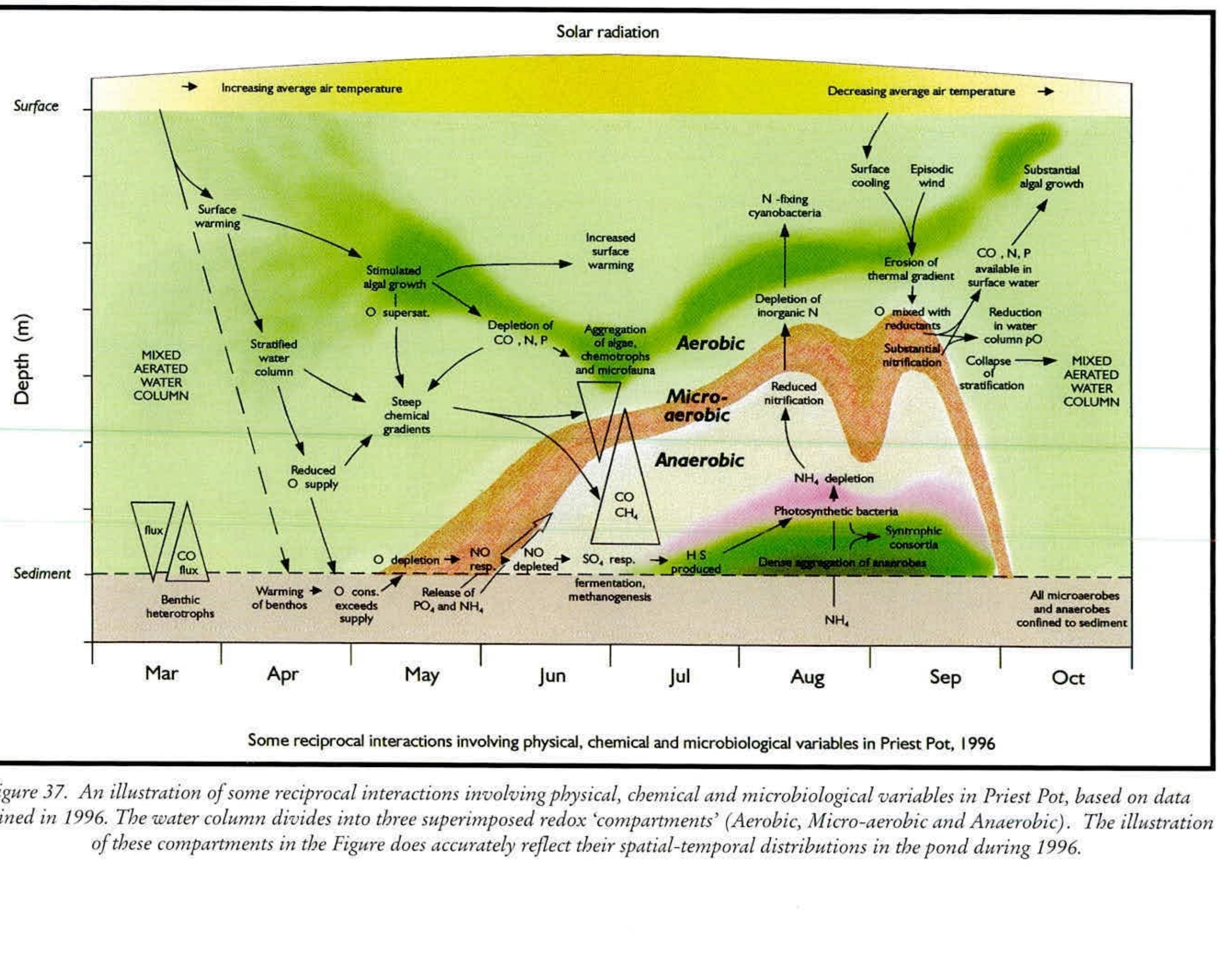
Biodiversity, the natural biological capital of the Earth, embraces genetic diversity, species diversity and ecosystem diversity. Its preservation and wise utilisation are ultimately linked to the healthy functioning of natural and semi-natural ecosystems, to the quality of life and to wealth creation. 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.

Programme 5 Biodiversity and Population Processes



Some reciprocal interactions involving physical, chemical and microbiological variables in Priest Pot, 1996

Figure 37. An illustration of some reciprocal interactions involving physical, chemical and microbiological variables in Priest Pot, based on data obtained in 1996. The water column divides into three superimposed redox 'compartments' (Aerobic, Micro-aerobic and Anaerobic). The illustration of these compartments in the Figure does accurately reflect their spatial-temporal distributions in the pond during 1996.

Microbial diversity in an ecosystem is never so impoverished that the microbial community cannot play its full part in biogeochemical cycling.

Microbial diversity and ecosystem function

Much effort is currently directed at understanding the role of biodiversity in the natural environment. At the heart of all such studies is the desire to discover if it makes any difference how many species are present. This question is difficult to answer for terrestrial communities of higher plants and animals, and the problem is essentially one of spatial and temporal scale. But in a lake or pond, the spectacular variation in microbial activity and diversity observed during a single summer exceeds that of the most dramatic successions of terrestrial plant communities spanning many years. In the course of a few days, the habitat of a microbial community may shift from oxygen supersaturation to anoxia: from an excess of dissolved nutrients to complete nitrogen depletion. New microbial niches will be created, filled and destroyed in rapid succession.

In a small freshwater pond, the nature and scale of ecosystem functions such as carbon-fixation and nutrient cycling appear to be governed by reciprocal interactions involving physical, chemical and microbiological factors. Moreover, these interactions continuously create new microbial niches that are quickly filled from the resident pool of rare and 'cryptic' (and probably ubiquitous) microbial species. This means (a) that microbial activity and diversity are both a part of, and inseparable from pond ecosystem function, (b) that microbial diversity in an ecosystem is never so impoverished that the microbial community cannot play its full part in biogeochemical cycling, and (c) that concepts such as 'redundancy' of microbial species, and the 'value' of conserving biodiversity at the microbial level have little meaning.

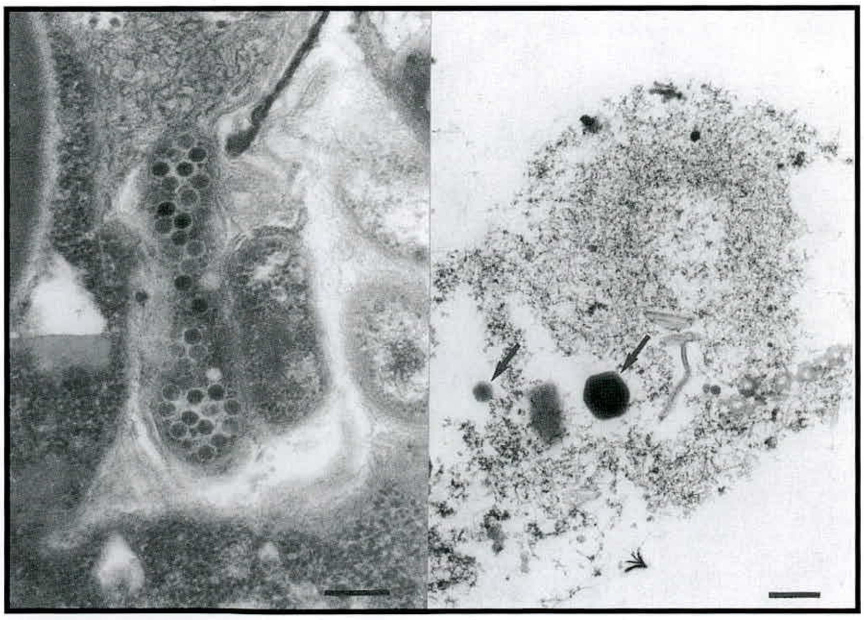


Figure 38 (left). Particles of a virus in lytic phase within a bacterium ingested by the ciliated protozoon Euplotes. *Scale bar = 0.25 µm.*
Figure 39 (right). A ciliate waste-food pellet with surviving virus particles (arrows). Scale bar = 0.25 µm.

Protozoan grazing triggers free-virus production

Aquatic lysogenic bacteriophages can exist within bacteria, without forming virus particles. The infected host may pass through several generations before the virus finally enters the lytic phase, causing the host to burst, releasing infective phage particles into the surrounding water.

Transmission electron microscopy (TEM) shows that the process of ingestion by protozoa of bacteria infected with a lysogenic virus, appears to induce the lytic phase. A comparison between the numbers of bacteria containing virus particles inside protozoan food vacuoles, with similarly infected bacteria in the surrounding water, shows that there is typically a twenty-fold increase in the proportion of virus particle-containing bacteria in food vacuoles (Figure 38).

Food-waste pellets recently expelled from ciliated protozoa and examined by TEM, are frequently found to contain apparently viable virus particles. Many of these particles will be viruses that have survived the digestion of their bacterial host, by the ciliate, as a direct result of completing the lytic phase during ingestion. The particles' eventual release as free-viruses is dependent on the disintegration of the pellet (Figure 39).

Survival of a bacteriophage lysogenically infecting the bacterial food of a protozoon is enhanced, therefore, by the triggering and rapid completion of the lytic phase following ingestion of the host bacterium.

Environmental role found for the largest known bacterium

Achromatium oxaliferum is a morphologically conspicuous, sediment-dwelling bacterium and is probably the largest known to exist. The organism has yet to be cultured in the laboratory and very little is known about its physiology. The presence of intracellular inclusions of calcite and sulfur have given rise to speculation that the bacterium is involved in the carbon and sulfur cycles in the sediments where it is found.
A collaborative project with Newcastle University and the Freshwater Biological Association was first to determine the phylogenetic position of this organism within the γ-*Proteobacteria* close to bacteria known to oxidise sulfur. Depth profiles of oxygen concentration and *A. oxaliferum* cell numbers in a freshwater sediment revealed that the *A. oxaliferum* population spanned the oxic/anoxic boundary in the top 3-4 cm of sediments. Some of the *A. oxaliferum* cells resided at depths where no oxygen was detectable suggesting that these cells may be capable of anaerobic respiration. The distribution of solid phase and dissolved inorganic sulfur species in the sediment revealed that *A. oxaliferum* was most abundant where sulfur cycling was most intense. The sediment was characterised by low concentrations of free sulfide. However, a comparison of sulfate reduction rates in sediment cores incubated with either oxic or anoxic overlying water indicated that the oxidative and reductive components of the sulfur cycle were tightly coupled in the *A. oxaliferum*-bearing sediment. A positive correlation between porewater sulfate concentration and *A. oxaliferum* numbers was observed in field data collected over an 18 month period, suggesting a possible link between *A. oxaliferum* numbers and the oxidation of reduced sulfur species to sulfate (Figure 40). The field data were supported by laboratory incubation experiments in which sodium molybdate-treated sediment cores were augmented with highly purified suspensions of *A. oxaliferum* cells. Under oxic conditions, increased rates of sulfate production in the presence of sodium molybdate were found to correlate strongly with the number of cells added to sediment cores, providing further evidence for the role for *A. oxaliferum* in the oxidation of reduced sulfur.

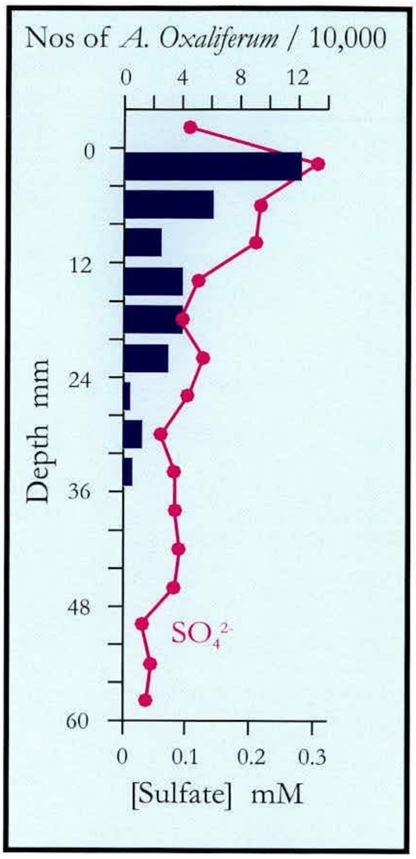


Figure 40. Verical distribution of A. oxaliferum *and sulfate in sediment cores from Rydal Water (Cumbria).*

The molecular phylogeny of vahlkampfiid amoebae

Amoeboid organisms are a diverse and ubiquitous group of eukaryotes and they play an important role in microbial food webs. Small subunit ribosomal DNA (SSU rDNA) sequence comparisons provide evidence that, rather than representing a primitive form of life, the amoeboid lifestyle has evolved independently in several diverse lineages (see Figure 41). Identification and classification of amoeboid organisms within these lineages have traditionally been based on morphological and ultrastructural characters, but investigations of the molecular biology of amoebae have revealed that these characters may be a poor indicator of evolutionary relationships (or phylogeny), and are

There are more differences in ribosomal DNA sequence between certain identical-looking amoebae than there are between humans and frogs.

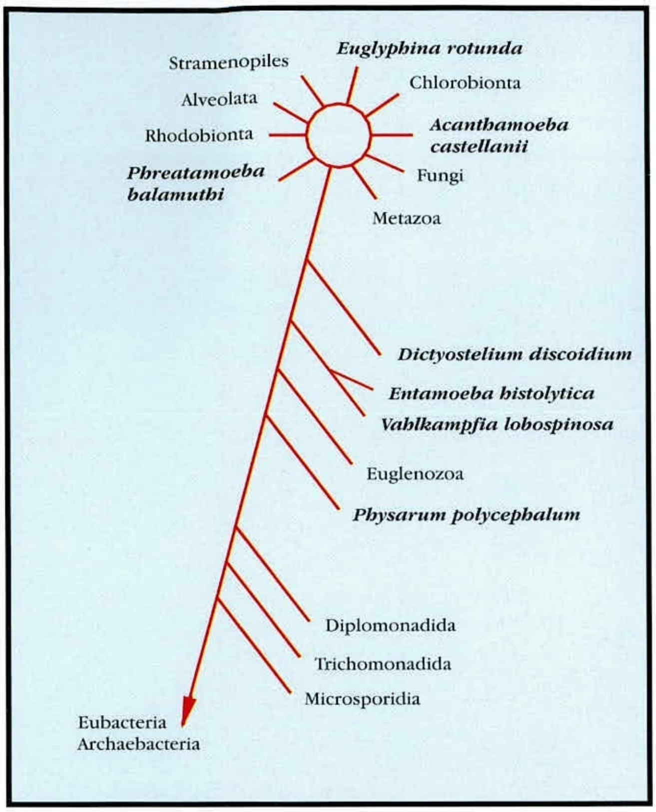


Figure 41. Phylogenetic tree illustrating hypotheses of evolutionary relationships between eukaryotes based on small subunit ribosomal DNA sequence comparisons. Amoeboid protists are indicated by bold italics.

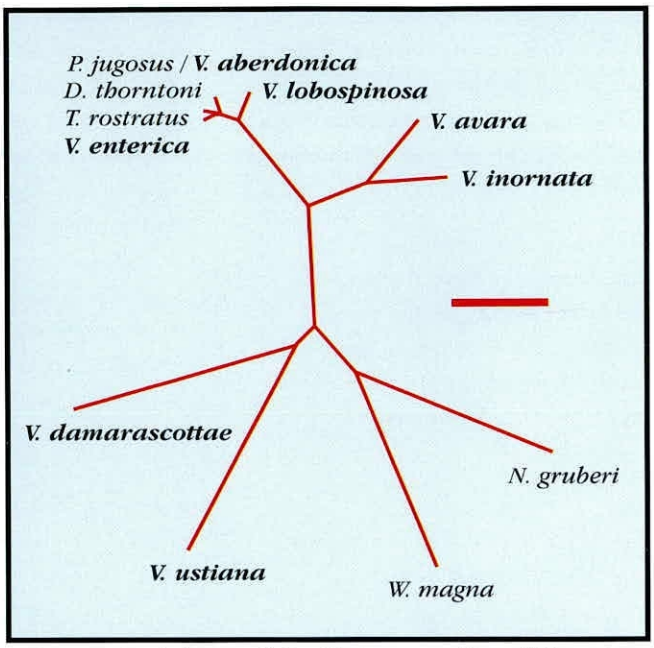


Figure 42. Evolutionary relationships between vahlkampfiid amoebae inferred from small subunit ribosomal DNA sequences. Vahlkampfia *species are indicated by bold type. The evolutionary distance corresponding to 10 changes per 100 nucleotide positions is indicated by the bar.*

A detailed comparison has been made between the phenotype-based classification and the rDNA-base phylogeny of the Vahlkampfiidae.

inadequate for the identification of potentially pathogenic strains.

In collaboration with the Scientific Institute of Public Health-Louis Pasteur (Brussels), the first detailed comparison has been made between the phenotype-based classification and the rDNA-based phylogeny of a major group of amoeboid organisms; the family Vahlkampfiidae. Comparisons between SSU rDNA sequences of seven *Vahlkampfia* species and species representing five other vahlkampfiid genera reveal a high degree of SSU rDNA sequence variation within the genus *Vahlkampfia* and generate phylogenetic trees that are incongruent with the phenotypic classification of this family. The SSU rDNA sequences of three *Vahlkampfia* species are more similar to those of *Tetramitus rostratus, Paratetramitus jugosus* and *Didascalus thorntoni* than they are to other *Vahlkampfia* species, and evolutionary distances within this group are similar to those within the single genus *Naegleria* (Figure 42).

The current classification scheme for the family Vahlkampfiidae is based principally on several variable and negative phenotypic characters and it is proposed that it should be replaced by a scheme based on rDNA phylogeny. To achieve this aim, sequence data continues to be generated from vahlkampfiid species held by the Culture Collection of Algae and Protozoa and other collections.

River management and the decline of the Great Ouse and fenland fisheries

The nature and objectives of management in the River Great Ouse have remained similar over many centuries but management intensity has increased enormously. Three phases of management seem to be implicated in a long-term decline in the quality of the fishery; fenland drainage in the latter part of the seventeenth century, improved efficiency of pumping during the latter part of the nineteenth century and major engineering work carried out between 1970 and 1978.

The large-scale drainage of the fens marked the beginning of the effective isolation of the lower river from much of its flood plain but this does not appear to have resulted immediately in major changes in fish stocks. Documentary evidence leaves no doubt that there was an abundance and great diversity of fish species in the river system in medieval times and this situation seems to have persisted well beyond the main period of fenland drainage. The first substantial decline in fish stocks appears to have occurred during the second half of the nineteenth century, associated with the introduction of steam pumping engines that greatly improved the efficiency of the drainage and resulted in many of the smaller drains, that formerly abounded with fish, becoming dry in summer.

The advent of the railways led to the demise of the Great Ouse navigation

Figure 43. A side channel of the Great Ouse after dredging.

which was largely derelict by 1930. The decline in management during this period would be expected to have been advantageous to fish populations and for much of the present century the Great Ouse was still regarded as one of the premier mixed coarse fisheries in England. However, the 1970s saw massive changes, with extensive dredging and canalization of the river and restoration of the navigation. In the circumstances of greatly reduced habitat diversity a community heavily dominated by roach has developed, while species with more specific habitat needs, such as bream, chub and barbel have declined markedly.

Food available to cyprinid larvae in regulated rivers – where, when and how much?

In regulated rivers within the UK, including the Great Ouse, Thames, Trent and Yorkshire Ouse, the IFE has been studying the availability of food to young fish during their first few weeks of life. These studies complement parallel work on the Great Ouse and Thames examining habitat utilisation, growth rates and the comparative abundance of the young fish at different locations and in different years.

Optimal Growth

The larval fish intercept food suspended in the water, taking items of increasing size and mobility as they grow. The continuous availability of a diverse food resource is critical to supply their metabolic requirements and maintain optimal growth rates. Interruptions in food supply may be caused by 'washout' during floods or a gap in the sequence of suitable prey available. The latter may be associated with a simplified food web within the comparatively uniform habitat structure prevailing in many regulated rivers (Figure 45).

Food Availability

During early summer a peak of diatom growth is followed by the appearance of planktonic rotifers. These organisms are utilised as the first food taken by young cyprinids. The fish then progress to larger organisms such as Cladocera and first instar chironomid larvae. The IFE has established that a highly variable spatial distribution of the larval

Figure 44. Electro-fishing on the Great Ouse using a boom boat.

The continuous availability of a diverse food resource is critical to supply their metabolic requirements and maintain optimal growth rates.

Figure 45. A regulated river with a lack of habitat diversity.

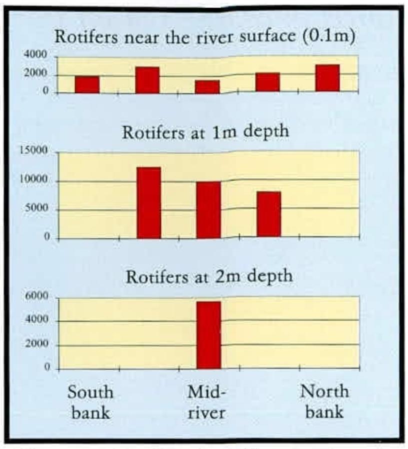


Figure 46. Planktonic rotifers, numbers per litre, reach peak population densities in early summer, when they are patchily distributed within the water column of the River Great Ouse.

fish prey develops within the river (Figure 46) and this has been compared with the distribution of young fish, which select particular microhabitats as they grow.

Flexible/Inflexible Responses

Regulated rivers generally provide sub-optimal feeding conditions for young cyprinids in late summer. The most common species, Roach (*Rutilus rutilus*), switches its diet when the preferred wide range of small invertebrate prey become less abundant. At this time they ingest the flocculent mixture of detritus, algae and microorganisms which accumulates on the submerged water plants. This diet change is accompanied by a reduced growth rate and other cyprinid species which fail to utilise this food resource are strongly outnumbered by the roach.

Saving the schelly

Successful first phase of introduction programme.

The schelly (*Coregonus lavaretus*) is a rare fish species protected under the Wildlife and Countryside Act 1981 and found in only seven UK lakes, including Haweswater of the English Lake District. However, the Haweswater schelly population has been reproducing inconsistently for a number of years and now has an estimated population size of only several hundred adults.

This decline in abundance is probably attributable to frequent and marked changes in the water level of Haweswater which result from its use as a reservoir. Elsewhere, such fluctuations are known to influence adversely the spawning and recruitment success of schelly and similar species. An additional concern at Haweswater is the recent establishment of a breeding colony of cormorants (*Phalacrocorax carbo*). While these two issues are currently being addressed by projects investigating the feasibility of improving spawning conditions and assessing the impact of cormorant feeding activities, two new populations of Haweswater schelly are being established as a safeguard against the possible extinction of this population.

In February 1997, spawning schelly were captured at Haweswater and their eggs stripped and fertilised before being transported to two suitable recipient water bodies, Blea Water and Small Water, in the catchment. Eggs were introduced to both sites in a series of incubation boxes which allowed them subsequently to be periodically examined by video camera and temporarily removed for direct inspection. Egg fertilisation and survival were very high and development during incubation progressed as expected. Hatching and subsequent survival of young schelly will be monitored in the late spring and summer of 1997, although it will be several years before the success of the project can be evaluated in terms of the establishment of two new self-sustaining populations of schelly.

Figure 47. Eggs being stripped from a Haweswater schelly.

Figure 48. Fertilised schelly eggs being introduced to an incubation box.

Pollution of fresh waters occurs by direct discharge, run-off from the land and by atmospheric deposition. The processes (physico-chemical 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.

Programme 7 Pollution Assessment and Control

Any useful emergency response model must be both generally applicable, and based on input parameters which are known, or easily measurable.

Chernobyl radiocaesium in lakes – developing an emergency response model

1996 saw the tenth anniversary of the reactor fire at the Chernobyl Nuclear Power Station in Ukraine. The "short-lived" radioisotopes deposited by the accident have by now decayed away, but several long-lived isotopes remain. Radiocaesium (Cs-137) is of particular environmental importance since it has a relatively long half-life, taking about 30 years for the amount of radioactivity to reduce by one half. Because of its chemical similarity to an important nutrient, potassium, it is accumulated by plants and animals.

Radiocaesium in aquatic systems.

Studies, by the IFE and others, on the contamination of aquatic systems after Chernobyl have shown that Cs-137 accumulation in freshwater fish can provide a significant radioactive dose to consumers. In many lakes in the Chernobyl affected regions, activity concentrations of Cs-137 in fish were significantly higher than maximum permissible levels for consumption. In some areas, these problems continue to the present day. Radioactivity in the aquatic system is of particular concern to Ukraine where 15 million people use water from the Dnieper river-reservoir system for drinking and irrigation.

A simplified emergency response model.

The IFE is working in a group of scientists from eight different European countries to develop models for the mobility and bioaccumulation of radioactivity in freshwater systems. During the years following Chernobyl, Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research and IFE monitored Cs-137 in 20 different lakes in Cumbria. In collaboration with MAFF, these data have been used to develop and test a model for Cs-137 contamination of lakes following a nuclear accident. We have shown that time-changes of Cs-137 in lakes can be described by two distinct components. Over a period of

Figure 49. Lake Svyatoe, Belarus. Ten years after the Chernobyl accident, many lakes in Belarus and Russia still have fish with radiocaesium activity concentrations which are above recommended maximum levels for human consumption.

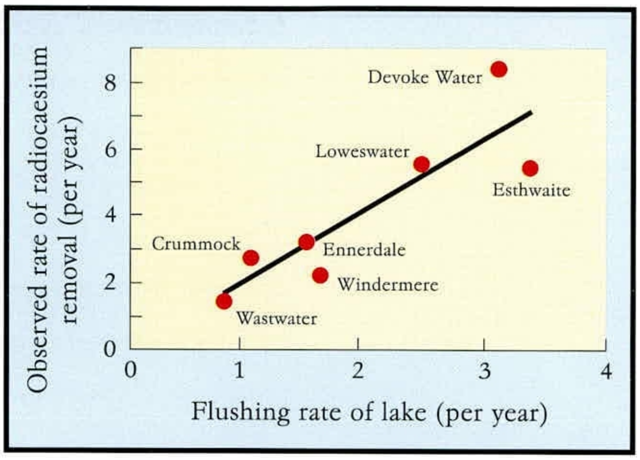


Figure 50. The rate of radiocaesium removal from the lakewater is strongly influenced by the rate of "flushing" of water through the lake outflow.

weeks-months after the deposition of radioactivity, the concentration declines relatively rapidly as a result of "flushing" of the lake and removal to bottom sediments. In the long term (years), however, radioactivity can remain at significant levels as a result of slow remobilisation from the surrounding catchment and the bottom sediments.

Any useful emergency response model must be both generally applicable, and based on input parameters which are known, or easily measurable. Based on our studies on a large number of lakes, we have developed a simplified model to predict long term Cs-137 contamination levels. The model requires as inputs only an estimate of radioactive deposition to the system, and (usually well-known) physical characteristics, such as catchment area and lake mean depth. Some of the results of this work are being incorporated in the aquatic part of the Commission of the European Communities "RODOS" emergency decision support system.

Many years after a nuclear accident, radiocaesium in lakes can remain at significant levels as a result of remobilisation from catchment soils and bottom sediments.

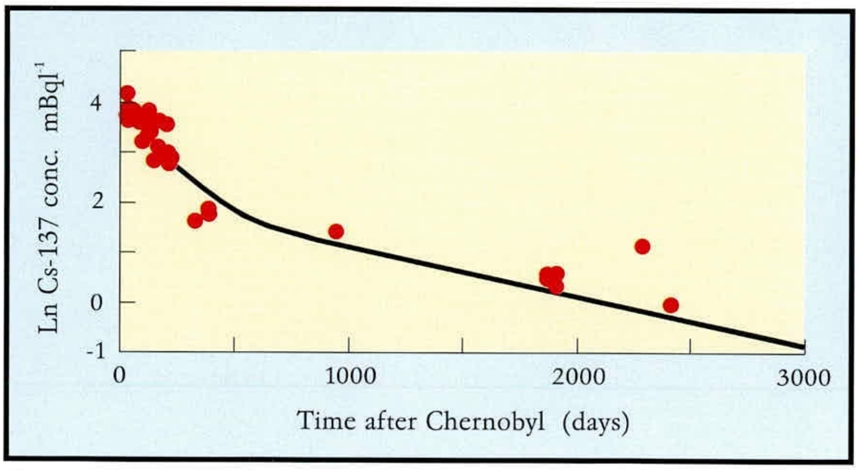


Figure 51. Measurements of radiocaesium activity concentration in Windermere after Chernobyl showing characteristic "two component" decline over time. The solid line shows the prediction of the generalised model.

Extreme natural events, such as floods, droughts, gales and fires, can have dramatic effects on ecological communities. This research programme increases our understanding of how environmental extremes impact on mankind and on the natural environment and aims to develop models and methods for estimating the magnitude, frequency and occurrence of extreme events. These will be used to understand the role of rare environmental events on natural systems and to design forecasting and decision support tools for flood, droughts and water quality deterioration.

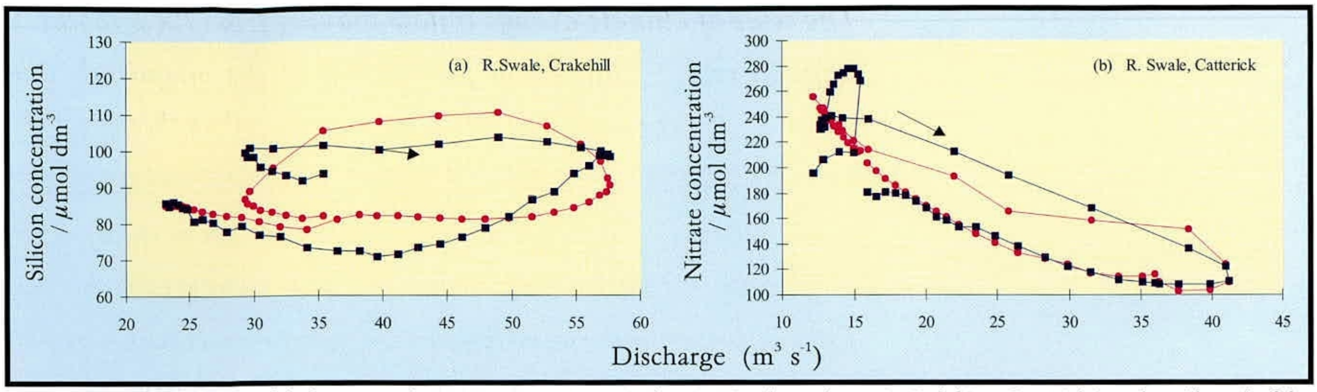
Programme 8 Environmental Risks and Extreme Events

Hysteresis of nutrient concentrations during storm events

Nutrient sources – diffuse or point?

During storm periods, the concentration of some chemicals and suspended sediments in rivers change in response to water discharge. This change may reflect the dilution of contaminants discharged to the river, i.e. point-sources, or may be dominated by the contribution of drainage water from fields or urban areas, generally described as "diffuse" sources. The drainage water may be from direct run-off, termed surface run-off, from land or sub-surface runoff derived from tile drains etc and is generally very difficult to quantify. However, it is often necessary to assess the relative importance of point-sources of particular chemicals compared with diffuse inputs to aid in water quality management and the assessment of the best measures to maintain water quality standards in catchments. Most catchments in the UK have contributions from both point and diffuse sources making it difficult to disentangle the sources using temporal data on chemical concentrations. Sometimes, when sources are dominated by point-inputs, e.g. dissolved phosphorus from sewage treatment works, the relationship between the inverse of the river water discharge and concentration of the chemical is close to linear, so providing evidence for the dilution of the chemical with storm water. These data may then be used to estimate the flux of the point-inputs as well as the effective concentration of the chemical in the diffuse inflows in the catchment.

This approach has been extended to describe the changes of chemical concentrations in rivers during storm events. In such situations the chemical concentrations may differ markedly during periods when the river water discharge is increasing, i.e. on the rising limb of the hydrograph, compared to decreasing during the falling limb. This difference in concentration measured at the same water discharge but at



Figures 52 & 53. Examples of the hysteresis of nutrient concentrations in the river Swale catchment in Yorkshire. Catterick is at the mid-reach of the Swale and Crakehill is before the confluence with the river Ure in the southern part of the catchment. The filled squares are the experimental data and the filled circles are the model predictions. The arrows on the field data indicate the time sequence during the storm. Parameters have been determined which estimate the degree of hysteresis and the concentration of the nutrients in diffuse inflows to the river.

Analysis of the hysteresis behaviour permits an estimate of the relative importance of point and diffuse inputs to rivers.

different stages of the storm hydrograph, is referred to as an hysteresis effect. The effect has been described in more detail using a semi-empirical model, *viz*:

$$C(j) = (q_l c_l + m_{net}) / Q + (h + p\, dQ/dt)(1 - q_l / Q)$$

where C(j) is the concentration of the chemical at the j th point or section along the river, $q_l c_l$ is the flux at low flow – the product of the water discharge, q_l and concentration, c_l; m_{net} is the gain or loss within the river, e.g. material disturbed from the bed-sediment or bank erosion; Q the total river discharge; the concentration in diffuse inflows, c_d, is characterized by: $c_d = h + p\, dQ/dt$ where t is time and h, p are constants for a particular event. The parameter, h, relates to the concentration in the diffuse inflow, c_d, when the river discharge is not changing and p is a response factor which reflects the sensitivity of the concentration of the solute to changes in water discharge and the direction of the hysteresis – indicated by the arrows in the Figure.

As part of the Land Ocean Interaction Study (LOIS), hysteresis of dissolved calcium, silicon, nitrate, nitrite, ammonium and phosphorus fractions, i.e. soluble reactive phosphorus, total dissolved phosphorus and total phosphorus, in river waters during a major storm in the river Swale catchment in Yorkshire (UK), have been quantified using this semi-empirical model. Examples of the results for dissolved silicon and nitrate are shown in the Figure. The magnitude of the diffuse inputs is related to river water discharge so that the size and rotation of the hysteresis loop is characterized by a single parameter. The approach has been applied to chemical and water discharge data collected at 2 h intervals from three river sites in the catchment over a complete storm hydrograph. The results illustrate hysteresis effects for all the determinands with the majority showing "clockwise" hysteresis, i.e. higher concentrations during the rising limb of the hydrograph compared with those measured during the falling limb. The model parameters, computed by optimizing agreement between the predicted and measured concentration – discharge relationships, are generally consistent with land-use patterns in the catchment and give some estimate of the relative importance of diffuse inflows during the event. The method has potential for further development to enable comparisons of chemical and nutrient dynamics in river catchments and the assessment of the relative importance of diffuse and point sources during high flow conditions when the greatest loads are exported from catchments.

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.

Programme 9 Global Change

Figure 54. Esthwaite Water, Cumbria.

Latitudinal movements of the Gulf Stream influence the dynamics of deep, thermally stratified lakes.

The impact of north-south movements of the Gulf Stream on the summer biomass of phytoplankton in Esthwaite Water (Cumbria).

Recent studies in the English Lake District have demonstrated that many of the year-to-year changes recorded in these lakes are related to north-south movements of the Gulf Stream in the western Atlantic.

Latitudinal movements of the Gulf Stream influence the dynamics of these deep, thermally stratified lakes by regulating the movement of the weather systems that determine their mixing characteristics.

Thus 'north' Gulf Stream years are characterised by more prolonged periods of calm and 'south' Gulf Stream years by periods of more intense mixing. Most of the analyses completed to date have emphasised the qualitative effects of these year-to-year changes on the seasonal succession of the phytoplankton. In this report, we explain how year-to-year variations in the intensity of mixing can influence the quantity as well as the quality of the phytoplankton produced in mid-summer.

Esthwaite Water (Figure 54) is a small, thermally stratified lake that frequently produces dense blooms of algae in late summer. Weekly measurements of the variations in phytoplankton biomass have been recorded since the mid 1960s and demonstrate that the summer maximum varies from year-to-year in a way that can not simply be related to the external nutrient loading. One of the most important factors influencing the magnitude of this summer maximum is the quantity of nutrients transferred from the hypolimnion into the epilimnion by wind-induced mixing. In some years, the mid-summer thermocline is relatively shallow and very little phosphorus is entrained into

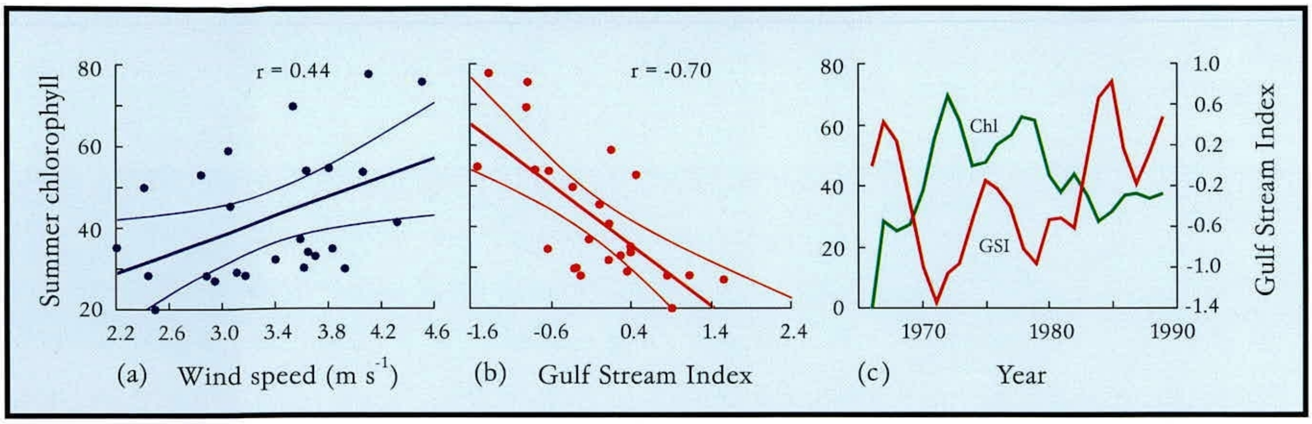


Figure 55a. The relationship between the late summer biomass of phytoplankton and the average wind speed in the previous month. Figure 55b. The relationship between the late summer biomass of phytoplankton and the position of the Gulf Stream. Figure 55c. A time-series plot showing the impact of north-south movements of the Gulf Stream on the late summer biomass of phytoplankton (both series smoothed by a three point moving average).

Results of this kind imply that the physical and biological responses of thermally stratified lakes are capable of amplifying the effects of year-to-year changes in the weather.

the epilimnion. In other years, the mid-summer thermocline is very deep and large quantities of phosphorus are transferred from the hypolimnion into the epilimnion. No direct measurements of this internal flux are currently available, but the year-to-year variations in the biomass of phytoplankton show that much higher densities are recorded in windy summers.

The cross plots in Figure 55a show the relationship between the late summer biomass of phytoplankton and the average wind speed recorded in the previous month. The highest phytoplankton crops are invariably recorded in windy summers when the seasonal thermocline is deep and more nutrients have been transferred from the hypolimnion into the epilimnion. A linear regression fitted to the plotted points shows that a significant proportion of the year-to-year variations in the summer biomass of phytoplankton can be explained by changes in the average wind-speed ($r = 0.41$, $p < 0.05$). A much higher proportion of the measured variation can, however, be explained by a more general 'weather pattern' index which simply records the annual position of the Gulf Stream in the Atlantic.

The position of the north-wall of the Gulf Stream has been monitored at regular intervals since the mid-1960s using a combination of ship-board and satellite observations and an empirical index of latitude derived using principal component analysis. Figure 55b shows the relationship between the late summer biomass of phytoplankton recorded in Esthwaite and this index of Gulf Stream position. There is a very strong negative correlation ($r = -0.70$, $p < 0.01$) between these two measurements with much higher chlorophyll concentrations being recorded in years when the Gulf Stream is well to the south.

The time-series plots in Figure 55c show the way these two variables have changed over the twenty-five year period covered by the present study. For much of the period, the relationship is quasi-cyclical but the Gulf Stream moved well to the north in the late 1980s and has remained in this position for five successive years.

Results of this kind imply that the physical and biological responses of thermally stratified lakes are capable of amplifying the effects of quite subtle year-to-year changes in the weather. Whilst similar responses have been recorded in the seas around the European shelf, the lakes in the English Lake District appear to be particularly effective integrators of recent climatic events.

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.

Programme 10 Integrating Generic Science

CCAP will form a key component of the newly formed UKNCC.

The CCAP a constituent collection of the UKNCC

The Government response to an independent review of the UK microbial Culture Collections, "A New Strategy for the UK Microbial Culture Collections", was published in July 1996. As a result, the Culture Collections Advisory Group (CCAG) was established to act as a focal point for the development of a consensus on strategy and activities to develop a shared identity and advise on best practice for cataloguing, marketing, research, acquisition and curatorial gaps. The primary responsibility of the CCAG is to oversee the development of the UK National Culture Collection (UKNCC). This collection will be responsible for the maintenance of biological materials as diverse as animal viruses, bacteria, fungi and mammalian cell cultures. The Culture Collection of Algae and Protozoa located at the IFE (Windermere laboratory) is one of the nine constituent Collections of the UKNCC and is responsible for the maintenance of a wide range of cyanobacterial and protistan strains.

In addition to its individual identity the CCAP will, in future, also appear under the corporate identity of the UKNCC. This is currently being established with the objectives:

1. To provide a single contact point for the UKNCC, and giving access to its full potential ensuring the customer and enquirer can access the UKNCC catalogue data through one entry point.

2. To develop a marketing strategy under a corporate UKNCC identity aimed towards identified markets, whilst examining the possibility of new markets.

3. To consider a uniform standards and quality control policy which incorporate quality assurance and quality control procedures in place in the UKNCC collections.

4. To avoid duplication of effort.

Options to achieve these objectives are currently under consideration and strategies will be developed and implemented over the forthcoming year.

Instrument Development

Enhanced Phytoplankton Biomass Sensor

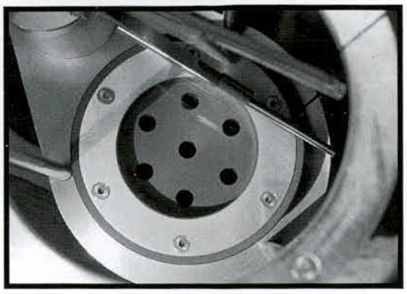


Figure 56. The active sensors and wiper mechanism of the Enhanced Phytoplankton Biomass Sensor.

A prototype 'Phytoplankton Biomass Sensor' was described in last year's IFE Annual Report. It can be used to determine the concentrations of functional groups of phytoplankton and other suspended materials by measuring the relative transmission of light at six carefully selected wavelengths within the visible spectrum, together with the broadband transmission. Each functional group of phytoplankton and other classes of material in suspension (such as peat, clay, *etc.*) have a unique 'spectral signature'. Algorithms are being developed to enable these overlaid 'spectral signatures' to be retrieved and hence the concentration of the respective groups to be inferred. A 'production' version of the sensor (Figure 56) has now been developed. It is physically smaller than the prototype and offers significantly enhanced electronic and optical performance. The sensor can be coupled to the Automatic Water Quality Monitoring Station (AWQMS), described below, for continuous monitoring or can be operated as a 'stand alone' instrument. In the latter case the results are displayed and stored using a hand-held rugged microcomputer.

Automatic Water Quality Monitoring Station

Following prototype trials last year, Automatic Water Quality Monitoring Stations have been installed in Ireland and Spain as well as the UK. Figure 57 shows the system being installed at Embalse de Iznajar (a reservoir in the South of Spain) during the summer of 1996. The station records a range of both meteorological and water quality parameters. Data recorded by the system can be accessed remotely using a PC equipped with a telephone modem. The station communicates via u.h.f. radio telemetry to a 'Shore Station' which in turn is accessible via the telephone network. The development of these systems was carried out under the European Union's LIFE programme with support from the

The development of an enhanced optical sensor for determining phytoplankton biomass and of monitoring stations that can provide real-time data from lakes across Europe.

Figure 57. Testing the Automatic Water Quality Monitoring Station during installation at Embalse de Iznajar (Spain).

Environment Agency. In addition to applications such as high resolution environmental monitoring and the validation of computer models of the response of a lake to changes in the weather, it is intended to develop the system as a tool for reservoir management.

Automatic River Monitoring Station

A prototype system has been produced with the support of the Environment Agency for river monitoring applications. This shares some of the technology developed for the AWQMS. Water is ducted through a flow cell that is fitted with a number of water quality sensors and a 'Phytoplankton Biomass Sensor'. Operational trials will take place in the coming year.

A long-term study of the macroinvertebrate fauna of a chalk stream

Following the droughts of recent years, there is widespread concern over the low-flow conditions experienced in many of the famous chalk streams of southern England. Two obvious changes which frequently accompany low flows are deposition of silt on the river-bed and poor growth of aquatic macrophytes. These changes also affect the amount and quality of the habitat available for utilisation by invertebrates and fish.

The low flow regimes recently experienced in chalk streams have been extreme, and the long-term biological consequences may be difficult to assess unless reliable historical data are available to act as a baseline.

Between 1971 and 1979, detailed ecological studies were undertaken at two sites in the lower perennial section of the R.Lambourn in Berkshire. Each site was mapped at monthly intervals and, less frequently, quantitative samples of macroinvertebrates were collected on each of five different habitat types. The study period included a minor drought in 1973 and a major drought in 1976.

Recently, the macroinvertebrate data for the nine-year study have been entered into Microsoft Access, a Relational Database Management System (RDBMS) for Windows. This makes data manipulation more efficient and ensures that these historical data are available for comparison with future results obtained using the same methodology.

The value of a long term data-set is already apparent. During the drought of 1976 there were some notable increases in the abundance of a limited number of macroinvertebrates, whilst other taxa exhibited a negative response to low flows. Overall, the fauna appeared to be capable of rapid recovery after one extreme drought event which lasted for just over a year.

Now we need to establish whether the repeated droughts of recent years have impacted on the macroinvertebrate assemblages and taken them beyond the range of variability observed in the 1971-1979 data-set.

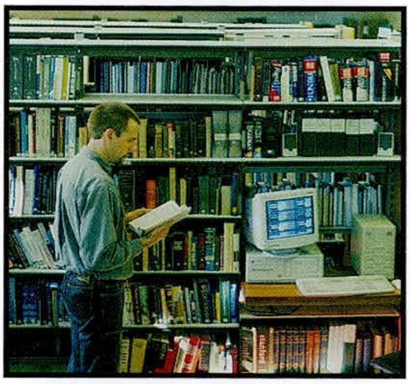
Figure 59. The Fisherman's Mayfly (Ephemera danica).

Historical data-sets should help to establish the biological consequences of recent droughts.

Figure 58. River Lambourn at Bagnor.

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.

Access to the library catalogue is available from the world wide web.

The library and information service

Library and information services are provided to all of the Institute's sites, either from a local library in the case of Wareham and Windermere, or by arrangement with the sister Institute at shared sites. Increasingly, integration with the other Centre for Ecology and Hydrology (CEH) libraries is being sought, although not to the extent of becoming a unified service. The CEH libraries are currently planning the implementation of an automated library management system to be shared between the Institutes.

The library

The library continues to catalogue about 5,000 items each year. Some inroads have been made into converting older records from catalogue cards to digital form, and the online catalogue now holds 130,000 records, with approximately 200,000 still to convert. As ever, library stock is augmented by our exchange programme, whereby Freshwater Biological Association publications are exchanged for serials and reports from 77 different countries.

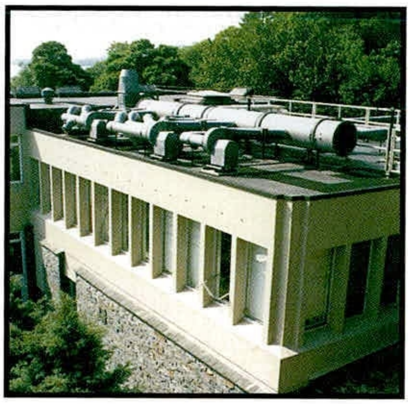
We thank the libraries of the Institute of Terrestrial Ecology for their continued assistance in providing services to our regional laboratories at Edinburgh and Monks Wood.

The information service

We have continued to increase the range of CD-ROM databases available to users. Plans are afoot to produce a union list of CD-ROMs for the CEH libraries, in order to better co-ordinate services between the Institutes. Access to the library catalogue has been improved on the Windermere site by the use of a Windows version of the CDS/ISIS catalogue software. Users on other IFE and CEH sites, as well as FBA members, can now use the catalogue via our new World Wide Web pages at www.ife.ac.uk where this Annual Report can also be found.

National and international networks

As an input centre for the Aquatic Sciences and Fisheries Abstracts service, we are trialling a new electronic input system (A$FISIS) based on the CDS/ISIS database software. International links have been maintained through EURASLIC and IAMSLIC, and nationally through the Water Industry Librarians Group and Aslib Northern Branch.



External refurbishment of Pearsall Building.

Laboratory services

Windermere Laboratory – Corrosion was discovered to the steel reinforcement of the concrete structure of the Pearsall Building. A major refurbishment programme took place to correct these defects and the exterior exposed surfaces covered with a waterproof/breathable membrane. The roof of the Pearsall Building has also been made water-tight with the relining of the stairwell walls.

The system for fume extraction in the Pearsall Building has been completely upgraded with new aerodynamic surrounds fitted to the cupboards along with new ducting, fans and final discharge systems on the Pearsall roof.

The accommodation property in Windermere has been completely refurbished including a new fire alarm system throughout.

Other tasks carried out 'in-house' include the start of renovating the gardens and grounds, the re-covering of our jetty to the rear of Ferry House and the painting of the entire exterior of the ground floor of the Annexe building and other out-buildings around the site.

The refurbishment of the buildings and grounds continues apace.

River Laboratory – Work on the water supply system has continued with the partial relaying of the mains water to the main buildings and student cottages. Internally, the cold water supply has been renewed throughout the main building due to numerous leaks in the old system.

The rear of the farmhouse building has been re-rendered, following the re-pointing of some very loose old brickwork and a chimney on the roof to stop rainwater penetrating the corridor below.

The window replacement programme continued with four more windows in the main building being changed. Also the re-wiring programme continues and most areas have now been fitted with category 2 lighting suitable for computer use.

Other tasks included the fitting of the stores with central heating, the removal of a partition to create a larger working area for visitors and short-term students and the replastering and decoration of one of the chemistry laboratories.

Electronics and instrumentation

As well as the major developments described in the section 'Integrating Generic Science', the department has been engaged in several smaller projects.

Long term monitoring

A high resolution, field conductivity, temperature and pH recorder has been designed and deployed for long term monitoring work on Esthwaite Water. It uses a custom designed circuit board, is rugged and consumes little power. All sensors are duplicated to increase confidence in the results and are fully electrically isolated to prevent interaction.

Improved Smolt Counter

The smolt counter described in last year's report (p. 36) has been significantly enhanced. It now distinguishes the smolt swimming upstream and downstream. Counts for each channel, together with total counts (for all channels) are provided. A facility to trigger a time-lapse video recorder to capture a picture of the smolt swimming through the detector has also been incorporated.

Other work

The department continues to undertake repair and maintenance work on commercial instrumentation, electrical and computer equipment for all IFE sites.