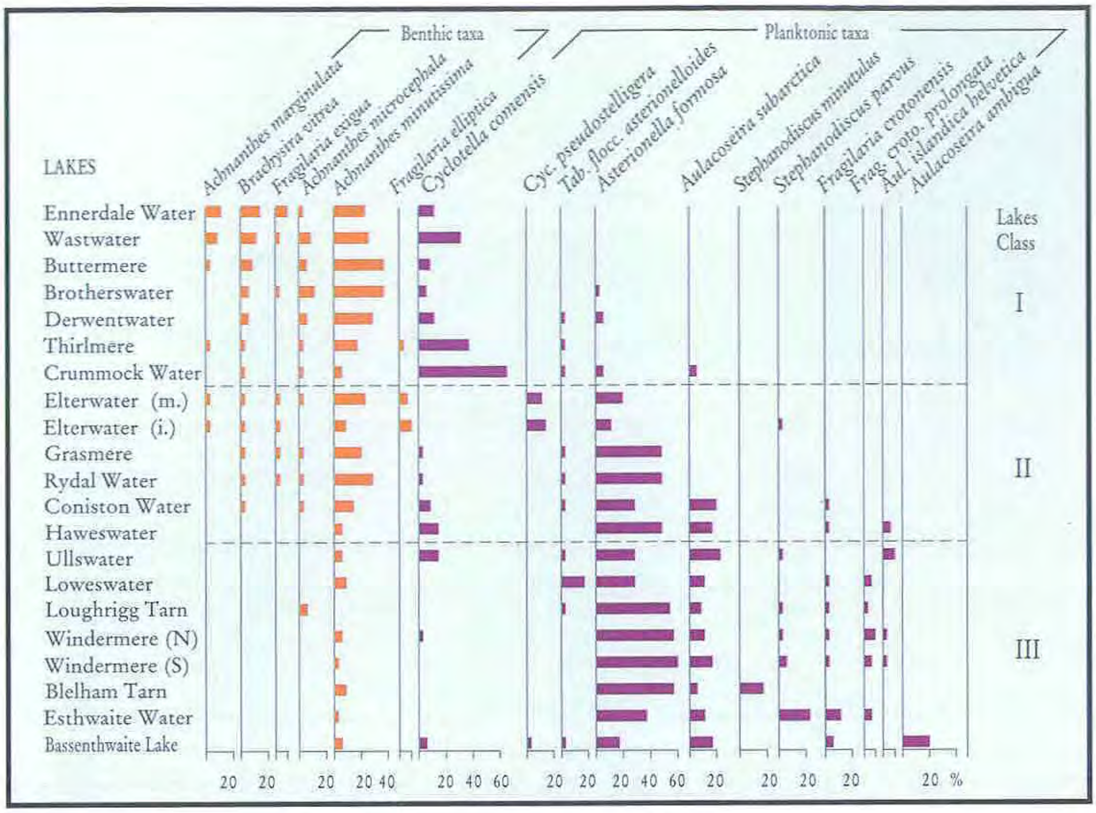


Figure 19. Distribution of dominant diatom taxa in the surface sediment of Lake District lakes in 1995. Elterwater (m.) = middle basin. Elterwater (i.) = inner basin. Windermere (N) = North basin. Windermere (S) = South basin.

The diatom diversity in this set of lakes indicates a wide range of ecological situations of habitat, nutrient level and pollution level. The majority of taxa prefer circumneutral to slightly alkaline waters but taxa of highly acid or alkaline waters are rare. Ennerdale has the most acidwater taxa (25 = 25%) and Elterwater the most alkaline (27 = 44%). Rather more taxa (46) are typical of oligotrophic waters than meso-eutrophic (34) or eutrophic waters (35) while of the six hypertrophic types, five occur in Elterwater. Overall 26 plankonic diatom taxa were found in these samples with the majority in Ullswater, Bassenthwaite and Loughrigg Tarn. There were also seven taxa typical of subaerial habitats (representing inwash) and are most obvious in Ennerdale, Buttermere and Wastwater samples.

Palaeolimnological studies show that most of the taxa have been in the area since the last deglaciation, many in the sites themselves. However, it is apparent that several are recent incomers, eg. *Pinnularia cardinaliculus* in Brotherswater, *Aulacoseira ambigua* in Bassenthwaite and *A. islandica* ssp. *helvetica* in Windermere, Ullswater and Haweswater; the latter by water transfer from Ullswater.

Diatoms are indicative of the wide range of aquatic conditions, including some recent changes.

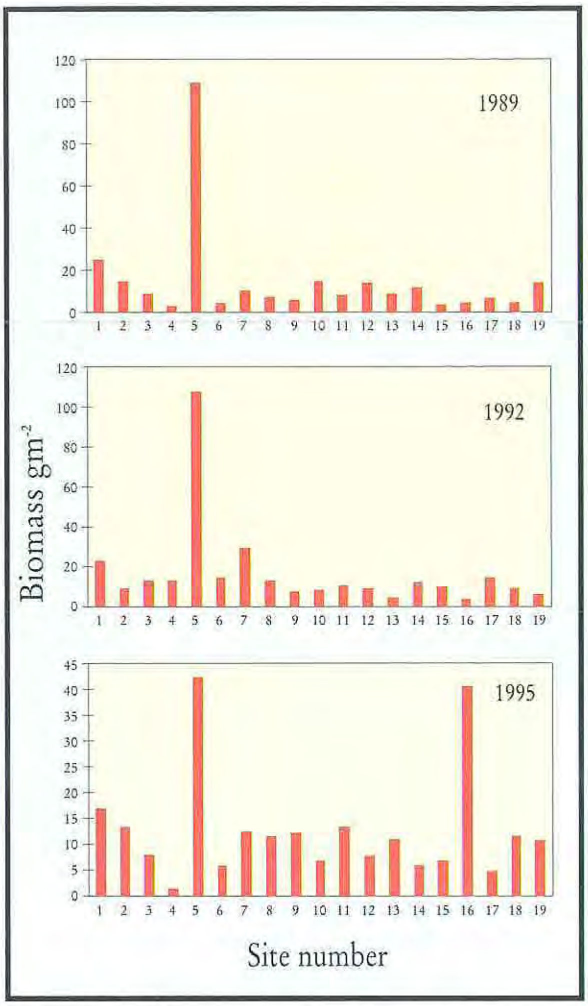


Figure 20. The biomass (g m^{-2}) of all fish species at 19 sites on the Great Ouse from Bedford (site 1) downstream to Brampton (site 19), based on NRA fish surveys in 1989, 1992 & 1995; the peaks for site 5 (Great Barford) and site 16 (1995) are caused by high biomasses of common bream.

Fish habitat requirements

Importance of habitat diversity

Reduced habitat diversity in lowland rivers, particularly along river margins and in backwaters, can cause major changes in the composition of fish communities. Not only do the habitat needs of fish differ between species, but those for an individual species change as it develops from a newly-hatched larva to a spawning adult.

Not only do the habitat needs of fish differ between species, but those for an individual change as it develops from a newly-hatched larva to a spawning adult.

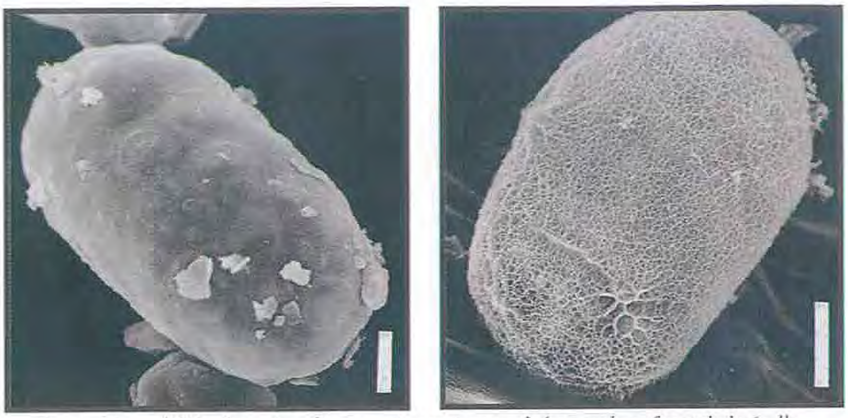
The richness of habitat in the River Great Ouse has been compromised over many years, but especially so over the last 20 to 30 years, when the river channel has been increasingly altered to meet flood control, navigation and water abstraction needs. Today, there are few natural backwaters, river levels are kept high by means of sluice gates to support boat traffic, the channel is routinely dredged and the aquatic weeds are cut back.

Generalist and specialist fishes

Under such conditions, only the more adaptable fish species can thrive, and those with more specialised habitat requirements often become more restricted in their distribution. In the Great Ouse, the roach is the survivor *par excellence*. It occurs throughout the river and is almost always the most numerous species in fish survey catches. Pike and perch are also widespread, but their numbers are very much less than those of roach. Some species, the common bream is a good example, occur in large numbers at only a few favoured places, and can persist in importance for many years (see Figure 20). Such sites need to be identified for each species, and their protection assigned a high priority because their loss could have a severe impact on the fish community structure.

Phylogenetic analysis of an unculturable bacterium

Achromatium oxaliferum was first described over a century ago yet knowledge of its phylogeny, physiology and ecology remains scant. It is an unusually large (ranging in width from 5 μm to 40 μm and from 15 μm to greater than 100 μm in length), morphologically conspicuous, sediment-dwelling bacterium. *A. oxaliferum* cells contain characteristic intracellular inclusions of sulphur and calcium carbonate (see Figure 21). The role of the calcite has not been elucidated although it may be



Figures 21a and 21b. Scanning electron microscopy revealed a number of morphologically distinct A. oxaliferum *cell-types including those with (a) smooth and (b) rough outer cell surface membranes, (size bar represents 5 µm.)*

involved in buoyancy regulation and chemotaxis, buffering of pH or maintaining a high intracellular partial pressure of CO_2 to aid inorganic carbon fixation.

The first phylogenetic description of *Archromatium oxaliferum.*

A. oxaliferum has been observed in a diverse range of aquatic sediments. An understanding of the bacterium and its role in sediments has been hampered by an inability to cultivate the organism in the laboratory. Therefore the use of small subunit ribosomal RNA (rRNA) sequence analysis, to infer the phylogeny of microorganisms, was particularly appropriate for this study.

In collaboration with Department of Fossil Fuels and Environmental Geochemistry and the Freshwater Biological Association, *A. oxaliferum* cells were purified from a wetland region close to Rydal Water (Cumbria, UK). Scanning electron and transmission electron microscopy revealed that a number of morphologically distinct *A. oxaliferum* cell-types, based on cell surface features and the size and abundance of calcite and sulphur inclusions within the cells, were present in a single sample of purified cells.

The polymerase chain reaction was used to amplify almost full-length 16S rRNA gene sequences from DNA extracted from *A. oxaliferum* cells directly purified from sediments. Comparative sequence analysis showed that three related groups of *A. chromatium* were present with this group forming a deep branching lineage within the γ-subdivision of the Proteobacteria. *A. oxaliferum* was found to be related most closely to the *Chromatium*- assemblage that includes sulphur-oxidising symbiotic bacteria, purple sulphur bacteria and sulphur and iron-oxidising Thiobacilli. Further analysis concluded that *A. oxaliferum* was related to organisms of the Chromatium-assemblage but constituted a novel lineage within this group of bacteria. This represented the first phylogenetic description of this organism since its discovery at the turn of the century. Studies examining the population dynamics, physiology and role of this organism in geochemical cycles in the environment are continuing.

Macroinvertebrate richness of running-water sites in Great Britain

Streams and rivers contain only a small proportion of the freshwater on our planet, but their importance to man is difficult to under-estimate. They provide drinking water, a source of food, a means of transport and a method of removing waste.

Despite this, our knowledge of the biodiversity of running-water systems around the world is very inadequate, and therefore of concern in view of the current threats to riverine species, habitats and ecosystems.

Britain has a long history of research into the taxonomy of the freshwater fauna. Identification at species level

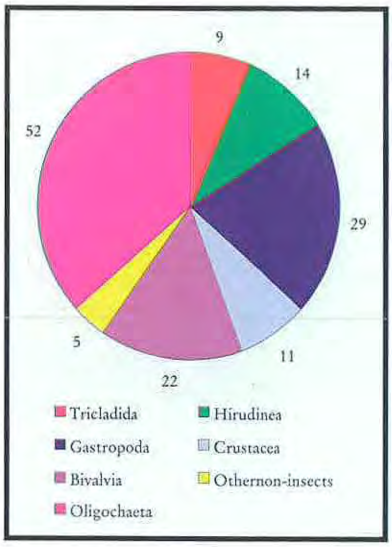


Figure 22. The 142 non-insect taxa by major group.

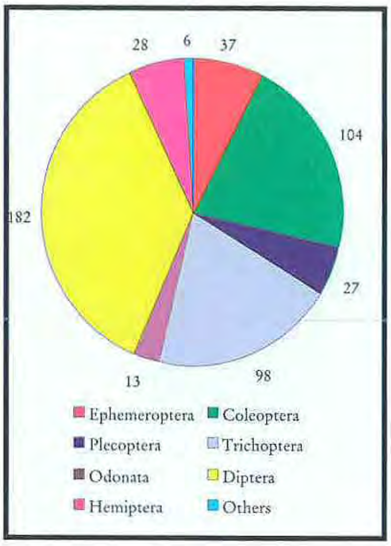


Figure 23. The 495 insect taxa by major group.

was therefore, possible for many of the major groups of macroinvertebrates when 614 reference sites in Great Britain were examined during the development of RIVPACS (River InVertebrate Prediction And Classification System).

Information on the macroinvertebrate fauna of British rivers is unrivalled.

At each site a standard sampling procedure was used in spring, summer and autumn before identification was undertaken to a uniform level at all sites. A total of 637 'species' were recorded at the reference sites, including 142 non-insect taxa (Figure 22) and 495 insect taxa (Figure 23).

The number of taxa recorded per site after standard sampling effort varied from 31 to 134. Low richness was characteristic of harsh conditions in Scotland and Northern England, whereas sites with high richness included a wider range of rivers in South Wales, Southern England and East Anglia.

Attempts to understand the patterns of species richness in nature are fraught with difficulty, because they are the end result of a wide variety of ecological and evolutionary processes and historical events.

However, information on species richness remains a priority and because detailed surveys are expensive, the use of short-cut methods for estimating richness is an active field. For example, in the GB macroinvertebrate data-set there was, as expected, a strong correlation between the number of species and families at the 614 sites (r=0.89).

This result should have practical application in Britain, and similar approaches for estimating richness should have relevance abroad.

Pollution of fresh waters occurs by direct discharge, run-off from the land and by atmospheric deposition. The processes (physicochemical and biological) controlling the dynamics and impacts of all major pollutants need to be measured and modelled if, ultimately, we are to develop realistic hazard and risk assessment procedures for the natural environment. This approach includes the development of new biological methods for detecting pollution through investigation of behavioural, physiological, cellular and genetic responses of a range of organisms.

Pollution Assessment and Control

Lake Tanganyika - designing a strategy for assessing pollution effects on biodiversity

Figure 24. Extensive physical and chemical variety - with rocky, to sandy and muddy environments, as well as the open water mass, contribute to the existence of at least 1500 species in Lake Tanganyika.

At 1470m, Lake Tanganyika is the world's second deepest lake. It is estimated to contain more species - including many endemics - than any lake with the exception of Baikal (Siberia). This impressive biodiversity can be attributed to the lake's considerable age (>20 M y), long period of isolation (1.8 M y) and substantial ecological diversity. Such an enormous waterbody (Table 1) can be viewed as immune to pollution in the short term. However, because this same feature ensures very efficient retention of wind- and water-borne materials including pollutants entering the system (Table 2), it is likely to be susceptible in the long term. Once so affected it would be extremely difficult, if not impossible, to restore.

Via the 'cascade' effect, pollution could bring about changes in the performance and thus biodiversity of organisms at all trophic levels - although pollution need not reduce overall biodiversity *per se*. Perhaps surprisingly too, this lake is extraordinarily dynamic with e.g. phytoplankton species composition, and fish distributions changing quickly. This can be attributed to fluctuations in factors that impinge on the 'whole' system; examples are incident radiation, wind-induced mixing, massive nutrient upwellings, as well as the food chain interactions. These contrast with impacts such as the external inputs of nutrients and pollutants, which are important in the long-term, but may have little startling or widespread effect until a threshold level of a particular substance has been attained.

Figure 25. Weather conditions, especially wind regimes, impact extensively on this enormous waterbody.

The IFE's expertise is being utilised in a study of the impacts of pollution on biodiversity in Lake Tanganyika.

The IFE is collaborating with the Natural Resources Institute (Chatham) and the Marine Resources Assessment Group (London) on a project 'Pollution control and measures to protect biodiversity in Lake Tanganyika'. Along with counterparts from Burundi, Tanzania, Zaire and Zambia, IFE is supervising work establishing the effects of the following on biodiversity: eutrophication, organic enrichment, heavy metal inputs, pesticide runoff, and spillages from shipping and oil exploration. Sustainable schemes are being developed to assess pollution levels in mainly the uppermost 200 m of the water column, including

Table 1. Some statistics demonstrating the very large size of Lake Tanganyika (from Coulter 1991, and Hecky and Bugenyi 1992).

parameter	value
catchment area	249 000 km^2
lake surface area	32 600 km^2
maximum depth	1 470 m
mean depth	580 m
length	*ca* 650 km
mean width	50 km
model volume	18 800 km^3

Table 2. Some hydrological features of Lake Tanganyika that result in very high retention coefficients for many of the substances that enter the lake.

feature	value
annual inflow volume	14 km^3
annual outflow volume	2.7 km^3
annual precipitation volume	29 km^3
flushing time (lake volume/ outflow volume)	7 000 y
residence time (lake volume/ (precip. + inflow volume)	440 y

inshore zones. In view of an ultimate aim of the project to establish aquatic reserves, sites of conservation value will also be investigated. Polluted and 'pristine' areas of similar topography (aspect, sediment type, water depth) will be investigated. In addition to the water itself, sediments, and tissue from e.g. molluscs and fish will be assayed.

Error, bias and variation in the assessment of the biological condition of rivers

In the River Quality Surveys of 1990 and 1995 the National Rivers Authority used aquatic macro-invertebrate assemblages to assess the biological condition of over 7,500 sites. Assessment depended on different invertebrates having differential tolerances to environmental stress.

Tolerances are quantified as scores attached to individual taxa. The higher the score the less the taxon's tolerance of the stress being evaluated. A site's score is an integration of the scores of the taxa present.

The assesment procedure chosen by the NRA was RIVPACS, a software

Figure 26. The Twyzell Burn, Northumberland. This site is one of sixteen locations throughout Great Britain at which experimental replicate sampling took place.

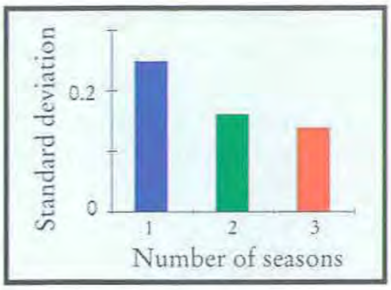


Figure 27. The average standard deviation of the square root of the number of aquatic macro-invertebrate taxa found in single season (1) samples and two (2) and three season combined (3) samples is used in determining the precision of Ecological Quality Index values. These standard deviations were each shown to be independent of the sites' environmental type and their biological condition.

system developed by IFE. The observed score of a site is compared with its expected score in the absence of stress. In RIVPACS the expected score for a site is predicted from its environmental characteristics. The Ecological Quality Index (EQI) for a site is the ratio of its observed to expected score.

Declining EQI's are taken to indicate loss of biological condition. However the significance of differences between EQIs cannot be evaluated without quantifying errors and variation associated with acquisition of biological and environmental data.

This problem has been resolved by an IFE/NRA research programme in which a range of sites of different biological condition and environmental type were subject to replicate sampling by teams of NRA and IFE biologists.

Data were assembled on variation inherent in collecting invertebrate samples, bias due to inefficient removal of animals from samples, errors in taxon identification and errors and variation in measuring environmental variables.

Statistical expressions representing variance terms at all stages of the process were derived and integrated into an algorithm for determining the variance associated with each EQI value.

For the first time, statistical tests have been developed for assessing the significance of temporal and spatial differences in the biological condition of sites. These tests will eliminate subjectivity in the assessment of biological change and provide a sound scientific basis for comparisons.

The results of the study are being implemented as an operational module of RIVPACS.

New research carried out by the IFE has greatly improved the statistical reliability of macro-invertebrate samples used to assess the ecological quality of streams and rivers.

Disposal of oiled beach materials

A consortium from IFE, ITE, BGS and Sir William Halcrow and Partners (Scotland) Ltd has been commissioned by the Marine Pollution Control Unit (Dept. of Transport) to assess if the disposal of oiled beach materials (OBM) by burial in low grade coastal pastures is a practical and environmentally-acceptable option. A major concern was that leaching of buried hydrocarbons would contaminate groundwater and provide a greater environmental hazard than existed with the OBM.

An experiment using large outdoor lysimeters was set up at Merlewood Research Station (ITE) in which the degradation of OBM hydrocarbons could be monitored. Water percolating through the lysimeters could be collected and analysed for contaminating hydrocarbons. The construction of the individual lysimeters and the lysimeter trench at Merlewood are shown in Figures 28 and 29. Three different oils with three weathering treatments were tested. Each treatment was in triplicate in a

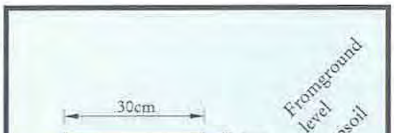


Figure 28. Lysimeter system for examining the behaviour of oil residues in OBM.

Figure 29. Lysimeter trench at Merlewood (Institute of Terrestrial Ecology).

randomised block design. The experiment was run for 17 months with regular analysis of CO_2 flux from the soil surface and leachate water for hydrocarbons. The CO_2 flux from the Kuwait crude oil is shown in figure 30. At the end of the experiment the activity of microbial populations and hydrocarbon content of the top soil, OBM layer and sub-soil were determined.

The results showed that microbial populations in beach sand rapidly adapted to degrade the oil hydrocarbons and mobility of oil between the soil layers was limited. The failure to detect hydrocarbons in the leachate water suggested that oil compounds were not leached from the OBM layer.

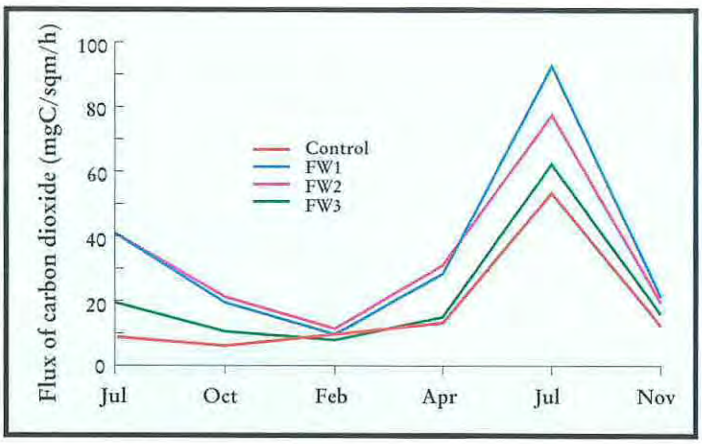


Figure 30. Flux of carbon dioxide from lysimeters containing no oil, unweathered oil (FW1), oil washed in sea water (FW2) and oil washed in sea water and exposed on an artificial beach for 10 days (FW3).

IFE has identified organic peat bogs as important sources of secondary radioactive contamination of water bodies following an accident.

Mechanisms of long term radioactive contamination of fresh waters following the Chernobyl accident

During the 10 years since the accident at the Chernobyl Nuclear Power Station scientists have been working to understand the movement of the radioactive fallout through the environment. IFE has been studying the effects of the accident on freshwater ecosystems, in particular focusing on transfers of remobilised radioactivity from contaminated soils to lakes and reservoirs. Fallout radiocaesium and radiostrontium from Chernobyl was deposited on the Pripyat Marshes in Belarus and on the floodplain of the Pripyat river close to the power station. Transfers of radioactivity via the Pripyat River to the reservoirs of the Dnieper have led to serious concern amongst the 2 million residents of Kiev as to the safety of their drinking water.

IFE's post-Chernobyl work on catchment-lake systems in the Lake District identified highly organic peat bog soils as the main transporters of radiocaesium to freshwaters. In mineral soils, caesium is bound to specific sites on clay minerals, particularly illites, and becomes essentially 'locked up' in the mineral lattice. In peat soils with very low mineral content, however, the caesium is much less strongly bound and remains available for transport in runoff water. In collaboration with Netherlands Energy Research, we have measured the distribution of Chernobyl radiocaesium between soil and water in the peat bogs of Devoke Water in the Lake District. Our modelling studies

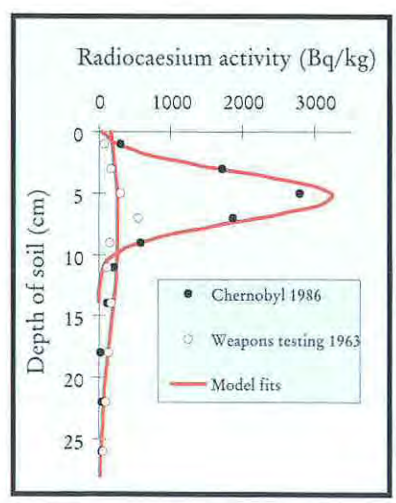


Figure 31. Model fits of vertical migration of radiocaesium from Chernobyl (1986) and Nuclear Weapons Testing (1958-63) fallout in a peat bog within the catchment of Devoke Water.

Figure 32. Sampling peat bog soils in the catchment of the Pripyat River, Belarus.

have shown that this measurement can be used to predict the vertical migration of radiocaesium in peat bogs, and the level of contamination in runoff water.

Working with the Institute of Geological Sciences in Belarus, we have applied the techniques developed in the Devoke catchment to peat bog soils in the catchment of the Pripyat River. The models of radiocaesium mobility, when adjusted for the higher levels of contamination in Belarus, gave good agreement. The radiocaesium appears to behave in a similar way, at the two sites, allowing us to develop general models for radiocaesium migration in these systems.

Nutrient sources and sinks in rivers

IFE is involved in a programme of research as part of the Land-Ocean Interaction Study (LOIS), aimed at understanding the fluxes of nutrients in large river systems in the Northeast of England. The work has focused on a 56 km section of the R. Swale extending in the north from Catterick to the south near its confluence with the R. Ure.

Sources of nutrients

The water flowing from the southern reach of the river Swale, as it enters the Ouse, originates from supplies in the Pennines in an area dominated by moorland and sheep/dairy farming as well as contributions from the lowland region with more intense agriculture and urbanisation. In the upland region the water is relatively soft but as it progresses eastwards through the steep valleys of Swaledale, it collects dissolved calcium from the Carboniferous Limestone and Triassic Mercia Mudstone. Major tributaries such as the R. Wiske, as well as 20 minor inputs, also join in the study section downstream of Catterick and contribute to the amount of nutrients carried to the estuary.

The nutrients studied include phosphorus, silicon, nitrate, nitrite and ammonium. Measurement of different phosphorus fractions permits the calculation of the dissolved inorganic, dissolved organic (or bound to this fraction) and the particulate phosphorus. On an annual basis, all three fractions contribute significantly (> 10%) to the total load of phosphorus delivered to the estuary with the particulate fraction contributing about 60 %. However, the majority of the organic and particulate fractions are transported by the rivers in storm events throughout the autumn and winter times. It has been found that the early autumn storms are richest in phosphorus content reaching concentrations of over 800 $\mu mol\ g^{-1}$ compared to summer contents of <100 $\mu mol\ g^{-1}$ presumably caused by the scouring of biological material that accumulates in the river bed during the summer.

Intensive sampling studies

A detailed understanding of the sources and sinks of nutrients in rivers, necessitates a different strategy from the normal weekly or monthly chemical monitoring. A campaign strategy is needed whereby the catchment is monitored at frequent intervals, e.g. hourly, during "typical" river conditions. Intensive sampling

Figure 33. View of the River Swale during high flow conditions.

Mass-balances applied to nutrient transport in rivers permit a better understanding of sources, transformations and fate.

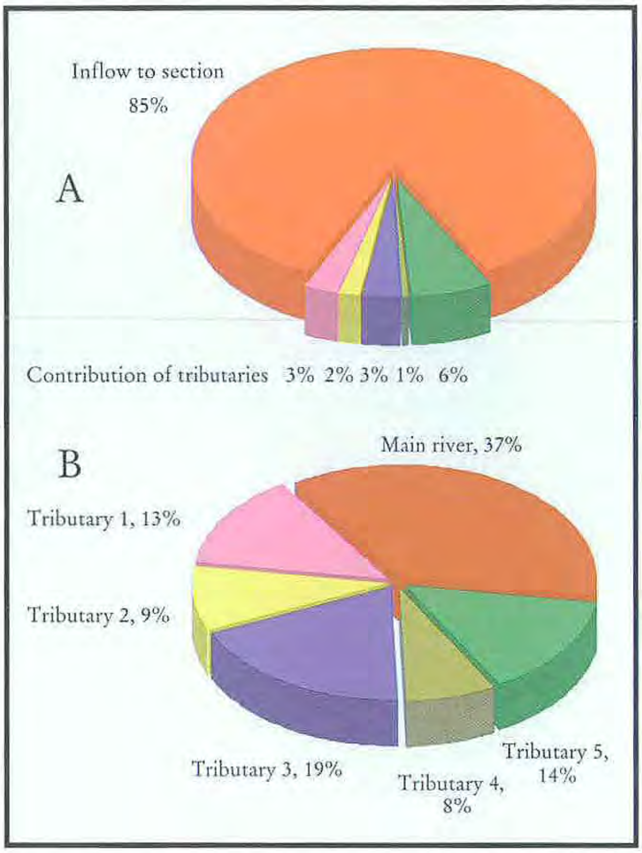


Figure 34. Relative contributions to the water discharge (% by volume) and contributions of nitrate (% by mass).

events of between 24 and 110 h have proved successful on the river Swale and have produced valuable information about the changes in the concentration of nutrients in changing flow conditions. Figure 34 shows one example of the impact of the lowland section of the river Swale on the mass of nutrient, in this case nitrate, delivered to the estuary during a 24 h storm event. About 85 % of the water passing the downstream site comes from the upper catchment above Catterick with the rest from the major and minor tributaries entering the study reach. This contrasts with the nitrate budget, in which 37 % of the nitrate delivered at the lower site originates from the area above Catterick. The tributaries contribute the majority of the nitrate flux mainly from runoff from agricultural land in the lowland area.

Internal sinks and sources of nutrients

The above approach provides valuable information about the role of the processes which occur during the transport of nutrients in rivers. These processes may be important in the control of nutrient concentrations and biological availability in the water. Research so far indicates that there may be a net loss or gain of phosphorus in the water which may be attributed to internal riverine processes. The loss of dissolved phosphorus from the water may be attributed to the interaction of soluble phosphorus, introduced mainly from the tributaries in the lowland section, coming into contact with suspended sediments originating from the upper catchment and bank erosion. Such sediments have a high sorption affinity for phosphorus and so remove some of the soluble material from the water. This result is supported by the analysis of mineralogically similar suspended material collected at three sites along the study section.

The majority of particulate and organic phosphorus is transported by rivers in storm events.

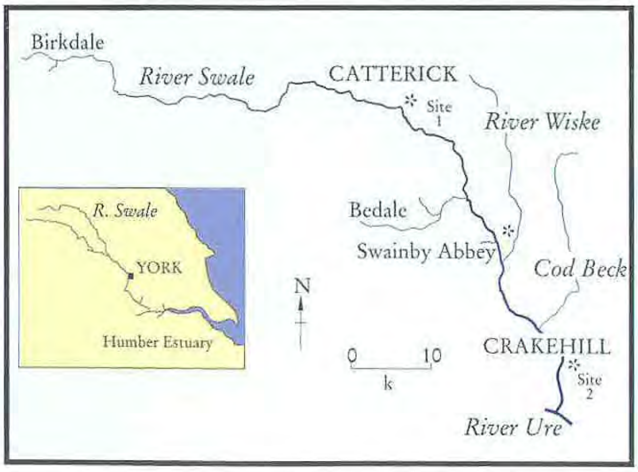


Figure 35. Map of River Swale

The effects of oestrogenic contaminants on growth and reproduction in fish

The alkylphenol ethoxylates (APEO's) are a major group of non-ionic surfactants. Biodegradation of these compounds is incomplete in sewage treatment, thus they are ubiquitous aquatic pollutants. All the main degradation products of APEO's have been demonstrated to have oestrogenic properties *in vitro* and recent work at the IFE has examined the impact of these chemicals *in vivo*.

Effects of alkylphenolic compounds on the growth of trout

Exposure of juvenile rainbow trout to a range of alkylphenols at environmentally relevant concentrations caused significant alterations in the growth patterns of the fish and growth effects were still apparent one year after exposure ceased. The size of the gonad relative to body weight was also significantly affected by some of the chemicals. These results clearly demonstrate that even low concentrations of alkylphenolic compounds can modify growth rate and gonad size in juvenile fish. This is of particular concern because body size is an important factor in the survival of fish in the natural environment, and an appropriate level of gonadal development is a crucial factor in successful reproduction.

Effects of alkylphenolic compounds on the reproductive performance of trout

The impact of these compounds on reproductive processes was further examined in a second study, in which adult trout were exposed to alkylphenols during the pre-spawning period. In female fish all the treatments had effects. Included among these were significant increases in plasma vitellogenin levels, relative fecundity, egg volume, progeny survival to hatch, and size of progeny. In the blood of male fish exposed to the alkylphenols, vitellogenin (Vg), normally a female specific protein, was detected at levels much higher than in untreated males. Secondary sexual characters, such as skin structure, were also modified in exposed male trout although no effect on sperm counts was seen. Overall, exposure of female trout to alkylphenolic compounds appeared to have a broadly positive influence on reproductive status. Most effects appeared to be related to the assumed oestrogenicity of the compounds. The elevation of plasma Vg levels in male fish also appears to be a consequence of the oestrogenic character of these compounds. The mechanism underlying the other effects in males is as yet unclear. It is obvious that concerns regarding the possible influence of "endocrine disrupting" pollutants on freshwater biota are not without foundation.

Figure 36. Apparatus used to expose groups of juvenile rainbow trout to a range of five alkylphenols at three concentrations (1, 10, and 30 $\mu g\ l^{-1}$).

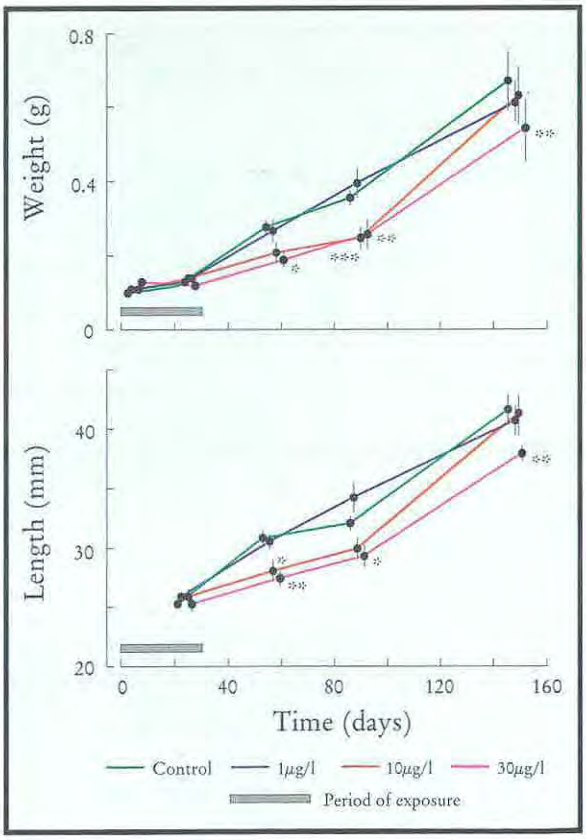


*Figure 37. Body weight and fork length of rainbow trout exposed to nonylphenol for 35 days at concentrations of 0, 1, 10, and 30 $\mu g\ l^{-1}$. The asterisks indicate significant differences between treated and unexposed, control, fish at each time point. * $p<0.05$; ** $p<0.01$; *** $p<0.001$.*

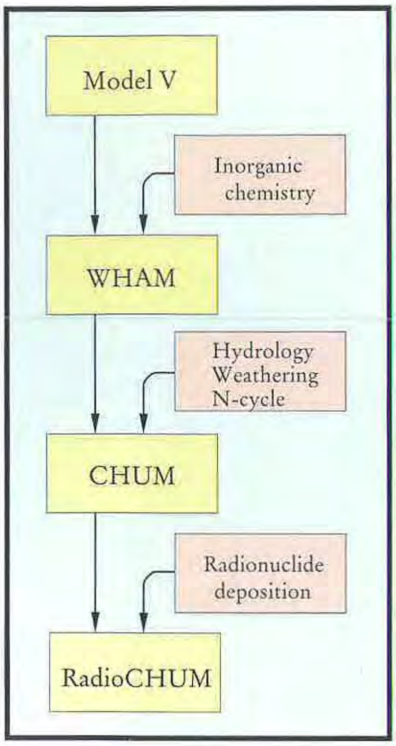


Figure 38. Hydrochemical modelling hierarchy. WHAM = Windermere Humic Aqueous Model, CHUM = CHemistry of the Uplands Model.

RadioCHUM - modelling radionuclides in an upland catchment

The Chernobyl accident was a dramatic demonstration of the problems caused by the release of radionuclides into the environment, and it emphasised the need for methods to predict radionuclide behaviour. A contribution to this effort has been a hydrochemical modelling study, funded by MAFF, to assess the retention and transport of different metallic radionuclides in an upland catchment in Cumbria.

The work was made possible by the development of a hierarchy of models (see Figure 38) based on Model V, which describes mathematically how protons and metal ions interact with natural organic matter. The addition to Model V of equations for other chemical reactions produced WHAM, a computer code that can be used to calculate element distributions in waters, sediments and soils. The dynamic catchment-scale model CHUM was then generated by combining WHAM with sub-models for hydrology, chemical weathering and nitrogen cycling. RadioCHUM is the version of this model that deals with atmospheric inputs of radionuclides.

RadioCHUM was used to simulate the behaviours of a suite of radionuclides, including strontium, caesium and actinide elements, following their deposition in single rainfall events.

The calculations show that retention and transport depend strongly upon the chemical properties of the different radionuclides. For the Tarn Head Beck catchment, caesium is weakly adsorbed by soil solids, strontium adsorbs more strongly, and Am is tightly bound. Thus the rate of release from the catchment soils to streamwater is in the order caesium > strontium > americium (see Figure 39).

The rate of release also depends on how the deposited radionuclides enter the soil. Maximum retention occurs if they are initially held by the organic matter in the upper part of the soil, which is most likely when there is a significant soil moisture deficit, or when deposition of particulate forms occurs (Figure 39, panel A). Deposition of dissolved radionuclides onto a wet catchment, results in penetration to the deeper, less retentive mineral soil (Figure 39, panel B).

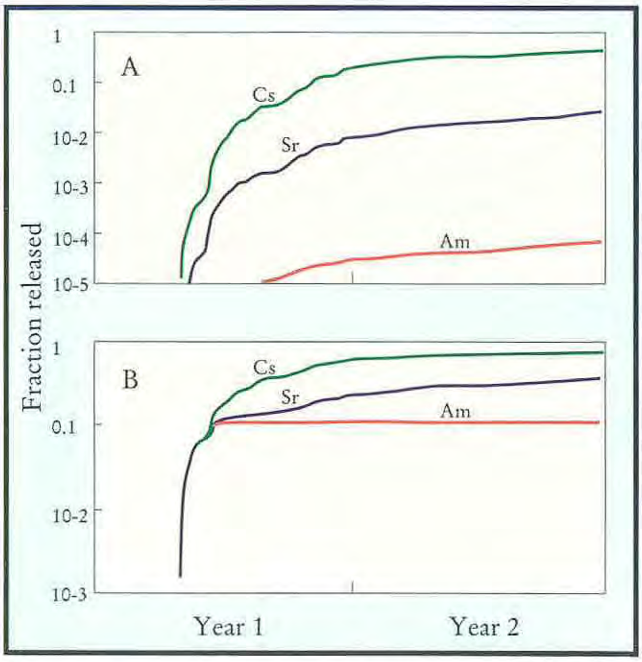


Figure 39. Calculated release of radionuclide elements - Sr, Cs, Am - from the Tarn Head Beck catchment to streamwater. Deposition was assumed to occur in a single event on day 147 of year 1. Panel A shows results following initial retention by organic matter in the surface soil. Greater penetration to the less-retentive mineral soil gives the results in panel B.

The issue of climate change is now moving from the hypothesis stage to reality, and GCM predictions of the magnitude and speed of change are large enough to suggest that there will be major impacts in the UK. However, the full nature of the biotic feedbacks involved is not understood but is likely to be important in conditioning the eventual impacts and responses. Thus, a better understanding of the links between the physical and biological processes, using both field experiments and modelling, is critical to the advancement of this area of science.

Global Change

This work on Alder-flies shows how the effects of potential climate change, and other environmental changes, can be assessed when long-term data are available and quantitative relationships have been established.

Emergence and pupation of Alder-flies over 30 years

From 1966 to 1995, dates were recorded when adult alder-flies, *Sialis lutaria* L., were first seen (30-year range: 23 April - 25 May), 50% of the maximum density occurred (4 May - 4 June), and maximum density occurred (11 May - 17 June) along 200 m of Windermere shore. Emergence dates occurred at similar temperatures, estimated by mean values for both the emergence date and the week prior to emergence (Figure 40).

Final instar larvae pupated in damp soil just above the water line. Dates for larvae leaving the lake to pupate were back-calculated from dates for adult emergence, using a power-function derived from laboratory experiments to determine the relation between temperature and pupation time. Mean temperatures for estimated dates on which larvae left the lake to pupate were less variable than those for adult emergence, being 7.5°C (± 0.20) for the start of pupation, 9.4°C (± 0.16) for 50% maximum density, 13.7°C (± 0.16) for maximum density. These values are similar to those obtained in the laboratory and can be used to predict pupation and adult emergence for different temperature regimes.

As the data for the present study cover a period of 30 years, the patterns for the coldest and warmest periods for larvae leaving the water to pupate provide a good indication of the temperature tolerance range. The coldest spring occurred in 1979 with the estimated dates being 2 May for larvae first leaving the lake, 12 May for 50% maximum density and 2 June for maximum density (Figure 41). The warmest spring occurred in 1981 with the estimated dates being 30 March for first movement, 11 April for the 50% value, and 13 May for maximum numbers. Water temperatures were very similar in the two years for each of these three points. For the months in which larvae moved from the lake, temperature differences between the coldest and warmest years were about 2 - 3°C and therefore close to the maximum forecast as a result of climate change. It is therefore unlikely

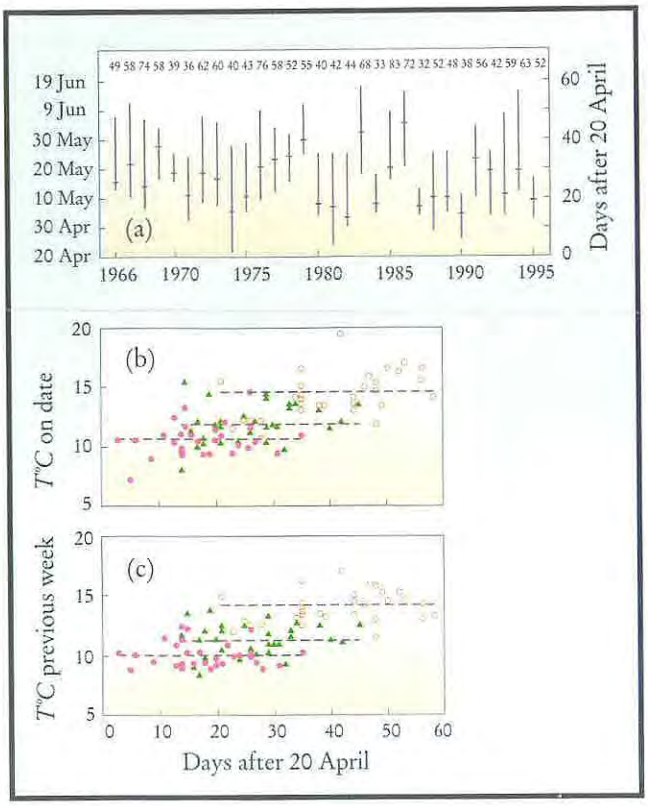


Figure 40. (a) Dates for adult emergence in each year from 1966 to 1995; lower limit of vertical line is the date on which adults were first recorded, cross is the date on which 50% of the maximum density occurred and the upper limit of vertical line is the date on which the maximum density occurred (actual numbers for the latter are given at the top of the figure); (b) Relationship between temperature on emergence date and actual date for start of emergence (●), 50% maximum density (▲) and maximum density (o); horizontal lines are mean values for the 30 years; (c) Relationship between mean temperature for the week prior to emergence date and actual date for start of emergence (●), 50% maximum density (▲) and maximum density (o); horizontal lines are means for the 30 years.

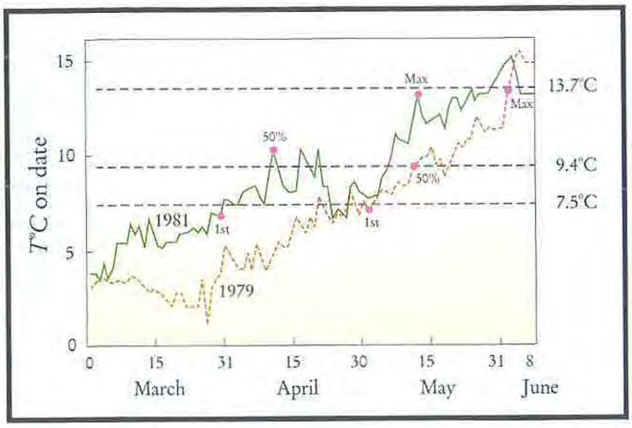


Figure 41. Daily water temperatures during the period when larvae left the lake to pupate in the coldest (1979) and warmest (1981) spring for the period 1966-1995; estimated dates are given for when larvae first left the lake to pupate, 50% of the maximum density occurred and the maximum density occurred; broken horizontal lines are the mean temperatures (over 30 years) for start of pupation, 50% maximum density and maximum density.

that such a change would have a catastrophic effect on the emergence and pupation of Windermere alder-flies. This example shows how the effects of potential climate change, and other environmental changes, can be assessed when long-term data are available and quantitative relationships have been established. Unfortunately, such information is still rare for aquatic insects but is urgently required to evaluate the effects of changing temperature regimes on these important components of the aquatic ecosystem.

Contributions to global change programmes of TIGGER and LOIS.

IFE, Royal Holloway College, University of London and others have undertaken an multi-proxy study within the **Terrestrial Initiative in Global Geological Environment Reconstruction** (TIGGER 2b) to the late-glacial environmental reconstruction, based on pollen, macro-fossils, diatoms, chironomids and beetles, of two infilled lake sites, one in the north-east of Scotland, (Borrobol) and one in the south east, near Hawick (Whitrig Bog). The two very different geological areas, one a heather-peat upland catchment, the other a calcareous sandstone, provide very different fossil assemblages, both indicating episodes of high amplitude, short-term climatic changes. Diatom assemblages reflect the changing environment in these shallow lakes and concentrations are indicative of differences between organic and minerogenic sedimentary units related to warmer or colder periods. However, the remains of terrestrial beetles and of midges appear as the closest indicators of an early rise in temperatures.

A *Land-Ocean Interaction Study (LOIS)* of post-glacial sediment fluxes in the Tees Estuary is part of the *Land-Ocean Evolutionary Perspective Study (LOEPS)* is an IFE collaboration with University Departments at Liverpool, Durham and Aberystwyth, and BGS Coastal Unit, co-ordinated by Dr A.J. Plater. The series of Holocene sediment cores of the last interglacial have been collected from: the infilled river valley at Billingham, the estuary below Middlesborough and the offshore area of the Geordy Trough. Stratigraphic sections close to the present Billingham Beck include well preserved intercalated peat, sand and clay layers resulting from changes in the depositional environment. Diatoms indicate changes from deposition on a tidal mud-flat to a more stable marsh with increasing freshwater influence. Later, increasingly marine deposition indicates a positive sea-level tendency and a lagoonal environment. Lower down the present estuary the sediments are mainly marine, with some non-diatomaceous sections. Analyses indicate long-term changes from marine to fresh/brackish environments along the landward transect.

IFE has also collaborated with London (UCL), Southampton, Liverpool, Edinburgh Universities and others in a programme led by Prof. R.W. Battarbee and Dr K. Barber to study the Proxy Records of Climate Change in the UK Over the Last Two Millennia - TIGGER 2a. These include: the study of historical climate records in Scotland; proxy-climate indicators in lowland and upland lake sediments and raised bogs; and developing tephra analysis methodology. This search is for climate signals of relatively small amplitude and duration compared to those of Glacial- Interglacial changes, further complicated by human impacts and requiring more precise chronology for short-term. The IFE contribution to this multi-aspect study has been to relate annual patterns of accumulation within very recent sediments to known changes in the phytoplankton and faunal populations of Windermere over the last 50 years. The relationships have illustrated the effects of sudden climatic events such as severe storms, winter weather etc. and lend weight to the interpretation of similar types of changes occurring in other sedimentary records where no such comparison is possible and where dating becomes increasingly difficult.

Figure 42. Locations of the IFE study sites within the TIGGER and LOIS programmes in the UK.

The IFE is collaborating in climate change studies in northern Britain to ascertain long-term sea-level and lacustrine changes.

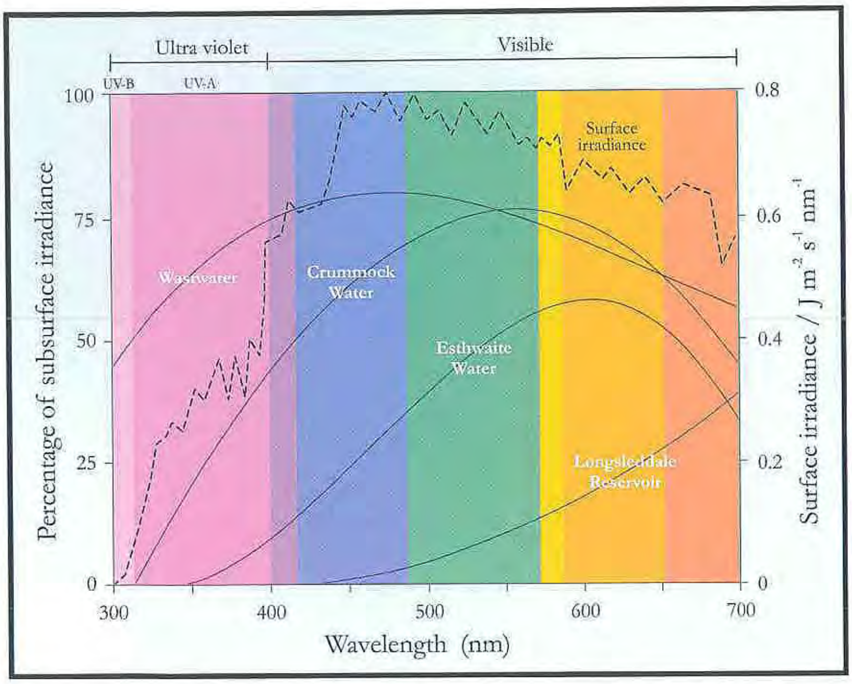


Figure 43. Percent of sub-surface irradiance for ultraviolet and visible radiation at a depth of 1 m in four contrasting Cumbrian lakes. A typical energy distribution for sunlight shows the small amount of ultraviolet compared to visible radiation.

Although ultra-violet radiation does not penetrate to great depth in most fresh waters, it can reduce phytoplankton productivity.

Effect of UV-B radiation on the photosynthesis of freshwater phytoplankton

Attenuation of UV-B in lake water

The recently detected reduction in stratospheric ozone, and associated increase in UV-B radiation, has stimulated interest in the possible harmful effects of UV radiation on ecosystem function. In clear oceans, and exceptionally clear lakes, UV-B radiation can penetrate to 30 m (1% of sub-surface). In many lakes, however, particles and dissolved organic molecules will rapidly remove these short wavelengths. A study of thirteen lakes in Cumbria has highlighted the large variation in the attenuation of UV-B (Figure 43). The depth at which the sub-surface light was reduced to 1% varied between 0.07 m at a site with brown water, and 4.3 m in a clear oligotrophic lake.

Ultra-violet radiation and inhibition of productivity

An *in situ* experiment in Esthwaite Water, Cumbria, assessed the effects of UV-B, UV-A (long-wavelength ultra-violet, which is unaffected by changes in atmospheric ozone) and visible light on rates of production by natural populations of phytoplankton. Production in bottles close to the surface was strongly photo inhibited, but selective removal of UV-B and UV-A wavebands lessened the inhibition. The response was consistent with a model which described the effect of UV radiation on productivity by marine phytoplankton (Figure 44). If the model is correct it suggests that UV-B radiation is only responsible for about 17% of the observed photoinhibition with UV-A radiation causing the remaining 83%. Current levels of UV-A radiation therefore appear to be more important than UV-B in reducing phytoplankton productivity under present-day conditions.

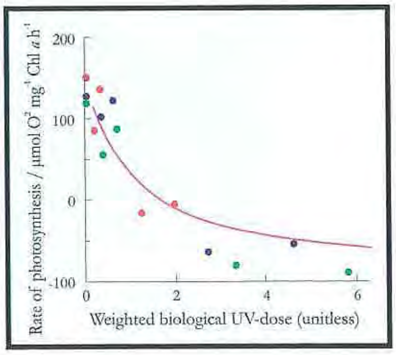


Figure 44. Rate of photosynthesis by phytoplankton from Esthwaite Water incubated in bottles which transmitted all UV radiation (●), removed most of the UV-B (●) and removed the UV-B and most of the UV-A (●). The line is the response modelled using a published biological weighting function for UV radiation.

The Loch Leven ice record

A daily record of ice cover has been kept at Loch Leven, Kinross, since 1968. Originally monitored by the Nature Conservancy for its effect on wildfowl behaviour, ice and meteorological data are collated by the IFE as part of a long-term ecological study. Ice cover at Loch Leven is characterised by its variability between years and within winters. Partial, but extensive freezing of the shallow or sheltered areas is common, complete cover much less so (Figure 45). The dominant factor determining the frequency of ice occurrence is air temperature (Figure 46), but wind mixing often keeps the exposed central area of the loch clear.

Ecological impact

Complete and prolonged ice cover has important ecological effects. Abundant light, oxygen and nutrients are essential to sustain the high planktonic biomass of eutrophic waters such as Loch Leven. Sunlight is virtually eliminated by opaque or snow-covered ice. Wind mixing to supply oxygen no longer operates and that already dissolved is used by respiratory action and decomposition. Nutrient recycling from the sediments enhanced by wind-induced disturbance also stops. The overall effect is a dark, relatively still water mass with diminishing resources to sustain life, leading to reduced primary production and increased mortality. However, complete ice cover here is not sufficiently long for a 'winter kill' of fish by suffocation. Ice sheet movement and 'packing' can disrupt littoral substrate stability on which some plants and animals depend.

Climatic trends

Increasingly, such historical records are important in the study of climatic change. The records themselves may display important trends, for example the pattern of complete ice cover (Figure 45) suggests a 20-year cycle. Also, the strong relationship with air temperature (Figure 46) enables an extension of climatic predictions to freshwater environmental and ecological consequencies.

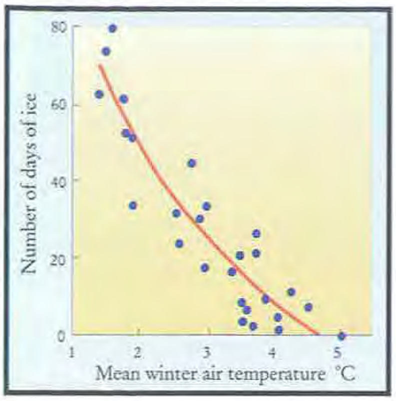


Figure 46. The strong influence of winter air temperature in determining the duration of ice is demonstrated by the relationship above ($r^2 = 0.85$). Sub-zero mean daily air temperatures are required to produce ice.

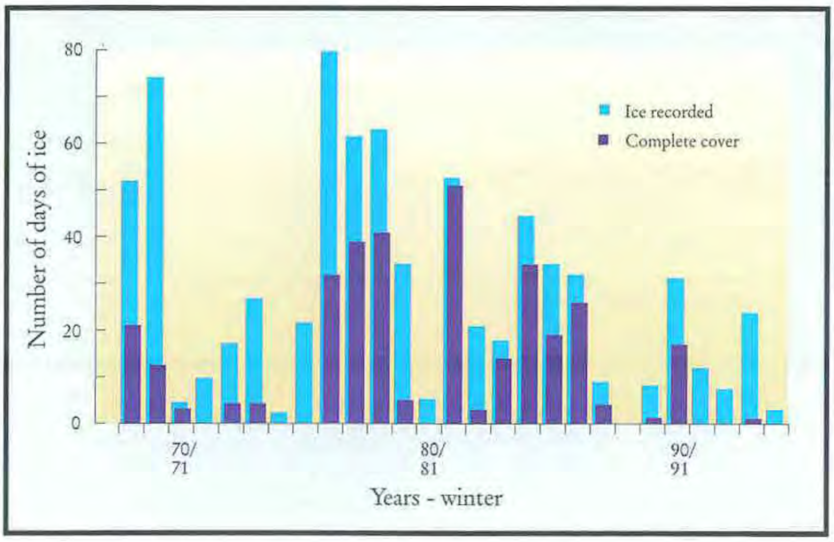


Figure 45. The 27 year ice record for Loch Leven. On average, ice is present for 28 days per winter, and complete cover for 12 days. However, each winter may have several separate ice phases, or indeed none, as in 1988/89.

The Loch Leven Ice Record is probably unique in Great Britain and valuable for ecological and climatic studies.

Several of our activities cut across all research areas and are essential to the overall success of the Core Strategic Programme. These include: environmental assessment, economics and history; remote sensing; instrumentation and technology development; analytical chemistry; databases and reference collections. Whilst interacting throughout the different programme areas, the scientists involved in these activities also develop their own subject areas to ensure that the research programmes have access to the best available information and techniques.

Integrating Generic Science

Using the Compact Airborne Spectrographic Imager (CASI) to monitor water quality in a series of Cumbrian lakes.

Using remote sensing techniques to identify different taxonomic groups of algae

The recent development of imaging spectrometers like the Compact Airborne Spectrographic Imager (CASI) offers great potential for extending the range of water quality parameters that can be measured by airborne remote sensing. Conventional broad band sensors provide useful information on the spatial distribution of phytoplankton but cannot usually identify the taxonomic group responsible for these spatial patterns. Freshwater phytoplankton are known to contain a wide variety of photosynthetic pigments which absorb light at discrete wavelengths. Airborne spectrometers like the CASI should be able to resolve these features and use these 'spectral signatures' to identify different groups of phytoplankton.

The remote sensing group at the IFE is currently developing new methods of analysing the reflectance signatures of selected species of freshwater phytoplankton. In this study, pure cultures of algae obtained from the Culture Collection of Algae and Protozoa are placed in a deep tank and their optical characteristics measured under controlled conditions. The plots in Figure 47 show the reflectance signatures of a diatom (*Asterionella*), a green alga (*Chlorella*) and a blue-green alga (*Microcystis*). The main difference between the spectra is the position of the reflectance maximum but the *Microcystis* spectrum also shows an absorption trough at 610-620 nm that is produced by the accessory pigment phycobilin. A variety of numerical and statistical techniques can be used to classify algae according to their spectral signatures. Figure 48 shows the results of applying one classification technique (canonical discriminant analysis) to the reflectance measurements recorded at

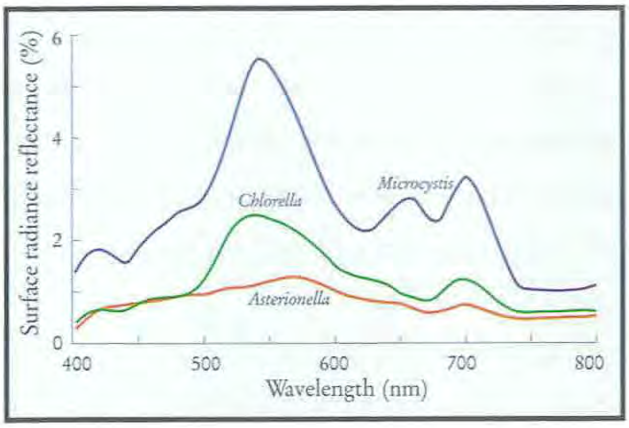


Figure 47. The reflectance spectra of three different species of algae; Asterionella *(a diatom),* Chlorella *(a green alga) and* Microcystis *(a blue-green alga).*

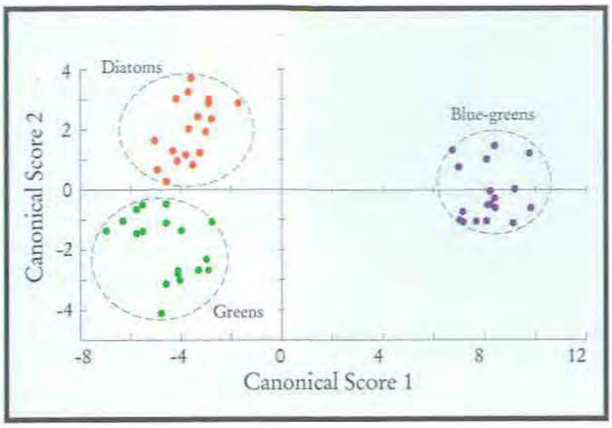


Figure 48. Plot of the canonical discriminant scores for the reflectance spectra from three classes of algae: diatoms, greens and blue-greens.

15 wavelengths selected according to the known optical properties of marker pigments. Two canonical scores were sufficient to separate the algae into three taxonomic categories: diatom, green and blue-green.

A GIS-based model for the management of lake eutrophication

The eutrophication problem

Freshwater lakes and reservoirs are a vital resource on which water supply, power generation, commercial fisheries and numerous leisure activities depend. The quality of these waters is of utmost importance and there can be significant health and financial consequences if they become polluted.

One major cause for concern is the nutrient enrichment, or eutrophication, of these waters. Most, if not all, eutrophication problems have been caused by man's activities within the catchment. These include the disposal of nutrient-laden sewage and industrial effluents, and the application of fertilisers to land used for agriculture and forestry.

Estimating nutrient losses from the catchment

Although attempts have been made to reduce the enrichment problems by controlling effluent discharges into freshwater systems, serious problems continue to occur as a result of diffuse nutrient losses from the catchment. These are much more difficult to quantify and control.

The IFE, in collaboration with the IH, the ITE, the Lake District National Parks Authority, Kendal, the Soil Survey and Land Research Centre, Cranfield University, and the Department of Geography, Edinburgh University, is developing a Geographical Information System (GIS)-based mathematical model to predict nutrient losses from lake catchments using widely available information such as land cover, soil type and rainfall. Initially, most of the work is being carried out on the very contrasting catchments of Bassenthwaite Lake, England, and Loch Leven, Scotland. However, the aim is to produce a generic model which can predict nutrient runoff for any catchment.

Predicting the effect on lakes

Ultimately, the IFE plans to link the catchment model described above to lake management models which have already been developed by the IFE to

Most eutrophication problems have been caused by man's activities within the catchment.

Figure 49. Sewage effluent discharge - an example of a point source of nutrient inputs to lakes.

Figure 50. Upland forestry - an example of a diffuse source of nutrient inputs to lakes.

predict lake water quality and algal productivity from nutrient inputs. This would allow us to predict the effects of changes within the catchment on water quality and on the likelihood of troublesome, and often toxic, algal blooms in lakes.

Culture Collection of Algae and Protozoa

CCAP Database

The Culture Collection of Algae and Protozoa (CCAP) acts as the UK Service Collection for algae and protozoa, providing cultures and their associated information for the scientific community. A new database of the Collection's holdings has been produced. This led to the publication of the sixth edition of the Culture Collection of Algae and Protozoa Catalogue of Strains. The database has also formed the basis of a fully-searchable electronic catalogue, accessible free on the Internet via the CCAP home page (URL http://wiua.nwi.ac.uk/ccap/ccaphome.html).

Continuous acquisition of water quality and meteorological data.

The development of an automatic water quality monitoring station

In recent years, it has become clear that many of the long-term changes recorded in lakes are influenced by changes in the weather that operate on a regional or even global scale. In 1994, the IFE was commissioned under the European Union's 'LIFE' programme (with additional support from the National Rivers Authority) to design and test monitoring stations that could be installed in lakes to record their day-to-day response to changes in the weather. A prototype station (Figure 51) was installed on Esthwaite Water during the spring of 1995. This station has been used to test transducers and sub-systems prior to the planned deployment of seven full systems in the UK, Ireland and Spain during 1996. The station records a wide range of meteorological and water quality parameters and in its final version will be able to transmit recorded data via radio telemetry to a shore station and on via the telephone network to a remote operator anywhere in the world.

The automatic water quality monitoring stations are to be fitted with an IFE designed multi-band transmissometer that will measure water colour features and derive an estimate of phytoplankton biomass. The prototype sensor, which was fabricated jointly by the IFE's mechanical workshop and electronics section, is shown in Figure 52. The sensor is designed for submersion up to 100m depth. It includes a pulsed white light source and measures the relative transmission of broadband white light and that of light at six carefully chosen wavelengths within the visible spectrum. Techniques similar to those described earlier in this section in relation to remote sensed images will be used to process the resulting data enabling phytoplanton and other suspended materials to be identified and quantified. Early results have been promising. Work is currently underway to improve the technical performance and to reduce the physical size of the sensor.

Figure 51. The prototype Automatic Water Quality Monitoring Station installed on Esthwaite Water

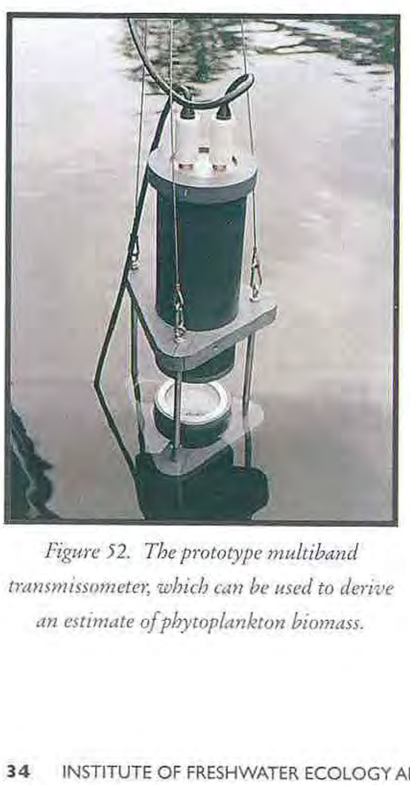
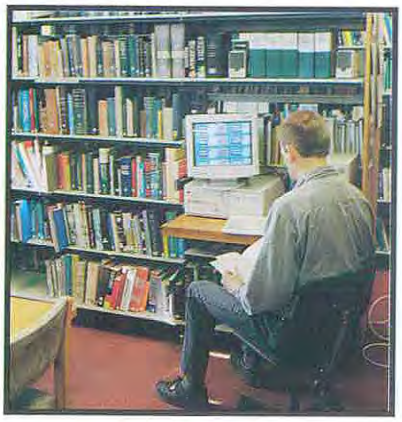


Figure 52. The prototype multiband transmissometer, which can be used to derive an estimate of phytoplankton biomass.

The Library, Laboratory Steward's office, Electrical, Electronics and Mechanical Workshops provide valuable support for the Institute's scientific programme. Not only do these sections provide day-to-day support to the scientific staff, but they are also increasingly working alongside scientists on major projects. Here we describe the changes to the Library and information services, the work undertaken to maintain the laboratory buildings and major facilities, and some of the new instrumentation developed by the Institute's Electronics Workshop.

Laboratory Services



The Windermere Laboratory Library

The library and information service

This year saw the retirement of Ian Pettman as Senior Librarian and of Kath Pearson as AO. Such a reduction in numbers has had to affect the services offered, and we have ceased publication of the Current Awareness Service and the British List of Hydrobiological Papers.

The library

Due to the reduction in staff numbers during the year, the library has catalogued fewer items (9,400) than in previous years, however, the online catalogue has now exceeded 100,000 records. Our exchange partners have continued to supply us with reprints and reports from 77 different countries.

We thank the libraries of the Institute of Terrestrial Ecology for their continued assistance in providing services to our regional laboratories at Edinburgh and Monks Wood.

The information service

We have endeavoured to increase the range of information sources available to our users, who now have desktop access to the Science Citation Index databases, Biological Abstracts online (BIOSIS), ASFA and WRA on CD-ROM, the British Library catalogues and the IFE Library catalogue. The Institute World Wide Web pages are now available at http://wiua.nwi.ac.uk/ and have been designed to give internal users some pointers to useful external sources of information, as well as to inform the public and potential customers of our own activities.

National and international networks

The provision of input to ASFA has continued throughout the year, and some inroads into the backlog have been made. International links have been maintained via EURASLIC and IAMSLIC, with three members of the library staff attending the IAMSLIC conference at Southampton Oceanography Centre in October.

Re-roofing of Pearsall Building

Recent technology advances enable the development of new areas of instrumentation.

Laboratory services

Windermere Laboratory - The major projects completed this year include the installation and commissioning of the access control and security systems and the complete re-roofing of the Pearsall Building. Unfortunately, further work is required to ensure the building is watertight. This work is scheduled for 1996/97. Minor upgrades to some offices and laboratories have taken place and steel profile roofs have been fitted to most of the 'temporary' buildings in a bid to reduce on-going maintenance costs.

River Laboratory - A major internal refurbishment programme of many areas has taken place this year, including the library, meeting room, stores, cloakrooms, corridors and offices. An access control and security system has been installed and commissioned. A new hot water system has been fitted throughout the laboratory and the ground floor windows of the Farmhouse have been replaced.

The Waterston site has been closed and most of the equipment removed back to RL for storage. Also the public footpath through the site has been diverted around the perimeter providing more security for the site.

Electronics and instrumentation

In addition to the instrumentation described in the section 'Integrating Generic Science', the department has also been engaged in a number of smaller projects.

Spectrometer

Relatively low-cost, miniature spectrometer sensing heads have recently become available commercially. Such a device could form the basis of a number of instruments to analyse the spectral quality of reflected or transmitted light and hence enable the concentration and composition of suspended materials, including phytoplankton, to be derived. The development of algorithms with which to process the 'spectral signatures' obtained using such a device will build on the remote sensing work described in the section 'Integrating Generic Science'. Initial laboratory experiments have used a miniature spectrometer sensor manufactured by Zeiss illuminated by a white light source via samples containing different suspended materials at various concentrations. They indicate that the spectrometer is sufficiently sensitive to provide useful information. This work is supported by funding from the National Rivers Authority.

Smolt counter

Each year in April and May a large number of young salmon (smolt) migrate seawards. A prototype device has been developed and installed in the fluvarium at the IFE's River Laboratory to count these fish. The unit consists of a series of short tubes stacked vertically within two glass channels. A bubble screen is used to ensure that fish migrating downstream have to swim through one of the tubes. Each tube contains a pair of electrodes enabling fish to be detected by the accompanying increase in conductance and recorded on an array of counters. Experience gained with the prototype will enable an improved counter to be developed for installation next year. (see also page 9.)

Other responsibilities

The department has continued to provide an instrument and computing equipment repair service. Significant electrical installation and safety inspection work has also been undertaken at both the Windermere and River Laboratories.

Dr D T Crisp

Dr A F H Marker

Mr B E Dear

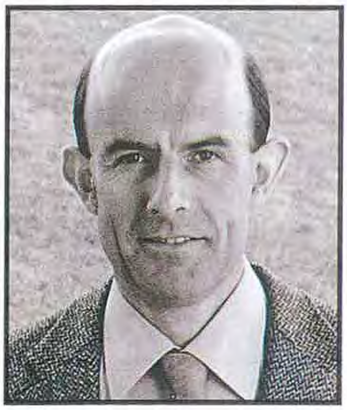
Mrs K J Pearson

Mr G Gregson

Mr I Pettman

Staff and External Activities

Miss K M Atkinson



Dr P A Cranwell

Staff changes

1995/96 saw the retirement of eight long-serving members of staff. Miss K M Atkinson retired from the Windermere Laboratory after 34 years and we were delighted when she was awarded the MBE for services to science as well as organisations connected with the conservation and management of the Lake District. Other retirements after many years loyal service were Dr P A Cranwell after 27 years, Dr D T Crisp after 31 years, Dr A F H Marker after 29 years, Mr I Pettman after 25 years, Mr B E Dear after 24 years, Mrs K J Pearson after 18 years and Mr G Gregson after 17 years. Other staff departing the Institute in 1995/96 were Mr D S Cordwell from the River laboratory, Dr J A Taylor to take up a new appointment at Lancaster University, Mr M S Glaister to work in America, Mr M R Wright and Mr L G Nolan to work in Bristol, Miss H G Orr to work at Lancaster University and Miss K Ross to work for the FBA. Our best wishes are extended to all of them in their future careers.

New appointments during the year (see photographs on pages 38 and 39) were Mr S Lofts (Scientific Officer), Miss J K G Ingram (Scientific Officer), Mrs S A Taylor (Administrative Assistant Part-time) and Mr S D Thomson (Professional & Technical Officer). To all these new staff we extend a warm welcome to the Institute.

Honours and promotions

Professor A D Pickering was appointed Director of the Institute in August 1995 and was elected to the Fellowship of the Chartered Institute of Biology (CBiol and FIBiol). Dr A E Bailey-Watts was also elected to the Fellowship of the Chartered Institute of Biology, and was awarded the degree of Doctor of Science from the University of London for his research on freshwater phytoplankton and lake eutrophication. Dr L May was elected to the membership of the Chartered Institute of Biology (CBiol and MIBiol), and Dr J M Winder was elected a Member of the Institute of Field Archaeologists (MIFA).

Miss J K G Ingram

Mr S Lofts

Elections and promotions underline once again the high quality of the IFE staff and their work.

Promotion was achieved during the year by Mr I D McCulloch (temporarily appointed Acting Librarian at Windermere Lab), Dr S C Maberly (Grade 7) and Dr I J Winfield (Grade 7). These elections and promotions underline once again the high quality of the IFE staff and their work.

NERC activities

IFE staff continued to play key roles in the administration of NERC research programmes. Dr F H Dawson was chairman for the Waterland Symposium (NERC) and a member of the CEH Core Strategic Review, Prof J M Elliott was also a member of the CEH Core Strategic Review and a member of the Catchment Ecosystem Research Initiative (CERI) Steering Group, Dr B J Finlay was a member of the Steering Committee producing a joint NERC-NHM-JNCC bid to the Millennium Commission and also a member of the CEH Core Strategic Review, Dr D G George was a member of the Large Scale processes Review Group, the TIGER IV Working Group and Secretary to CEH Review Panel (Panel 4), Dr W A House was a member of the NERC LOIS Core Chemical and Biological Working Group and the Freshwater Sciences Research Grants & Training Awards Committee, Professor J G Jones (FBA) was a member of the NERC RACS Committee and TIGER II Working Group, Dr S C Maberly was a member of the CEH Core Strategic Review and Secretary for the special topic "Testable Models of Aquatic Ecosystems", Dr A F H Marker was a member of the NERC RACS Chemical and Biological Coordinating Group, Dr L May was a member of the Environmental Diagnostics sub-committee for data and quality assurance and the CEH Core Strategic Review, Prof A D Pickering was a member of the Catchment Ecosystem Research Initiative (CERI) Steering Group and the CEH Core Strategic Review, Dr RW Pickup was a member of the Freshwater Sciences Research Grants and Training Awards Committee,
Dr L C V Pinder was a member of the NERC Environmental Change Network working group, Prof C S Reynolds was a member of the CEH Core Strategic Review, and Dr J F Wright was involved in discussions with Dr M J Tricker (NERC Director of Technology Interaction) on commercialisation of RIVPACS.

On the more technical/administrative side, Mr W R C Beaumont was a representative on the NERC IPMS Branch Council meetings, NERC Departmental Whitley meetings and CEH Whitley Committee, Prof Pickering was a member of Promotion Panel 1 (SSO - G7), the CEH Management Board and an alternative member for the LINK Aquaculture Programme, and Mrs R Hindle was the Local Welfare Officer and a member of Health & Safety Committee.

Collaboration with other NERC Institutes

Extensive collaboration continued with sister Institutes including those of the Centre for Ecology and Hydrology (IH, ITE and IVEM). Dr P D Armitage presented a paper at the Waterland Workshop held at Monks Wood; Dr A E Bailey-Watts collaborated with IH in Uganda, Tanzania and Kenya for several weeks, preparing proposals for Water Quality and Land Use, including Wetlands studies on Lake Victoria (for UN FAO); Mr J A B Bass collaborated with an ITE colleague, Mr J Weeks, in jointly supervising a Dutch undergraduate (Joost Schaminee of the Van Hall Instituut, Groningen, Holland) working on freshwater mussels; Mr K J Clarke collaborated with IVEM (Oxford) on the role of viruses in the aquatic environment and Dr J G Day maintained close association with

CCAP at Dunstaffnage Marine Laboratory (DML). Ms M M Deville, together with Ms D Hewitt and Dr L May, collaborated with ITE (Merlewood) on the Environmental Change Network (ECN); Dr B J Finlay maintained a close association with IVEM and ITE on the Integrating Fund project; Dr D G George collaborated with the Plymouth Marine Laboratory (A H Taylor) on Gulf Stream influences, the Centre for Comparative Plant Ecology (P Grime) re TIGER, and IH (J Finch) on a Remote Sensing proposal, and Mr I D M Gunn co-ordinated IFE Edinburgh's input into a joint project with ITE Banchory on the subject of interactions between fish, their predators and their food (with D Carss, H. Kruuk and K. Nelson).

Dr G H Hall continued his collaboration with Dr A Harrison (ITE, Merlewood), Dr E Y Haworth collaborated with IVEM as part of Dr B J Finlay's Priest Pot project and with Prof P Whitehead (ex IH, now Reading University) to produce a paper on acid rain studies; Prof J G Jones (FBA), supported by The Leverhulme Trust, collaborated with IFE colleagues on the structure of the largest free living bacterium; Mr D V Leach continued his collaboration with other Institutes, especially IH as well as ITE, as part of his responsibility to the LOIS programme; Dr R W Pickup collaborated with ITE and IVEM (Dr P Ineson, Dr N Parekh and Dr I P Thompson) on the Integrating Fund project "Methane Oxidation in Soils"; Dr E W Tipping collaborated with ITE (Dr P Ineson) on the TIGER project, with ITE and IH (Dr B Reynolds and Prof I R Calder) on the Integrating Fund project "Canopy Closure" and with IH and ITE (Mr G J L Leeks and others) on LOIS Rivers Core Programme; Dr I J Winfield collaborated with ITE (Biological Records Centre) on the development of a UK Freshwater Fish Atlas, and Dr J F Wright hosted a visit by three Czech biologists to the River Lab to hear about RIVPACS and other projects; this was arranged through IH who have a project in the Czech Republic.

Scientific societies

IFE staff continued to play a full role in the work of a wide range of scientific societies. Mr J A Bass was on the Institute of Fisheries Management Branch Committee (Anglian Region); Dr J G Day was a UKFCC Committee member; Dr F H Dawson was on the National Membership Committee, National Environment Committee, Membership Committee, Environment and Water sub-committees of the Institute of Biology, and the CIWEM Membership Panel; Mrs M Hurley was a committee member of the Lancashire & Cumbria group of the Royal Statistical Society; Prof J G Jones (FBA) was on the International Committee for Microbial Ecology, the IOB Environment Committee and the Management Committee (Royal Society) for the Baikal International Centre for Ecological Research (BICER); Dr S C Maberly was on the Committee of the British Phycological Society. Dr R W Pickup was the Convener: Environmental Microbiology Committee of the Society for General Microbiology; Dr E W Tipping was a Board member: International Humic Substances Society; and Dr I J Winfield was on the Institute of Fisheries Management Branch Committee (North West Region), the council of the Fisheries Society of the British Isles, the steering committee of the 5th International Symposium on Ecology of Fluvial Fishes, the IUCN/SSC Freshwater Fish Specialist Group, IUCN/SSC Invasive Species and the specialist EIFAC Working Party on the Influence of Management Practices on the Environment.

Mrs S A Taylor

Mr S D Thomson

IFE staff continued to play a full role in the work of a wide range of scientific societies.

Other organisations

Dr P D Armitage served on the Biological Methods Committee (BSI), Dr A E Bailey-Watts on the Scottish Office Health Department Working Party on Blue-green Algae, Dr F H Dawson on the NRA Technical and Advisory Groups on River Habitat Classification and the NRA Scoping Group on Fisheries Inventory, Dr B J Finlay on the Freshwater Sediments Sub-Committee of the Scientific Committee on Problems of the Environment (SCOPE), Mr M T Furse on the Steering Group for DoE project "Countryside Information System Data Management" and as adviser to the NRA River Habitat Survey Working Party, Prof J Hilton on the Research Advisory Committee of the Centre for Aquatic Plant Management (Long Preston), Dr W A House on the Technical Committee on Detergents and the Environment (DoE) and Phosphorus Working Group (ADAS), and Dr M Ladle on the NRA Regional Fisheries Advisory Committee, NRA LFAC, Frome, Piddle and West Dorset Fisheries Assoc (Chairman) Fleet Study Group, Frome Conservation Trust (Chairman), Committee Somerset Wildlife Trust, Wessex NRA Catchment Steering Committee, Game Conservancy Wetlands Committee. Mr A A Lyle was on the Loch Lomond Research Group Committee, Dr A F H Marker and Prof J M Elliott on the DoE Standing Committee of Analysts (WG7), Mr I D McCulloch was secretary of the ASLIB Northern Branch, Professor A D Pickering was on the FWR Algal Toxin Research Forum, Dr R W Pickup on the EC Biotechnology Research Grant Committee. Dr L C V Pinder attended the Earth Centre meeting, Doncaster, for a Community Programme proposal on reclamation of industrial landscapes. Prof C S Reynolds was on the NRA: Toxic Algal Task Group and the SLDC: Agenda 21 Advisory Panel, and Dr J F Wright was on the Advisory Board for the Identification Qualification (IdQ) scheme run by the Nat. Hist. Mus. and a member of Moors River Standing Committee.

Members of staff continue to fulfil editorial responsibilities on behalf of many scientific journals.

Editorial commitments

Dr J G Day edited the UKFCC Newsletter, Prof J M Elliott continued as Series editor for the Scientific Publications of the FBA and was co-editor of the Proceedings of the Third International Charr Symposium, Dr B J Finlay continued to edit the Archiv für Protistenkunde, Prof J Hilton was co-editor of the Proceedings for Freshwater & Estuarine Radioecology, Prof J G Jones (FBA) edited Advances in Microbial Ecology and Freshwater Forum, Dr S C Maberly was a Guest Editor (with S I Heaney) of a special issue of Freshwater Biology. The Journal of Fish Biology had three assistant editors from IFE: Dr R H K Mann, Dr T G Pottinger, Dr I J Winfield, thereby underlining the strength of this area of science in IFE. Dr Winfield was also a guest editor for special issues of the Polskie Archiwum Hydrobiologii and the Archiv für Hydrobiologie. Prof C S Reynolds co-edited Archiv für Hydrobiologie.

The following members of staff also served as associate editors or members of the editorial board for a range of other scientific journals:

Dr P D Armitage - Regulated Rivers, Research & Management; Netherlands Journal of Aquatic Ecology; Water Research; Environmental Pollution;
Prof J M Elliott - Annales de Limnologie; Wasser und Abwasser;
Dr B J Finlay - FEMS Microbiology Ecology; European Journal of Protistology; Microbial Ecology;
Dr E Y Haworth - Journal of Palaeolimnology;
Dr W A House - Internationale Revue Der Gesamten Hydrobiologie;
Dr S C Maberly - Aquatic Botany; Internationale Revue Der Gesamten Hydrobiologie;

Dr R H K Mann - Ecology of Freshwater Fish;
Dr L May - Internationale Revue Der Gesamten Hydrobiologie; Rotifer News;
Prof A D Pickering - Diseases of Aquatic Organisms;
Dr R W Pickup - Microbiology;
Prof C S Reynolds - Journal of Plankton Research; Journal of Aquatic Sciences; Aquatic Ecosystem Health; Limnologia;
Dr E W Tipping - Environmental Technology.

Collaboration with Universities

Teaching

Prof J M Elliott was an Adjunct Professor in Freshwater Biology in the Norwegian College of Fishery Science, University of Tromsø, Prof J Hilton a Visiting Professor at the University of Reading, Prof J G Jones (FBA) a Visiting Professor at the University of Liverpool, Prof A D Pickering a Professor Associate at Brunel University, Prof C S Reynolds a Visiting Professor, Universidad de Buenos Aires, and Dr S C Maberly was for six months a Guest Professor in the Dept of Plant Ecology, Aarhus University, Denmark. Dr E W Tipping was a Visiting Reader and Dr I J Winfield a Visiting Lecturer at the University of Lancaster, Dr A E Bailey-Watts a Visiting Lecturer at Napier University, and Dr R W Pickup an Honorary Lecturer at the University of Lancaster. Drs Bailey-Watts and Pickup were also Honorary Visiting Research Fellows at the Universities of Edinburgh and Liverpool, respectively. Seminars were given by several IFE staff at different universities, and staff also served as external examiners for PhD degrees and MSc courses.

Research

In addition to the above teaching commitments, 1995/96 saw a continuation of the extensive research collaboration between the IFE and universities throughout the UK, Europe and further afield. Dr P D Armitage collaborated with Dr Pardo of the University of Santiago, Dr Malmqvist of the University of Umeå, Sweden and Dr Prenda of the University of Seville. Dr A E Bailey-Watts collaborated with the Dept. of Environmental Chemistry, Edinburgh, on research into heavy metals, stable isotopes and nutrients in sediments, with the Central Inland Capture Fisheries Research Institute, Barrackpore, West Bengal, and the British Council, Calcutta, India, with the Ministry of Water, Energy and Minerals (Tanzania) in relation to the Lake Victoria project, and on a UNDP (GEF) proposal on "Pollution control and other measures to protect biodiversity in Lake Tanganyika" prepared in conjunction with NRI (Chatham) and MRAG (Imperial College, London). Mr J A B Bass acted as adviser to two post-graduate students working on a Leicester University/Environment Agency project, Dr F H Dawson collaborated with K Szoszkiewicz, University of Posnan, Poland on water-plant associations and RHS, Dr J G Day continued cryopreservation research with the Universities of Stirling, Dundee and NIES/ Tsukuba, and Dr B J Finlay worked at the Marine Biological Laboratory at Univ. of Copenhagen. Prof J M Elliott continued as the EC project co-ordinator, collaborating with NINA (Norway), Netherlands Institute of Ecology, Swedish University of Agricultural Sciences, University of Oviedo (Spain). Mr M T Furse worked on collaborative research with the University of Valencia (Dr A Pujante), with Dr J Alba-Tercedor (University of Granada) and Dr A Pujante (University of Valencia) in the production of a bid to the EU Transfer of Technology Programme. Dr E Y Haworth worked on the TIGGER Project: Proxy Records of Climate Change: the last 2000 years,

IFE staff collaborate actively with universities throughout the world.

Collaborations involve all aspects of freshwater science.

with UCL Geography Dept., on the LOIS Tees project with Liverpool University Geography Dept. (together with M R Wright, 1 year staff appointment), Prof J Hilton worked with R Comans (ECN, Petten, The Netherlands). Prof J G Jones (FBA) worked with staff at the University of Newcastle on the activity and diversity of sulphide-oxidising bacteria in aquatic sediments and was also an Associate Researcher, Institute de Limnologia, La Plata, Argentina. Mr D V Leach was involved with a number of Universities, e.g. Exeter, Leeds, Reading, as part of providing support to LOIS Special Topics. Dr S C Maberly collaborated with Misni Sarif (University of Penang, Malaysia), Birgit Olesen and Tom Madsen (Aarhus, Denmark), Dr R W Pickup with the University of Liverpool on the palaeoecology of sediments, novel methods for detection of bacteria (St. George's Hospital Medical School, University of London), on the detection of pathogenic bacteria, and University of Newcastle on the ecology of *Achromatium* in fresh water. Dr T G Pottinger continued to work with Prof Sumpter's group at Brunel University; Dr Paul Balm at University of Nijmegen and Dr David O'Hare at Derby University, Prof C S Reynolds worked with colleagues at the University of Reading, Dept. of Geography, on phytoplankton modelling, Dr J T Smith worked with R Comans (Netherlands), Prof Anatoly Kudelsky (Belarus), Igor Bilyi (Ukraine) and Anatoly Bulgakov (Russia). Dr E W Tipping continued collaboration under the LOIS Special Topic: particle chemistry in rivers and estuaries, with the University of Plymouth (G E Millward), and Dr I J Winfield continued his joint research with the University of Ulster on the Ecosystem of Lake Baikal, Siberia, and with the University of Glasgow on the ecology of ruffe introductions. Dr J F Wright collaborated with Mr J C Peters (Reading University) and Dr A D Berrie in writing a scoping study for a monitoring programme for the R. Lambourn, Berks., with colleagues from Bournemouth University who demonstrated their progress in the design of a simple procedure for data entry to, and manipulation of data from, RIVPACS, with J Alba-Tercedor (Granada, Spain) over possible EC funds under the Technology Validation and Technology Transfer programme and also over collaborative work leading to development of RIVPACS in the Sierra Nevada and other regions of Spain, and was invited by Prof Narcus, University of Barcelona, to join a consortium of European Universities in a project BIMPAR (Biomonitoring of Pampasic Rivers).

Members of staff also acted as supervisors for students registered for PhD degrees:-

Miss J Anderton (Greenich P/t) The effects of lead mining on Ullswater, English Lake District (Dr Haworth)

Mr S Ball (Lancaster, CASE) The role of picophytoplankton in lakes of different trophic state (Dr Maberly)

Mr T M Beaumont (Liverpool, CASE) Interactions of cortisol and adrenosensitivity during chronic stress in salmonid fish (Dr Pottinger)

Mr C Brereton (London, CASE) The role of silt and mucus secreted by invertebrates in retaining organic matter over the substratum of streams (Drs Armitage and House)

Mr G Biagini (Cardiff, CASE) Metabolic pathways in free-living anaerobic protozoa (Dr Finlay)

Mrs A M Brookes (Southampton, FBA) An investigation of the influence of landscape variables on stream macroinvertebrates using a geographical information system (Mr Furse)

Miss S Brown (Liverpool, part-time) The molecular systematics of naked amoebae (Dr Finlay)

Miss D Bunker (Liverpool, CASE) Effects of sediment and water chemistry on sorption processes of various radionuclides in freshwater systems (Prof Hilton)

Miss A Campbell (Dundee, CASE) The carbon physiology in freshwater algal blooms (Dr Maberly)

Miss C E Cannan (Southampton) Extrapolation of reach level channel and riparian habitat information to catchment scale (Dr Armitage)

Mr F L Charlton (Edinburgh, CASE) Remote sensing of freshwater phytoplankton (Dr George)

Mr D Clarke (Exeter, CASE) Microthermal habitats in British rivers (Drs Crisp and Ladle)

Mr S Clough (Leeds, Esmeé Fairbairn Trust (FBA)) Composition, distribution and dynamics of populations of river fish (Dr Ladle)

Miss P S Davies (Leeds, TESCO (FBA)) Phosphorus dynamics in limnetic ecosystems (Dr Reynolds)

Mr D Deere (Liverpool, CASE) Identification of bacteria by flow cytometry (Dr Pickup)

Miss L A Fear (Lancaster, CASE) Microbial community changes in the gut of *Gammerus pulex* (Dr Pickup)

Miss N J Fielding (Liverpool, NERC Targeted) Algal nutrient cycling in brackish lagoonal systems: mechanisms to control algal development in isolated dock complexes: top-down control (Dr Maberly)

Mr R A Fleck (Dundee) Assessment of cell damage and recovery in cryopreserved freshwater protists (Dr Day)

Miss A S Fulcher (Lancaster) The physiological ecology of the rotifer community in the plankton of Loch Ness and the Cumbrian Lakes (Dr May)

Miss S Griffiths (St Andrews, CASE) Schooling dynamics of dace in the River Frome (Dr Ladle)

Miss A Hartley (Birmingham, CASE) Microelectrode studies of calcification and gas exchange within hardwater algal biofilms (Dr House)

Mr R Hastings (Liverpool, NERC) Distribution of nitrifying bacteria in lakewater and sediments (Dr Pickup)

Miss E Hawtin (Birmingham) Chironomids in lowland rivers in relation to water quality and physical habitat (Dr Pinder)

Mr R M Head (Lancaster, CASE) The role of sediments in blue-green algal blooms (Dr Bailey-Watts)

Mr R D Hedger (Edinburgh, CASE) Spatial scales of dynamics in lakes (Dr George)

Mr R Howarth (Newcastle, CASE) Phylogenetic analysis of Achromatium oxaliferum (Dr Pickup)

Mr D M John (Cardiff, CASE) Survival fate of organosilicone and alkyphenol ethoxylate pesticide adjuvants (Dr House)

Miss L A Jones (Brunel, NERC) Effects of alkylphenols and related chemicals on gonad development and sex determination and gamete quality of trout (Dr Pottinger)

Miss W Lester (Reading, CASE) The distribution and fate of micro-organic pollutants in river sediments (Dr House)

Miss J Long (Reading, LOIS Special Topic) Contribution of river sediments to the translocation of pesticides (Dr House)

Miss S J Marshall (Cardiff, CASE) Roles of natural surfactants in pollutant biodegradation in biofilms in river sediments (Dr House)

42 post-graduate students are engaged in research projects at IFE.

Projects cover the full range of IFE research interests.

Miss S McGowan (Liverpool, CASE) Palaeolimnology of blue-green algal bloom formation (Dr Haworth)

Mr I Miskin (Liverpool, CASE) Identification and distribution of bacteria and their plasmids in sediments (Dr Pickup)

Ms J Reeve (Canterbury, Development Programme) Polycultures of aquatic plants - nutrient removal from waste waters (Dr Dawson)

Mr G Rhodes (Liverpool, CASE) Molecular evolution of plasmids in deep sediments (Dr Pickup)

Mr M Scott (Manchester, CASE) Climatic effects on the export of dissolved organic matter from peat (Dr Tipping)

Mr R Skidmore (Durham) The effect of environmental conditions on the plankton production dynamics in the feeder rivers of the Humber Estuary and the flux of autochthonous carbon to the estuary (Dr Marker, Dr Maberly)

Mr D Short (Liverpool, CASE) Quantitative models of sediment records and atmospheric fluxes (Prof Hilton)

Miss R Stidson (Lancaster, CASE) Chemical weathering in upland catchments (Dr Tipping)

Mr S Walker (Aberystwyth, FBA) Otolith structure as a possible indicator of stress in fishes (Drs Winfield and Pottinger)

Miss C Whitby (Liverpool, CASE) Nitrification in freshwater systems (Dr Pickup)

Mr S L Woodruffe (Birmingham, CASE) Biomineralisation reactions with algal biofilms & phytoplankton assemblages (Dr House)

MSc Students from the University of Central Lancashire, Groningen (The Netherlands), Plymouth, Napier and Wageningen (The Netherlands) were supervised by Drs May, Pickup and Pottinger.

During the year the following research students were awarded the degree of Doctor of Philosophy: Mr P Garner, Birmingham University, Mr P Irving, Oxford University, Miss K Lawlor, Liverpool University and Miss S A Owen, University of Wales, Cardiff.

International meetings and visits

Dr P D Armitage was chairman and keynote speaker at the River Bottom symposium in Czech Republic. Dr A E Bailey-Watts presented a poster at a meeting held in Stirling on Water Quality - Defining the Undefinable, and also travelled to Tanzania, Kenya and Uganda to identify resources needed to strengthen water quality monitoring of, and associated research on, Lake Victoria as part of the UN FAO-funded Lake Victoria Environmental Management Plan; he also travelled to Lake Tanganyika Research (FAO, FINNIDA) at Bujumbura, Burundi to give a short talk, and attended the Lake Tanganyika Biodiversity Protection Inception Workshop leading discussions/ seminars on aspects of assessing pollution and its effects on biodiversity; he was involved in a UNDP project on Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika. Miss S Brown presented papers at the Second European Congress of Protistology, Clermont-Ferrand, France, and at the 7th International Conference on Small Freeliving Amoebae held in Adelaide, Australia. Mr K J Clarke attended the International Symposium on the Exploration of Biodiversity in Goslar, Germany, and was also the joint author with M. Embley (Nat. Hist. Mus.) of a paper given at the Symposium. Dr J G Day presented a poster at the International Conference on the Value and Valuation of Natural Science

Collections and also attended the University of Bielefeld, Germany, for a discussion on algal blooms and toxicity, and Dr F H Dawson attended a PCTE Project Meeting in Madeira, Portugal.

Prof J M Elliott (funded by the University) attended the University of Tromsø to teach and supervise graduate students. Dr B J Finlay was a keynote speaker/chairman in Goslar, Germany, at the International Symposium on Exploration of Microbial Diversity, spoke at the 15th Congress of the Spanish Society for Microbiology held in Madrid, attended the Plenary Lecture of the British Section of the Society of Protozoologists at Imperial College and visited the Marine Biological Laboratory (Copenhagen) and the University of Madrid for collaborative work on microbial diversity. Mr M T Furse was on contract to the Laboratorio Regional de Enghenaria Civil in Funchal, Madeira, Portugal, and served as voluntary course tutor at Picos de Europa, Northern Spain, an Outdoor Education and Environmental Science course (Lancaster). Dr D G George was an organiser of a NATO Advanced Research Workshop on Management of Lakes and Reservoirs during Global Change held in Prague, and also attended several EU "Life" Projects held in Spain and Ireland. Dr W A House attended the 5th symposium on Chemistry and Fate of Modern Pesticides held in Paris, and also attended a BCR meeting on pesticides in Brussels. Mr G P Irons attended a meeting on Sensors as Transducers IX, in Stockholm, Sweden. Prof J G Jones (FBA) was co-organiser of a meeting of the Austrian Committee of International Association on Danube Research for the First International Symposium at Krems, Austria, on the Ecology of Large Rivers, was also co-organiser at the FBA/IWSA Specialised Conference in London on the Microbiological Quality of Water, also attended the 7th International Symposium on Microbial Ecology in Santos, Brazil where discussions included: the role of research charities in protecting long-term research needs, and dynamics of *Achromatium oxaliferum* and reduced sulfur species in a freshwater sediment, and attended as Director at the NATO Advanced Research Workshop held in Prague on the subject of management of lakes and reservoirs during global change. Dr R H K Mann attended at the University Paul Sabatier in Toulouse, France, as part of the jury for the Habilitation of Dr G H Copp. Prof A D Pickering was a Chairman at the International Conference on "The Ecological Basis for the Management of Lakes" in Leicester. Dr R W Pickup attended EC proposal discussions in Barcelona, Spain, and Dr T G Pottinger was the keynote speaker at the 2nd Benelux Congress of Zoology in Leiden, The Netherlands.

Prof C S Reynolds was again in demand at meetings throughout the world. He was Chairman and Plenary Lecturer at the International Association of Limnology in São Paulo, Brazil, Chairperson and lecturer in Leicester on the Ecological Basis of Lake Management; he attended a NATO seminar on Global Change in Prague, attended meetings and gave lectures in Brazil, Uruguay and Argentina, and attended FBA meetings in Krems-am-Donau and Prague. Dr J T Smith summarised the IFE contribution to the final report of the CHECIR ECP-3 programme in Kiev/ Zelony Mys, Ukraine, attended a conference in Minsk, Belarus on "The Radiological Consequences of the Chernobyl Accident", and attended CHECIR programme meetings in Dresden and Rome. Dr E W Tipping was an invited speaker at a meeting on colloids in freshwaters held in Geneva, Switzerland, and whilst in Geneva, was a participant at a workshop on colloids

IFE staff have carried out duties in many countries of the world.

International collaboration figures prominently in IFE science.

in ground waters, was also an Invited Speaker in Pensacola, Florida at a workshop on metal toxicity (organised by SETAC), also attended the University of Umeå, Sweden (PhD Examination), and a meeting of PROTOS project participants (Framework IV, EU) in Oslo. Dr I J Winfield was Chairman at the Ecology of Fluvial Fishes seminar held in Poland, presented a paper and poster at PERCIS II symposium in Finland, presented a paper at a symposium in the Czech Republic on Climate Change, was also Chairman at a meeting on the Trophic Interactions of Age-0 Fish and Zooplankton held in Germany, also visited Lake Baikal and the Institute of Freshwater Research in Stockholm. Dr J F Wright was in demand as a keynote/guest speaker at several meetings. He was an Invited Speaker at the 1st Nordic Benthological Meeting in Uppsala, Sweden, under the title "The use of macroinvertebrates in surveillance and monitoring of aquatic biodiversity"where he spoke on "The development and use of RIVPACS in the UK", spoke at the 1st International Conference on Sierra Nevada: Conservation and Sustainable Development, Granada, Spain, where he delivered a talk on "Application of a prediction technique for determining the biological quality of high mountain rivers using macroinvertebrates" and participated in a round table discussion; he also attended the 26th SIL Congress in São Paulo, Brazil, and presented a paper entitled "Macroinvertebrate richness at running water sites in Great Britain. A comparison of species and family level data", and, following the Congress, he took part in a 4-day excursion to the Amazon region (Manaus, Rio Negro, Rio Solimoes) at his own expense.

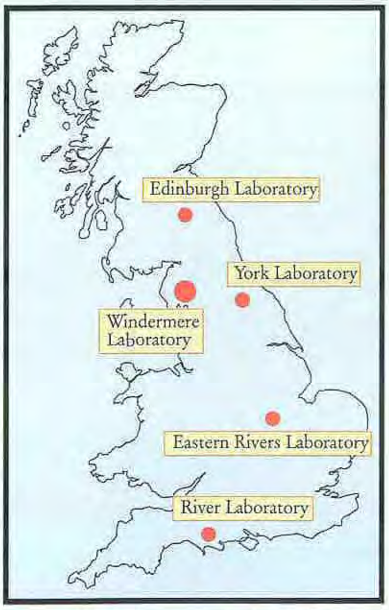
Of the many visitors from abroad to IFE laboratories, the following are worthy of note. The CCAP at Windermere was visited by several overseas researchers, including Prof M M Watanabe, NIES/Univ Tsukuba, Japan and Prof O R Anderson of Columbia University, USA (Dr J G Day). There were extended visits to Windermere by Dr Jan Köhler of IGB, Müggelseedamm, Berlin and Dr Marina Vardanian, University of Yerevan, Armenia (Prof C S Reynolds). Dr R Marchant, Curator of Invertebrates at Museum of Victoria, Australia visited the River Lab to discuss progress in both GB and Australia on RIVPACS, and presented a seminar on hyporheic invertebrates (Dr J F Wright).

Appendix 1

The Institute of Freshwater Ecology

The Institute of Freshwater Ecology (IFE) was formed in 1989 when the Natural Environment Research Council undertook the management of the staff and the laboratories of the Freshwater Biological Association (FBA) and, therefore, draws on more than 60 years experience into all aspects of strategic, freshwater research.

The IFE is a component Institute of the Centre for Ecology and Hydrology (see Appendix 2, for details) and as such, has the capability to adopt a truly multidisciplinary, scientific approach for the study of complex environmental problems. The Institute of Freshwater Ecology carries out research into freshwater, wetland and estuarine environments and offers a range of environmental services to an international user community, based upon a sound scientific knowledge of aquatic biology, ecology, chemistry and physics.

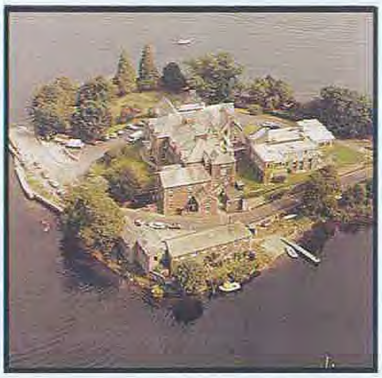


IFE Laboratories in the U.K.

The IFE operates from 5 laboratories located at strategic sites throughout Great Britain (the Windermere Laboratory in Cumbria, the River Laboratory in Dorset, the Eastern Rivers Laboratory in Cambridgeshire, the LOIS Laboratory in Yorkshire and the Edinburgh Laboratory in Midlothian) with its headquarters at the Windermere Laboratory. The staff complement is 95 posts of which 67 are directly engaged in scientific research and, at any one time, the laboratories also host over 30 visiting scientists, post-graduate students and temporary workers.

IFE scientists are active in national and international networks for environmental monitoring and research and many of the Institute's staff are visiting professors, readers and lecturers at UK Universities. Particularly strong links have been established between the IFE and Edinburgh, Lancaster, Liverpool, Birmingham, Brunel and Reading Universities. Staff hold key posts in appropriate scientific societies and serve on national and international committees and, through research collaboration and a network of contacts, are able to maintain their positions at the forefront of their respective fields.

The 'user community' of the IFE includes the NERC, Government Departments both in the UK and abroad, regulatory authorities, conservation bodies, private industry (including the water industry), the academic community and the general public, who are the ultimate end-users of research leading to wealth creation and improvement in the quality of life.



IFE Headquarters Windermere Laboratory

Further information on the services, facilities and research programme of the Institute of Freshwater Ecology can be obtained from:-

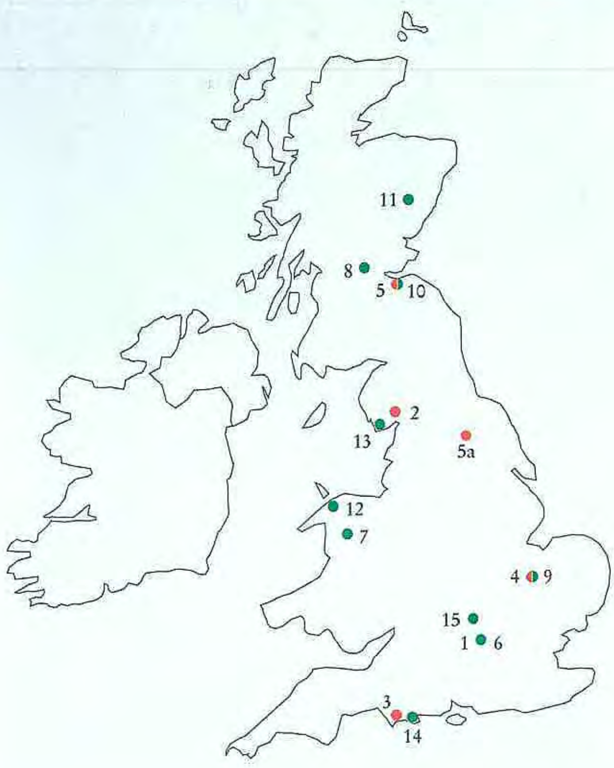
Professor A D Pickering
Director
The Institute of Freshwater Ecology
Windermere Laboratory
Far Sawrey
Ambleside
Cumbria LA22 0LP

Telephone: 015394 42468
Facsimile: 015394 46914
E-mail: ADP@wpo.nerc.ac.uk

Institute of Freshwater Ecology

Appendix 2

The NERC Centre for Ecology and Hydrology component institutes



Centre for Ecology and Hydrology (CEH)
1. Wallingford

Institute of Freshwater Ecology (IFE)
2. Windermere
3. Wareham
4. Monks Wood
5. Edinburgh

5a. York

Institute of Hydrology (IH)
6. Wallingford
7. Plynlimon
8. Stirling

Institute of Terrestrial Ecology (ITE)
9. Monks Wood
10. Edinburgh
11. Banchory
12. Bangor
13. Merlewood
14. Furzebrook

Institute of Virology and Environmental Microbiology (IVEM)
15. Oxford

Locations of recent research contracts undertaken by CEH institutes

Appendix 3

CEH INTEGRATING FUND PROJECTS				
TITLE	IFE	IH	ITE	IVEM
PROJECTS COMMENCING 1995/96				
The microbial basis of methane oxidation in soils	*		*	*
Interactions of viruses, aphids and *wild brassica*			*	*
Modelling the chemical availability of radionuclides in upland organic soils	*		*	
Combined growth and water-use modelling of mixed vegetation		*	*	
Upland forest canopy closure - its significance for chemistry, ecology and hydrology	*	*	*	
Molecular genetics and process-level events in the biodegradation of xenobiotics in rhizosphere soils			*	*
Microbial diversity and ecosystem function - Phase I	*	*	*	
PROJECTS COMMENCING 1996/97				
The role of seabirds in the epizootiology of Lyme Disease			*	*
Combined Hydro-ecological And Socio-economic Models of land use, land management and environmental degradation (CHASM)		*	*	
The environmental characteristics of urban Environments	*	*	*	
The role of microbial diversity in regulating ecosystem function - Phase II	*		*	*
50m solar grids for the UK		*	*	
Modelling the fate of viruses in the aquatic environment		*		*

Appendix 4

The Freshwater Biological Association

The FBA is an independent organisation, a registered Charity and a Company Limited by Guarantee

The Association conducts research into all aspects of freshwater science and technology, provides a Membership organisation and independent scientific opinion.

The FBA provides scientific continuity - it was founded in 1929 and has a long history of achievements in freshwater science. This includes the publication of more than 2000 papers in recognised scientific journals and a series of independent publications (including identification keys for freshwater taxa, analytical methods, etc.).

The FBA possesses one of the finest freshwater libraries in the world, and provides essential advisory services to its members. Many national and international awards and honours have been bestowed upon the Association and its senior staff in recognition of the quality and importance of their scientific achievements.

Membership is open to individuals and organisations that wish to support the Association. Members receive copies of the FBA's *Freshwater Forum*, and its newly launched *Newsletter*. They may obtain other publications at a substantial discount, visit the Laboratories, and use the Library by agreement with the Director.

The Mission of the FBA is to promote freshwater science:

- through an innovative research programme
- an active membership organisation
- by providing sound, independent scientific opinion

The FBA has four core objectives:

1. To support a programme of research of the highest quality by attracting scientists of the highest calibre as staff, research fellows, students and visitors and providing them with a well-found laboratory, opportunities and training to develop their interests.
2. To promote freshwater science by all means available, including education and provision of a membership organisation in which those committed to the subject can share common interests.
3. To provide sound, independent scientific opinion on matters relating to fresh waters and their conservation to local and national governments, organisations and individuals.
4. To maintain and develop the following services for a growing membership and the wider community:

- The library and other international archives including electronic access to new databases.
- A publication programme including scientific publications (including keys), special volumes, materials for general education and the application of new technology to provide greater access to our knowledge base.
- A programme of national and international meetings, collaborating with other bodies where appropriate.
- General and specialist courses.

All enquiries concerning Membership and the Association's activities should be addressed to:

The Director
Professor J Gwynfryn Jones
Freshwater Biological Association
The Ferry House
Ambleside
Cumbria LA22 0LP

Telephone: 015394 42468
International: 4415394 42468
Facsimile: 015394 46914
E-mail: JGJFBA@wpo.nerc.ac.uk

FRESHWATER BIOLOGICAL ASSOCIATION

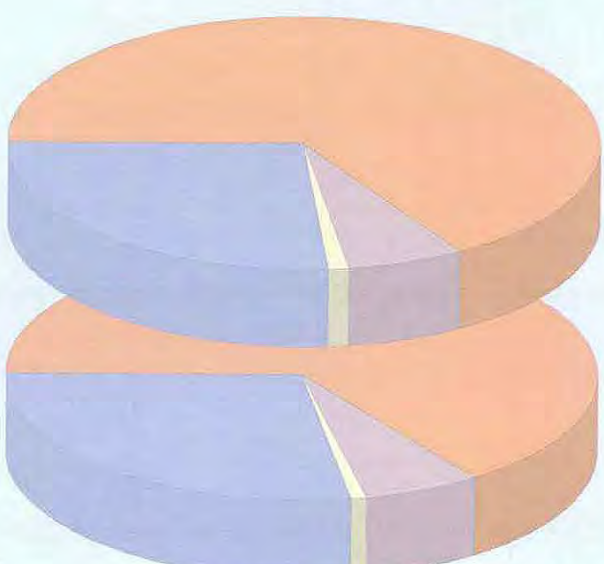
Appendix 5

Institute of Freshwater Ecology Finance

A summary of the financial accounts for the year ended 31 March 1996 is shown in the pie-charts below, together with the comparative charts for 1994/95.

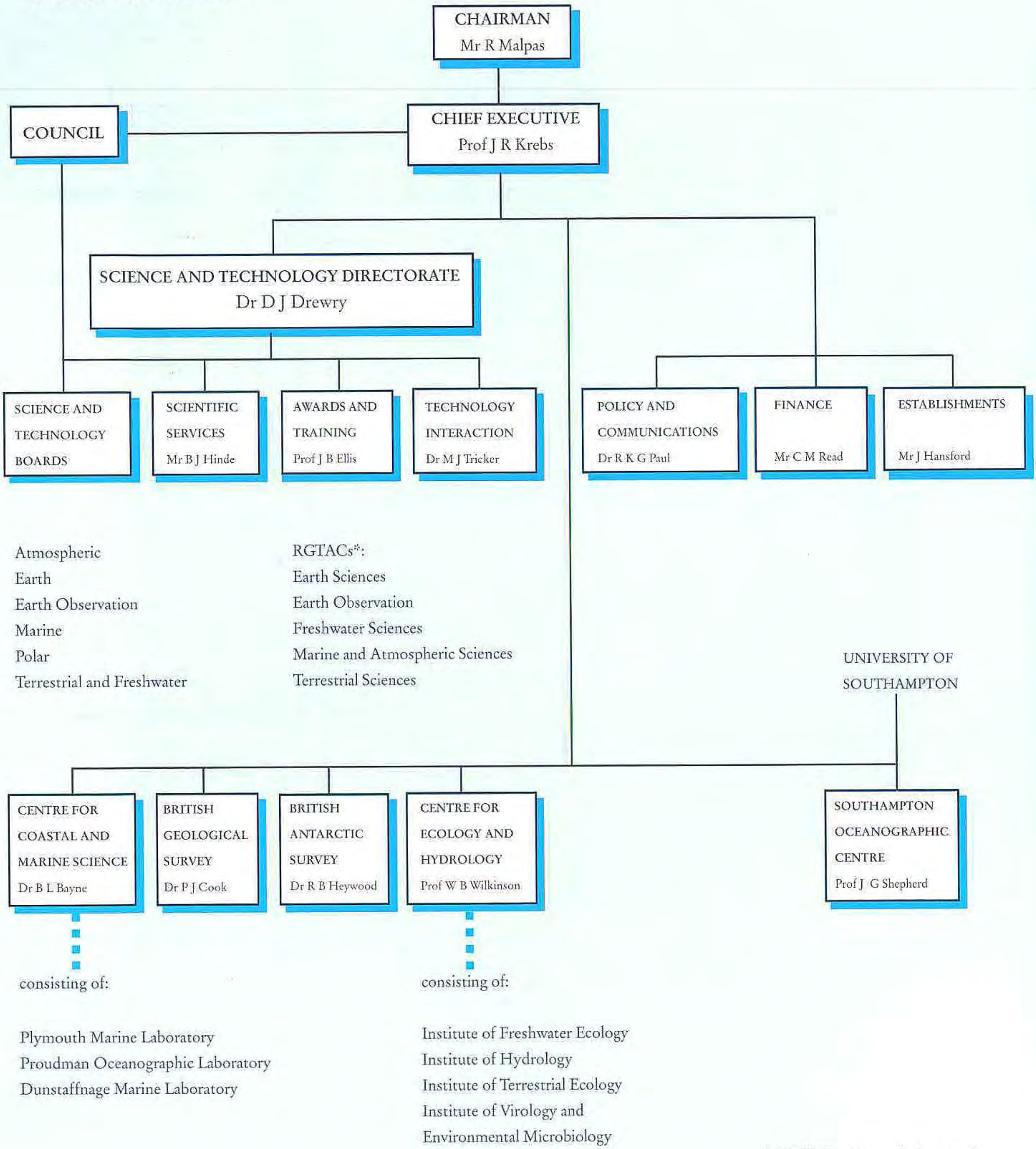
INCOME

EXPENDITURE



Appendix 6

Structure for NERC from 1995/96



* RGTACs - Research Grant and Training Award Committee

Appendix 7

IFE Management/ Administration/Services

- **Prof A D Pickering** — Director IFE
  - **Prof A D Pickering** — Head, Windermere Laboratory
    - **Mr C J Moakes** — Finance and Establisments
    - **Mrs M Thompson** — Secretarial Services
    - **Mr P V Allen** — Laboratory Services
    - **Mr M A Rouen** — Electronics
    - **Mr I D McCulloch** — Library
  - **Prof J Hilton** — Deputy Director and Head, Regional Laboratories
    - **Mrs D M Morton** — Station Secretary, River Laboratory
    - **Dr A E Bailey-Watts** — Edinburgh Laboratory
    - **Dr L C V Pinder** — Eastern Rivers Laboratory

IFE Divisional Structure

- **Prof A D Pickering** — Director IFE
  - **Prof J M Elliott** — Division 1: Fish Biology
  - **Dr B J Finlay** — Division 2: Microbial Ecology
  - **Dr E W Tipping** — Division 3: Aquatic Processes
  - **Prof J Hilton** — Division 4: Ecosystem Management

Appendix 8

Staff list at 31 March 1996

Management/Administration

Acting Director and Head of Windermere Laboratory	Prof A D Pickering	Band 2 (S)
Head of Regional Laboratories	Prof J Hilton	Band 3 (S)
Secretary to Director	Mrs M Thompson	Band 7 (A)
(Windermere)	Mrs Y Dickens	Band 8 (A) Pt
	Mrs S M Dent	Band 8 (T) Pt
	Mrs J C Rhodes	Band 8 (T) Pt
	Miss K Ross	Band 8 (A)*
(River Laboratory)	Mrs D M Morton	Band 7 (A)
	Mrs V B Palmer	Band 8 (A)
	Mrs S Smith	Band 9 (A) Pt
	Mrs S A Taylor	Band 9 (A) Pt
Finance Officer	Mr C J Moakes	Band 5 (A)
Finance and establishments	Ms P Parry	Band 7 (A)
	Mr N H Dorsett	Band 8 (A)
	Miss S Taylor	Band 8 (A) Pt
	Mrs A E Taylor	Band 8 (A) Pt
FBA Director	Prof J G Jones	Band 3 (S)

Fish Biology

Division Head	Prof J M Elliott	Band 3 (I)
	Mrs M A Hurley	Band 4 (S) Pt
	Dr M Ladle	Band 4 (S)
	Dr R H K Mann	Band 4 (S)
	Dr T G Pottinger	Band 4 (S)
	Dr J S Welton	Band 4 (S)
	Dr I J Winfield	Band 4 (S)
	Mr W R C Beaumont	Band 5 (S)
	Mr T R Carrick	Band 5 (S)
	Mr P R Cubby	Band 6 (S)
	Miss J M Fletcher	Band 7 (S)
	Dr P Garner	RF*
	Dr S E Hartley	RF*
	Mr T M Beaumont	RS
	Mr E D Clarke	RS
	Mr S C Clough	RS
	Mr R A Fleck	RS
	Miss S W Griffiths	RS
	Miss L A Ashfield	RS
	Mr S Walker	RS*

Microbial Ecology

Division Head	Dr B J Finlay	Band 3 (I)
	Prof C S Reynolds	Band 3 (I)
	Dr E Y Haworth	Band 4 (S)
	Dr S C Maberly	Band 4 (S)
	Dr R W Pickup	Band 4 (S)
	Mr K J Clarke	Band 5 (S)
	Dr G H Hall	Band 5 (S)
	Dr A E Irish	Band 6 (S)
	Mrs J E Parker	Band 6 (S)
	Ms M M Deville	Band 7 (S)
	Mrs R M Hindle	Band 7 (S) Pt
	Mrs H E H Mallinson	Band 7 (S)
	Dr G F Esteban	RF
	Dr J Porter	RF
	Mr S Ball	RS
	Mr G Biagini	RS
	Miss A Campbell	RS
	Miss S Davies	RS*
	Mr D Deere	RS
	Miss L A Fear	RS*
	Miss N A Fielding	RS
	Mr R Hastings	RS
	Mr R Howarth	RS*
	Miss S McGowan	RS
	Mr I Miskin	RS
	Mr G Rhodes	RS
	Miss V C Wanstall	RS*
	Miss C Whitby	RS
Culture Collection of Algae and Protozoa	Dr J G Day	Band 5 (S)
	Ms S Brown	Band 6 (S)
	Ms C Butterwick	Band 6 (S)
	Ms A Cook	Band 8 (S) Pt
	Ms J Tompkins	Band 8(A) Pt

Fritsch Collection of Algal Illustrations

Honorary Curator	Dr J W G Lund*	
	Mrs E G Devlin	Band 8 (S)Pt
	Mrs E B Monaghan	Band 8 (S)Pt

Aquatic Processes

Division Head	Dr E W Tipping	Band 3 (I)
	Dr D G George	Band 4 (S)
	Dr W A House	Band 4 (S)
	Mr I S Farr	Band 5 (S)
	Mr B M Simon	Band 5 (S)
	Mr C P Woof	Band 5 (S)
	Ms D P Hewitt	Band 6 (S)
	Dr G P Irons	Band 6 (S)
	Mr D V Leach	Band 6 (S)
	Mr E Rigg	Band 6 (S)
	Mrs S M Smith	Band 6 (S)
	Miss M S Warwick	Band 6 (S)
	Miss J K G Ingram	Band 7 (S)
	Mr A J Lawlor	Band 7 (S)
	Mr S Lofts	Band 7 (S)
	Mr D R Orr	Band 7 (S)
	Mr A C Pinder	Band 7 (S)
	Mr F H Denison	Band 8 (S)
	Mr J B James	Band 8 (S)
	Dr J T Smith	RF
	Mr F L Charlton	RS
	Miss A Hartley	RS
	Mr R D Hedger	RS
	Mr D M John	RS
	Miss W M Lester	RS
	Miss J Long	RS
	Miss S J Marshall	RS
	Mr M J Scott	RS
	Mr R E Skidmore	RS
	Miss R Stidson	RS
	Mr S L Woodruff	RS

Ecosystem Management		
Division Head	Prof J Hilton	Band 3 (S)
	Dr P D Armitage	Band 4 (S)
	Dr A E Bailey-Watts	Band 4 (S)
	Mr R T Clarke	Band 4 (S)
	Dr F H Dawson	Band 4 (S)
	Mr M T Furse	Band 4 (S)
	Dr L C V Pinder	Band 4 (S)
	Dr J F Wright	Band 4 (S)
	Mr J A B Bass	Band 5 (S)
	Mr R J M Gunn	Band 5 (S)
	Dr L May	Band 5 (S)
	Mr J H Blackburn	Band 6 (S)
	Mr I D M Gunn	Band 6 (S)
	Mr P Henville	Band 6 (S)
	Mr A Kirika	Band 6 (S)
	Mr A A Lyle	Band 6 (S)
	Mr G D Collett	Band 7 (S)
	Mrs K L Symes	Band 7 (S)
	Dr J M Winder	Band 7 (S)
	Mrs A M Brookes	RF*
	Mr S Harrison	RF
	Mr C Brereton	RS
	Miss D Bunker	RS
	Miss C E Cannan	RS
	Miss A S Fulcher	RS
	Miss E Hawtin	RS*
	Mr R M Head	RS
	Ms J Reeve	RS
	Mr D Short	RS
Laboratory Services		
Windermere Laboratory	Mr M A Rouen	Band 5 (S)
	Mr P V Allen	Band 6 (T)
	Mr M J Lee	Band 6 (T)
	Mr T I Furnass	Band 7 (T)
	Mr D I Aspinall	Band 7 (T)
	Mr J Crompton	Band 7 (T)
	Mr B M Godfrey	Band 7 (T)
	Mr P M Hodgson	Band 7 (T)
	Mr S Thomson	Band 9 (T) Pt
	Mrs J Gregson	Band 9 (T)
	Miss N E Pitts	Band 9 (T)
Library	Mr I D McCulloch	Band 7 (L)
	Miss C M Williams	Band 7 (L)
	Mrs K Crompton	Band 8(A) Pt
	Mrs O Jolly	Band 8(A) Pt
River Laboratory	Mr G A Richards	Band 9(T)
	Mrs J Whitmarsh	Band 9(T) Pt

Honorary Research Fellows

FBA	Dr A D Berrie*
	Mr T Gledhill*
	Dr J W G Lund*
	Dr H M Lund*
	Dr J F Talling*
	Dr L G Willoughby*

Abbreviations:

S	Scientific
A	Administration
L	Librarian
T	Technologist
I	Individual Merit Promotee
Pt	Part-time
RF	Research Fellow
RS	Research Student
*	FBA - not IFE establishment

Appendix 9

Scientific Papers

Armitage P.D., Blackburn J.H., Nilsson A.N. & Malmqvist B. 1995
Chironomidae in freshwater habitats in Tenerife, Canary Islands. In: *Chironomids: from genes to ecosystems* (ed. P.Cranston) p379-388. Australia. CSIRO. (P)

Armitage P.D. & Pardo I. 1995
Impact assessment of regulation at the reach level using macroinvertebrate information from mesohabitats. *Regulated Rivers Research and Management* 10(2/4) 147-158 (P)

Armitage P.D., Pardo I. & Brown A. 1995
Temporal constancy of faunal assemblages in 'mesohabitats' - application to management? *Archiv fur Hydrobiologie* 133(3) 367-387 (P)

Bailey-Watts T., Foxall C. & Wiltshire N. 1996
RAF/92/G32 - Pollution control and other measures to protect biodiversity in Lake Tanganyika. Baseline review - 4: pollution of international waters. Penicuik. Institute of Freshwater Ecology & Centre for Environmental and Risk Management - University of East Anglia, 38p & app.

Balm P.H.M., Carrick T.R., Coenen A.J.M. & Pottinger T.G. 1996
Trychophrya intermedia on the gills of rainbow trout acclimating to low ambient pH. *Journal of Fish Biology* 48(1) 147-150 (P)

Balm P.H.M. & Pottinger T.G. 1995
Corticotrope and melanotrope POMC-derived peptides in relation to interrenal function during stress in rainbow trout (*Oncorhynchus mykiss*). *General and Comparative Endocrinology* 98(3) 279-288 (P)

Barcelo D., House W.A., Maier E.A. & Griepink B. 1994
Preparation, homogeneity and stability studies of freeze-dried water containing pesticides. *International Journal of Environmental and Analytical Chemistry* 57 237-254 (P)

Bass J.A.B., Crosskey R.W. & Werner D. 1995
On the European blackfly *Simulium lundstromi* and inclusion of *S.latigonium* as a new synonym within this species. *Bulletin British Simuliid Group* No.5 7-19

Bean C.W. & Winfield I.J. 1995
Habitat use and activity patterns of roach (*Rutilus rutilus* (L.)), rudd (*Scardinius erythrophthalmus* (L.)), perch (*Perca fluviatilis* L.) and pike (*Esox lucius* L.) in the laboratory: the role of predation threat and structural complexity. *Ecology of Freshwater Fish* 4(1) 37-46 (P)

Bean C.W., Winfield I.J. & Fletcher J.M. 1996
Stock assessment of the Arctic charr (*Salvelinus alpinus*) population in Loch Ness, UK. In: *Stock assessment in inland fisheries* (ed. I.G.Cowx) p206-223. Oxford. Fishing News Books. (P)

Beaumont A.R., Bray J., Murphy J.M. & Winfield I.J. 1995
Genetics of whitefish and vendace in England and Wales. *Journal of Fish Biology* 46(5) 880-890 (P)

Blackburn J.H. & Forrest M.B. 1995
New records of *Hydropsyche saxonica* McLachlan (Trichopt., Hydropsychidae) from small streams in Great Britain. *Entomologist's Monthly Magazine* 131(1568/1571) 71-76 (P)

Canter-Lund H. & Lund J.W.G. 1995
Freshwater algae: their microscopic world explored. Bristol. Biopress Ltd, 376p. (P)

Castella E., Bickerton M., Armitage P.D. & Petts G.E. 1995
The effects of water abstractions on invertebrate communities in U.K. streams. *Hydrobiologia* 308(3) 167-182

Clymo R.S., Dawson F.H., et al. 1995
Conclusion: directions for research on wetlands in Britain. In: *Hydrology and hydrochemistry of British wetlands* (ed. J.Hughes & L.Heathwaite) p467-478. Chichester. John Wiley & Sons. (P)

Copp G.H. & Garner P. 1995
Evaluating the microhabitat use of freshwater fish larvae and juveniles with point abundance sampling by electrofishing. *Folia Zoologica* 44(2) 145-158 (P)

Crisp D.T. 1995
Dispersal and growth rate of 0-group salmon (*Salmo salar* L.) from point-stocking together with some information from scatter-stocking. *Ecology of Freshwater Fish* 4(1) 1-8 (P)

Crisp D.T. & Beaumont W.R.C. 1995
The trout (*Salmo trutta*) population of Afon Cwm, a small tributary of the Afon Dyfi, mid-Wales. *Journal of Fish Biology* **46**(4) 703-716 (P)

Crisp D.T. & Beaumont W.R.C. 1996
The trout (*Salmo trutta* L.) populations of the headwaters of the Rivers Severn and Wye, mid-Wales, UK. *Science of the Total Environment* **177** 113-123 (P)

Davison W., George D.G. & Edwards N.J.A. 1995
Controlled reversal of lake acidification by treatment with phosphate fertilizer. *Nature* 377(6549) 504-507 (P)

Day J.G. & DeVille M.M. 1995
Cryopreservation of algae. In: *Cryopreservation and freeze-drying protocols* (ed. J.G.Day & M.R.McLellan) p81-89. Totowa. Humana Press. (P)

Day J.G. & McLellan M.R.(ed.). 1995
Cryopreservation and freeze-drying protocols. Totowa. Humana Press, 264p (Methods in Molecular Biology 38)

De Jonckheere J.F. & Brown S. 1995
Willaertia minor is a species of *Naegleria*: evidence that *Naegleria* flagellates can divide. *European Journal of Protistology* **31**(1) 58-62 (P)

Deere D., Porter J., Edwards C. & Pickup R. 1995
Evaluation of the suitability of bis-(1,3-dibutylbarbituric acid) trimethine oxonol, (diBA-C4(3)-), for the flow cytometric assessment of bacterial viability. *FEMS Microbiology Letters* **130**(2/3) 165-170 (P)

Elliott J.M. 1995
The effect of temperature on egg hatching for three populations of *Sialis lutaria* (L.) and two populations of *Sialis fuliginosa* Pictet (Megaloptera: Sialidae). *Entomologist's Gazette* **46**(2) 155-159 (P)

Elliott J.M. 1995
Egg hatching and ecological partitioning in carnivorous stoneflies (Plecoptera). *Comptes Rendus Academie des Sciences Paris Sciences de la vie Biologie et pathologie animale* **318** 237-243 (P)

Elliott J.M. 1995
Fecundity and egg density in the redd for sea trout. *Journal of Fish Biology* **47**(5) 893-901 (P)

Elliott J.M. & Baroudy E. 1995
The ecology of arctic charr, *Salvelinus alpinus*, and brown trout, *Salmo trutta*, in Windermere (northwest England). *Nordic Journal of Freshwater Research* **No.71** 33-48 (P)

Elliott J.M. & Chambers S. 1996
A guide to the interpretation of sea trout scales. Bristol. National Rivers Authority, 60p (NRA R&D Report 22) (P)

Elliott J.M. & Elliott J.A. 1995
The critical thermal limits for the bullhead, *Cottus gobio*, from three populations in north-west England. *Freshwater Biology* **33**(3) 411-418 (P)

Elliott J.M. & Elliott J.A. 1995
The effect of the rate of temperature increase on the critical thermal maximum for parr of Atlantic salmon and brown trout. *Journal of Fish Biology* 47(5) 917-919 (P)

Elliott J.M. & Hurley M.A. 1995
The functional relationship between body size and growth rate in fish. *Functional Ecology* 9(4) 625-627 (P)

Elliott J.M., Hurley M.A. & Fryer R.J. 1995
A new, improved growth model for brown trout, *Salmo trutta*. *Functional Ecology* 9(2) 290-298 (P)

Embley T.M., Finlay B.J., Dyal P.L., Hirt R.P., Wilkinson M. & Williams A.G. 1995
Multiple origins of anaerobic ciliates with hydrogenosomes within the radiation of aerobic ciliates. *Proceedings of the Royal Society (B)* **262**(1363) 87-93 (P)

Embley T.M. & Finlay B.J. 1994
Phylogenetic diversity of methanogen endosymbionts of anaerobic ciliates. In: *Bacterial diversity and systematics* (ed. F.G.Priest). New York. Plenum Press. (P)

Esteban G., Fenchel T. & Finlay B. 1995
Diversity of free-living morphospecies in the ciliate genus *Metopus*. *Archiv fur Protistenkunde* **146**(2) 137-164 (P)

Fenchel T., Bernard C., Esteban G., Finlay B.J., Hansen P.J. & Iversen N. 1995
Microbial diverisity and activity in a Danish fjord wih anoxic deep water. *Ophelia* **43**(1) 45-100 (P)

Fenchel T. & Finlay B.J. 1995
Ecology and evolution in anoxic worlds. Oxford. Oxford University Press, 288p

Garner P. 1995
Suitability indices for juvenile 0+roach [*Rutilus rutilus* (L.)] using point abundance sampling data. *Regulated Rivers Research and Management* 10(2/4) 99-104 **(P)**

George D.G. & Taylor A.H. 1995
UK lake plankton and the gulf stream. *Nature* 378(6553) p139 **(P)**

Grobbelaar J.U. & House W.A. 1995
Phosphorus as a limiting resource in inland waters: interactions with nitrogen. In: *Phosphorus in the global environment: transfers, cycles and management* (ed. H.Tiessen) p255-273. Chichester. John Wiley & Sons. **(P)**

Hales B.A., Edwards C., Ritchie D.A., Hall G., Pickup R.W. & Saunders J.R. 1996
Isolation and identification of methanogen-specific DNA from blanket bog peat by PCR amplification and sequence analysis. *Applied and Environmental Microbiology* 62(2) 668-675 **(P)**

Hall G.H., Simon B.M. & Pickup R.W. 1996
CH_4 production in blanket bog peat: a procedure for sampling, sectioning and incubating samples whilst maintaining anaerobic conditions. *Soil Biology and Biochemistry* 28(1) 9-15 **(P)**

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