Fish population dynamics and management

Post-Chernobyl radiocaesium in fish from two Cumbrian lakes

The Chernobyl reactor accident occurred on the 26 April 1986 and the plume passed over England during 2-3 May 1986. Much of the remaining activity continued northwards over Scotland, but some moved westwards and then returned to traverse Wales and northern England during 7-8 May. Limited deposition occurred throughout the UK and the highest values were recorded in Cumbria, North Wales and parts of Scotland. Early monitoring of fish showed that, whilst the radiological significance of the fallout on marine fish was negligible, radionuclide accumulation by freshwater fish was significant, especially in high deposition areas such as the Cumbrian Lake District. It was soon found that there were wide variations between lakes, fish species and individuals of the same species in the same lake. The objective of the present investigation was to evaluate sources of variation in radiocaesium in fish from two lakes, Devoke Water and Loweswater. This work was performed in conjunction with staff from the Ministry of Agriculture, Fisheries and Food (MAFF) and was supported financially by NERC and the Commission of the European Communities.

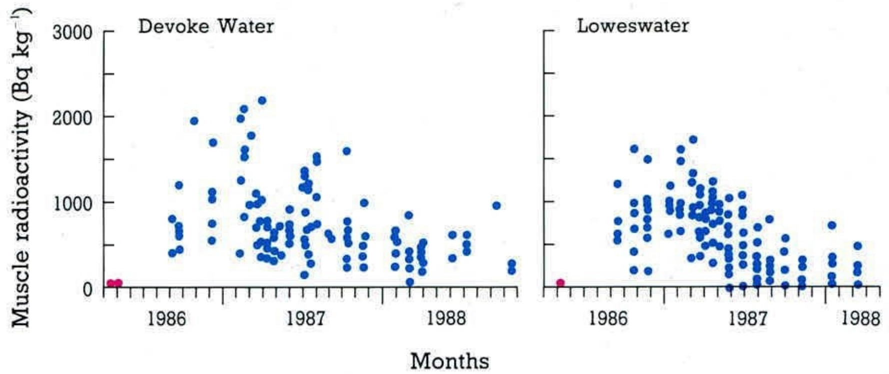


Figure 19 Muscle radiocaesium values (Bq kg^{-1} wet weight) for individual brown trout from Devoke Water (n = 160) and Loweswater (n = 145) (Pre-Chernobyl trout).

Overall geometric means for radiocaesium in brown trout (540 Bq kg^{-1}) and perch (1192 Bq kg^{-1}) in Devoke Water were significantly higher than those in Loweswater (trout 404, perch 989 Bq kg^{-1}), and mean values for perch were significantly higher than means for trout in both lakes. Mean values for pike (568 Bq kg^{-1}) in Loweswater lay between the values for trout and perch.

Radiocaesium content increased with fish weight for wild trout from both lakes, perch from Devoke Water but not perch or pike from Loweswater. Values for perch were generally higher than those for trout in Devoke Water (Figure 18), and the power-function relationship between radiocaesium content and fish weight invalidates the use of uncorrected means for temporal comparisons. Radiocaesium values in pre-Chernobyl trout and stocked trout were markedly lower than those in post-Chernobyl wild trout (Figure 18). This discrepancy between wild and recently stocked trout provides strong evidence that the food chain rather than the water is the main route of radiocaesium transfer to the fish.

The stomach contents of trout and perch from Devoke water indicated a diverse diet from zooplankton to sticklebacks. Both the trout and perch were in good condition according to their length-weight relationships and there was no indication that diet differences had any significant effect on the radiocaesium content of individual fish.

There was a large variation in radiocaesium values between individual fish, as data for trout from both lakes clearly show (Figure 19). When these values were scaled to a standard weight of trout to remove the marked effect of fish size, monthly geometric means for radiocaesium increased from April/May 1986 to a maximum in October 1986 in

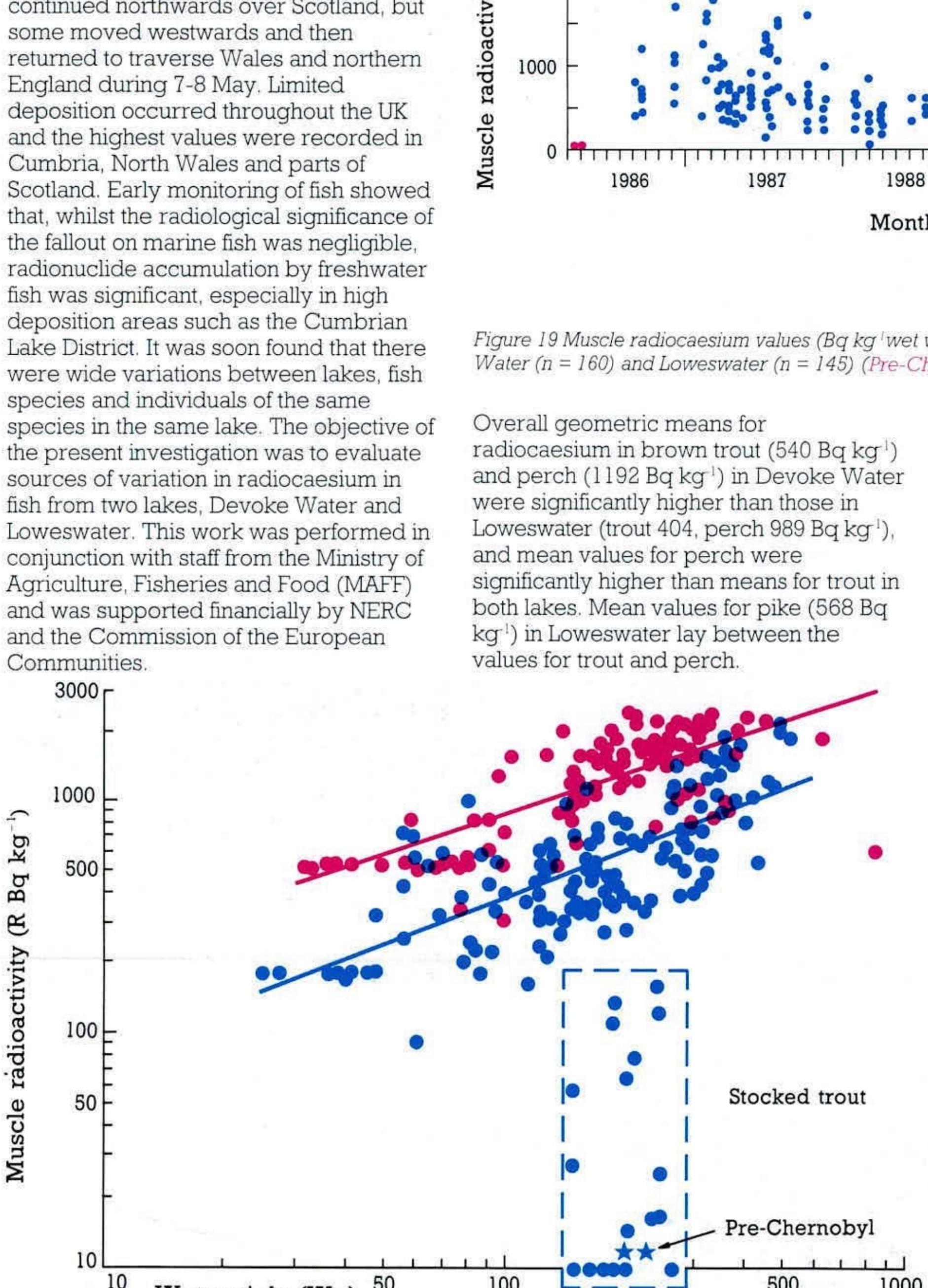


Figure 18 Relationship between muscle radioactivity (R Bq kg^{-1}) and wet weight (Wg) for individual brown trout and perch from Devoke Water: regression lines are fitted for both species but values for 18 stocked trout and 2 pre-Chernobyl trout were omitted from analysis (points enclosed by broken line).

Devoke Water and February 1987 in Loweswater, then decreased exponentially at a slow rate in Devoke Water and a fast rate in Loweswater, and finally increased slightly in Loweswater only (Figure 20). Geometric means for perch and pike followed a pattern similar to that for trout, except that maxima occurred in February/March 1987 for perch in both lakes and in June 1987 for pike in Loweswater.

Although this work has evaluated some sources of variation in radiocaesium content in fish, especially the effects of fish size and diet, it has also shown that there are many unsolved problems. Differences between species may be due to different metabolic rates (for example, different rates of gastric evacuation), and differences between lakes may be due to variations in their limnology and the nature of their catchments. These and related problems are now being investigated.

Studies on strategies for the planting of young, hatchery reared salmon

As part of a wider contract for MAFF, short-term studies have been made in recent years in an attempt to assess the relative value of planting out unfed salmon parr or of feeding the parr in the hatchery for five weeks before planting. Studies made by MAFF in natural streams and rivers have the advantage of dealing with the "real world" but suffer some problems in interpretation of the results because of difficulties of control and replication. The studies by IFE have used the Grassholme channels (Figure 21) as "streams" to be stocked. The four channels can be set up as replicates in terms of flow and bed material and the numbers of fish leaving the channels and dying in the channels can be accurately determined. The four channels provide two replicates of each of the two treatments (stocking with unfed parr and stocking with 5 weeks fed parr) (Figure 22). The results from these small artificial streams and those obtained from real streams are complementary to one another and will be published jointly.

Preliminary data analyses suggest that 10 weeks after the commencement of feeding, the fish stocked as unfed parr have a higher mean weight than the fish stocked as fed parr, but only about half the population density. Similar experiments are now in progress with trout.

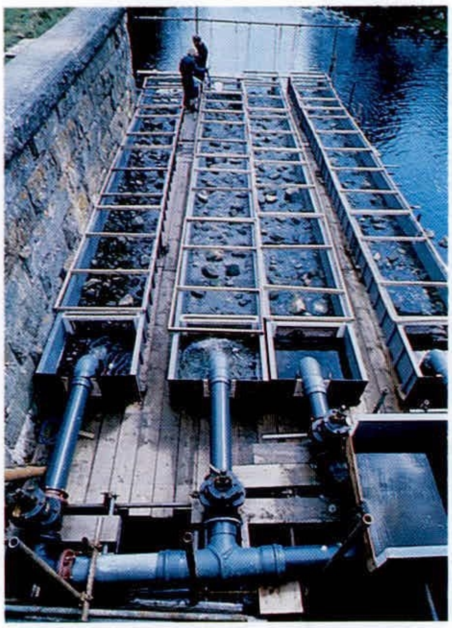


Figure 21 General view of Grassholme channels; each channel is 12 m long and 1 m wide.

Assessment of stress in wild populations of fish

Exposure of fish to environmental stress induces a complex series of physiological changes, collectively known as the stress response. A key element of the response is activation of the hypothalamic-pituitary-interrenal axis, resulting in elevation of the hormone cortisol. Although, in the short-term, the stress response is believed to be of adaptive value to the fish, in the longer term, unalleviated, or chronic, stress can be very damaging. Cortisol itself has been implicated as a causal

Figure 22 A salmon (Salmo salar) *parr.*

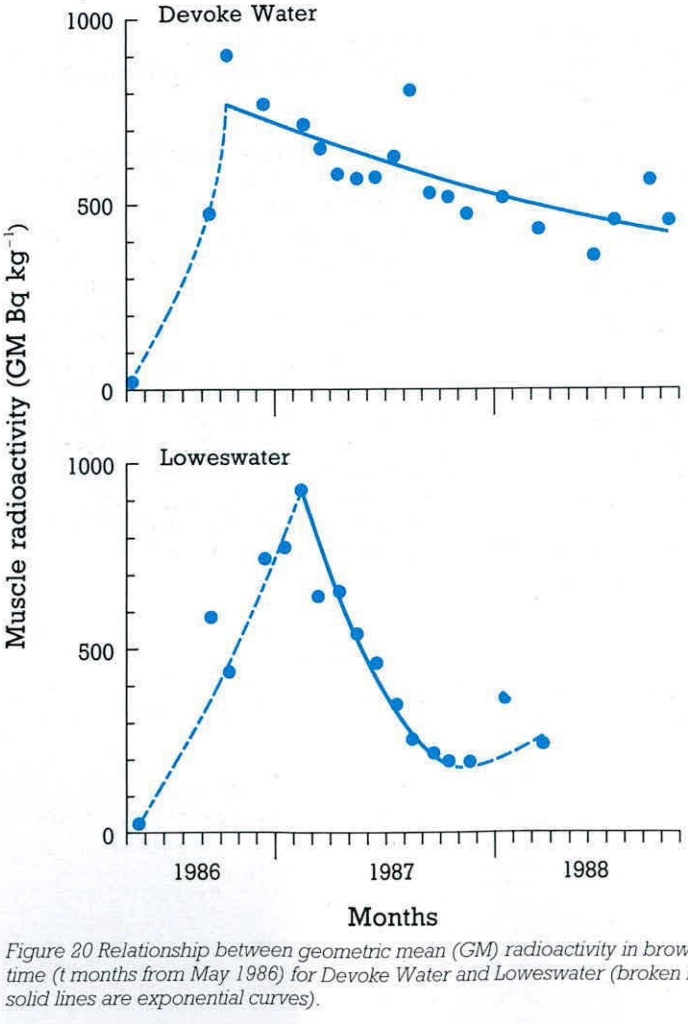


Figure 20 Relationship between geometric mean (GM) radioactivity in brown trout (GM Bq kg^{-1}) and time (t months from May 1986) for Devoke Water and Loweswater (broken lines simply show trends, solid lines are exponential curves).

factor in stress-induced reduction of growth, disruption of the reproductive system, and immunosuppression. Furthermore, the fact that cortisol elevation is a consistent feature of the stress response has led to its use as a reliable index of stress. Although most of our work, and that of others, has concentrated on the study of the effects of environmental stress on fish within the controlled conditions provided by the aquacultural environment, the measurement of plasma cortisol levels provides a potentially useful diagnostic tool for assessing the likely effects of environmental stress on natural populations of fish. However, despite the fact that plasma cortisol levels are a good indicator of stress, their very lability under conditions of stress is a problem. A clear demonstration of this is provided by removing fish individually from a single holding tank. After a few minutes, plasma cortisol levels in consecutive fish show a stepwise increment, due to the disturbance associated with the removal of previous fish (Figure 23). Under controlled experimental conditions, this problem can be overcome, but, when sampling from wild populations, prolonged disturbance of the fish is often unavoidable, particularly if trapping or netting is necessary to remove individuals. We have therefore been looking for an alternative to plasma cortisol levels to indicate the "stress status" of fish; an indicator of stress that is stable during short-term disturbance, such as that needed to sample the fish.

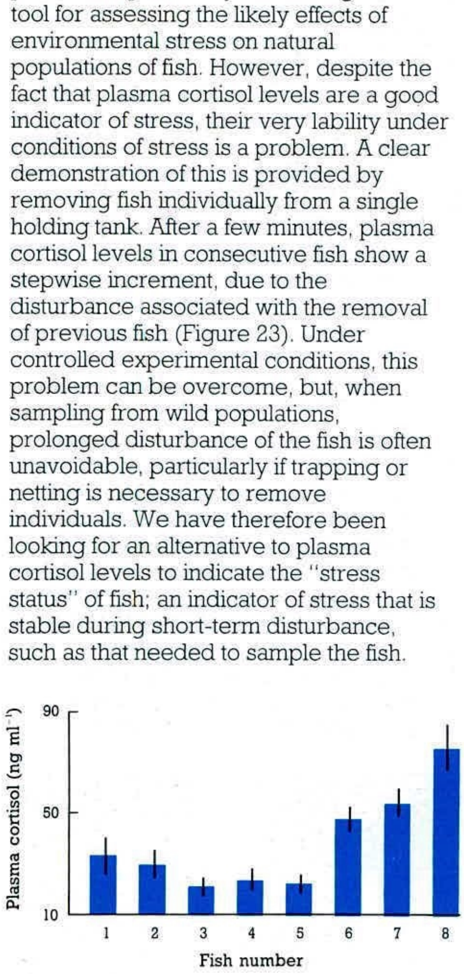


Figure 23 Relationship between the order in which trout are removed from a tank and their plasma cortisol level; each value is the mean for 16 fish ± S.E.

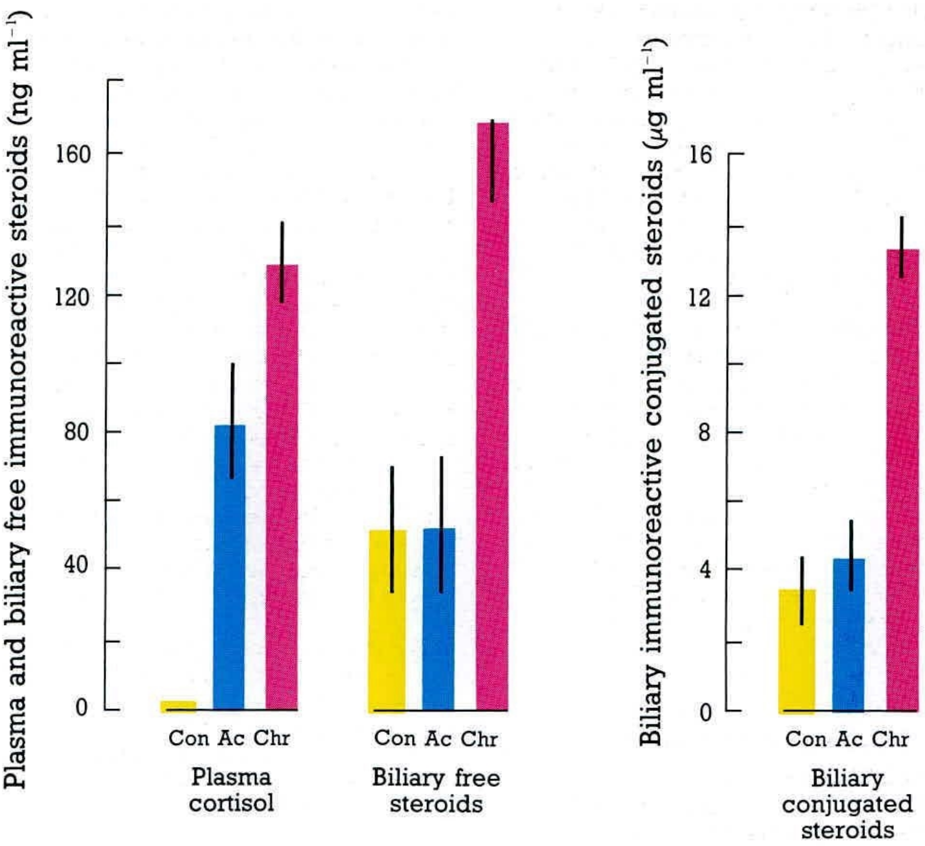


Figure 24 The levels of cortisol in the blood, and free and conjugated corticosteroids in the bile for rainbow trout at rest (Con), following one hour of acute stress (Ac) and following twenty-four hours of chronic stress (Chr); each value is the mean for 10 fish ± S.E.

When fish secrete large amounts of a hormone into the bloodstream, as is the case with cortisol during stress, rather than being allowed to accumulate in the blood, the hormone is removed, or "cleared". Clearance of cortisol occurs via two routes, the kidney (in the urine), and the liver (in the bile). In addition, to aid clearance, the hormone is usually metabolised to an inactive derivative, and chemically conjugated to another molecule to enhance its solubility in water. We studied the accumulation of cortisol and its derivatives in the bile of fish exposed to a brief stress (1 h of confinement) and a prolonged stress (24 h of confinement) and compared these with levels in fish subjected to no stress at all. Both acute and chronic stress significantly elevated blood cortisol levels when compared to those of the unstressed fish (Figure 24). However, acute stress had no effect on the levels of unconjugated and conjugated derivatives of cortisol in the bile. The levels of these compounds only become elevated after exposure to prolonged stress. Therefore, measurement of the levels of steroid derivatives in the bile of fish appears to provide a way of avoiding the confounding effects of capture stress when attempting to establish the "stress status" of wild populations of fish.

Microbes in the aquatic environment

An epibiont on *Chromatium*

During August 1990 a sulphide-rich solution lake in central Spain was studied jointly with the University of Valencia. In this lake a dense population of the large (5 x 3 μm) purple photosynthetic bacterium *Chromatium okenii* developed at 9 m depth in anoxic water. About 2% of the population carried a small (2 μm), non-motile epibiont. The epibiont, with its host, were prepared for electron microscopy and an unusual and apparently unique life cycle was revealed (Figures 25a, b). *Chromatium* is often found close to the top of the anoxic hypolimnion in lakes, especially if sufficient hydrogen sulphide is available (which the photosynthetic bacterium uses as reductant in the presence of light). Like most aquatic phototrophs, *Chromatium* excretes dissolved organic carbon (DOC), and because cell densities are so high, the *Chromatium* cells effectively swim around in a 'soup' of DOC of their own making. It is this DOC which, we believe, sustains the epibiont on the *Chromatium*. By remaining attached to the outside of the *Chromatium*, the epibiont profits not so much from material provided by its own host, as from DOC produced by the large number of neighbours of its own host.

After dividing once or twice, the epibiont produces a tail-like, detachable infective stage. This is transferred to another *Chromatium* cell by physical contact, and the 'tail' develops into a mature organism of the next generation. It appears that the extremely high population densities achieved by *Chromatium* are critical to the success of the epibiont - both for the completion of its life cycle and for the provision of dissolved organic carbon to support its growth.

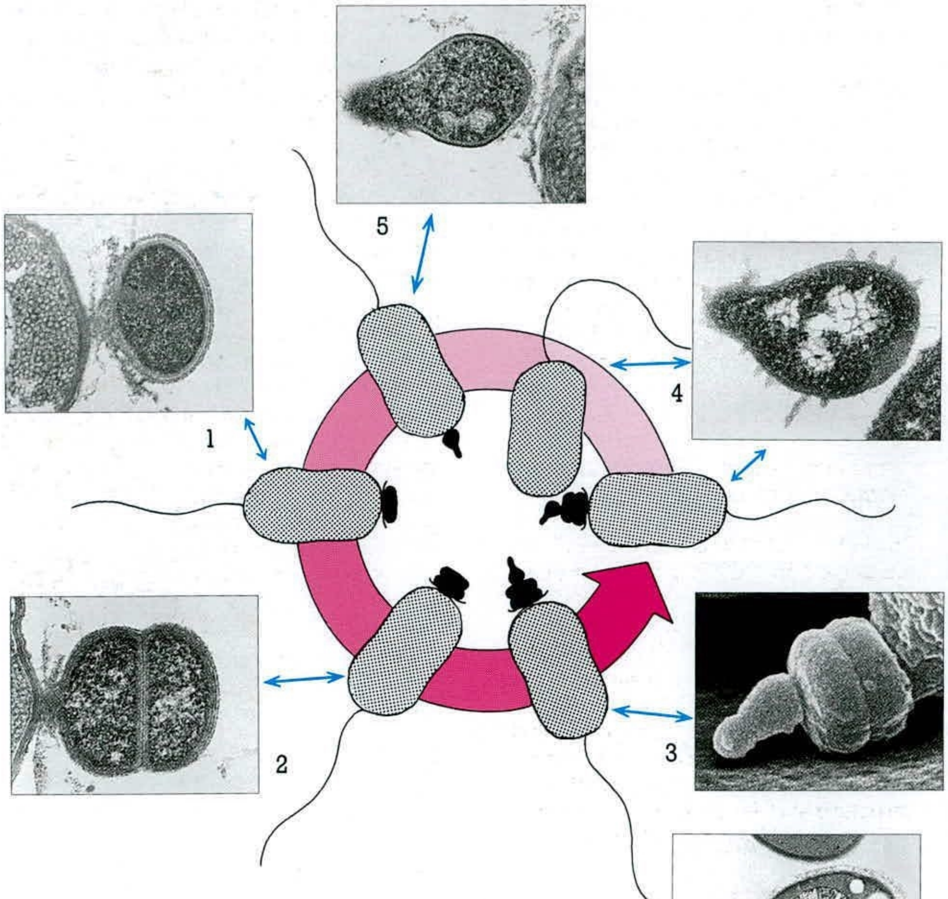


Figure 25a Life cycle of a bacterium living on the photosynthetic bacterium Chromatium.
Stage 1: Epibiont on Chromatium *(Transmission Electron Micrograph x27000).*
Stage 2: Mature epibiont (TEM x27000).
Stage 3: Epibiont with infective 'tail' (Scanning Electron Micrograph x27000).
Stage 4: Epibiont 'tail' makes contact with second Chromatium *cell (TEM of 'tail' x65000).*
Stage 5: Infective 'tail' transferred to second Chromatium. *This epibiont will develop into Stage 1 (TEM x52000).*

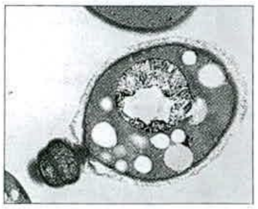


Figure 25b (bottom right) Transmission electron micrograph of entire Chromatium *with epibiont (x9000).*

Genetics of freshwater bacteria

Studies in this area remain focused on the transfer of genes and the detection of specific bacteria in the freshwater environment. Work on the detection of genetically modified microorganisms (GMMOs) is carried out in collaboration with the Department of Genetics and Microbiology at Liverpool University. Using *Pseudomonas putida* and other freshwater pseudomonads as model recombinant organisms, an assessment has been made of their ability to survive, and the fate of their recombinant genes. A range of molecular techniques has been developed to detect recombinant pseudomonads carrying a colorimetric marker gene. Some of the techniques that have been developed do not necessitate culturing the target organisms. This is important because, following their release into freshwater, it may not be possible to recover them using standard bacteriological methods, yet they may remain viable within the sample. These techniques include bioassay, DNA hybridisation and immunological detection. In general, the detection limit (ie the minimum number of cells required for positive identification) appears to be approximately 10^3 cells ml^{-1}, which is equivalent to the target organism accounting for <1% of the total number of bacteria in lake water. As a result of the need for the containment of GMMOs, microcosms that mimic the natural environment have been developed. Molecular techniques for the detection of GMMOs are being extended to include fundamental studies in aquatic bacteriology. A basic problem is the diversity of organisms encountered in most natural environments, but the diversity of aquatic ammonia-oxidising bacteria (nitrifiers) is considered to be relatively low, thus permitting the application of such techniques. Some success has been achieved (in collaboration with Liverpool University) in the development of DNA probes to detect and identify ammonia oxidisers obtained from culture collections. These probes are now being applied to natural communities.

Electron microscopy

Electron microscopy continues to be used within a wide range of projects. The two principal projects making use of the department's facilities in the past year were: an investigation of the transport of fine and flocculated particles in rivers under different flow conditions; and the investigation of the ultrastructure of anaerobic protozoa and their methane-producing bacterial endosymbionts. A study of bacterial parasites of salmonid fishes and their possible control by selected bacteriophages has also begun using high resolution transmission electron microscopy.

Various algal cultures have been examined for CCAP, and some novel bacterial reproductive structures have been examined in collaboration with Lancashire Polytechnic. The electron microscope facilities also supported the work of a visiting scientist from Leningrad studying the feasibility of cryo-preserving large amoebae, and scientists from the University of Valencia studying the structure and life cycle of the bacterial epibiont on *Chromatium* (see above).

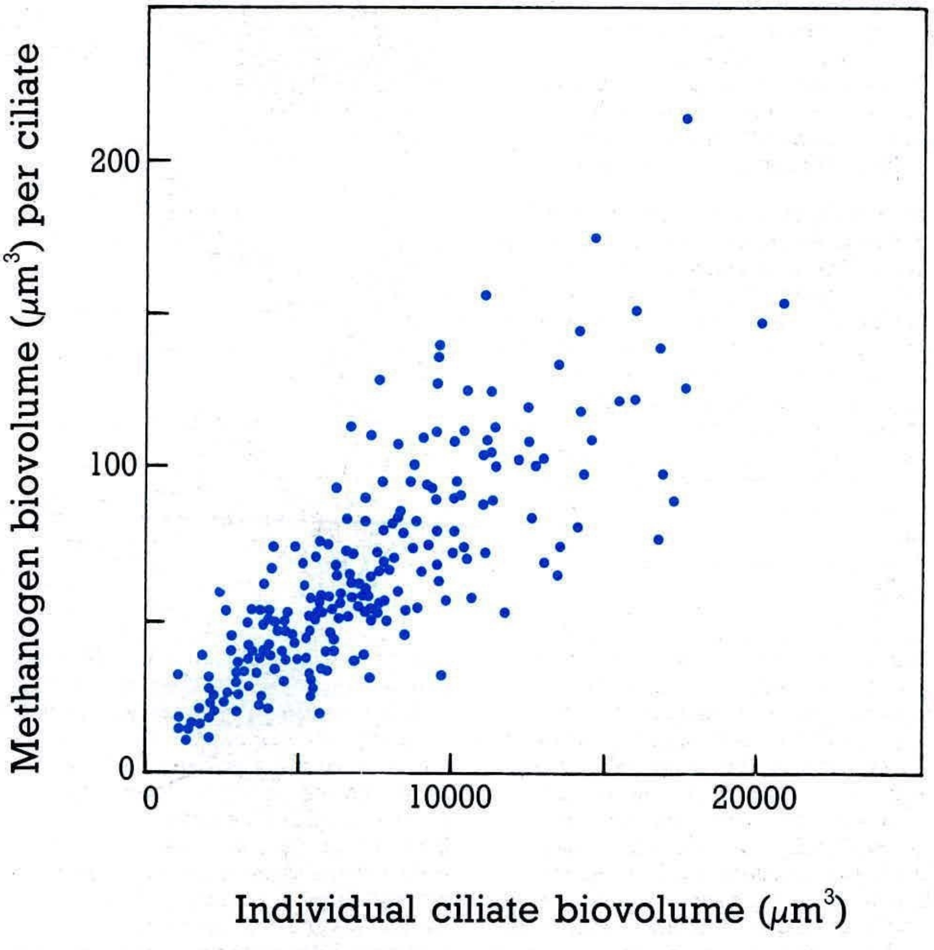
Culture Collection of Algae and Protozoa (CCAP)

CCAP and its activities were reviewed in 1990. The Review Group realised the academic and commercial importance of the Culture Collection and the need to continue to support it. The major changes in structure were the appointment of a single Curator for both freshwater algae and protozoa, and the making permanent of previously period appointments. CCAP continues to be one of the major depositories for microalgae, cyanobacteria and protozoa, and as such it is becoming increasingly recognised as an internationally important genetic resource centre. The service role of CCAP continues to expand as greater numbers of cultures are ordered, particularly by clients interested in algal biotechnology and ecotoxicity testing. Other services include contract research and the provision of a safe depository service. CCAP education services remain closely associated with the Shell Education Service, with another successful display of CCAP products at the annual exhibition of the Association for Science Education, in Birmingham in January 1991. Interest in the distribution of CCAP educational resource materials in the USA has led to discussions with a North American distributor.

There has been significant progress with cryopreservation, and with the development of new and improved techniques for the preservation of some strains of protozoa, especially small amoebae. Following adaptation to axenic culture, all the *Naegleria* strains in the Collection are now cryopreserved, with high post-thawing survival rates. Improved methods continue to be developed. These will permit a greater range of CCAP cultures to be cryopreserved, leading to significant cost savings.

Anaerobic protozoa

We have shown that the bacteria which live inside anaerobic ciliates do produce methane (so they are methanogens) and that their growth, at least within the one ciliate species investigated, is coupled to the growth of the host ciliate. In all protozoa most energy generation goes towards the synthesis of the macromolecules required for new growth (eg proteins, nucleic acids). Since we know that energy generation in anaerobic protozoa with hydrogenosomes leads to the production of hydrogen, and that hydrogen is a prime requirement of methanogens, we can expect some correlation between the synthesis of new protozoan biomass and the production of new methanogens. This correlation is clearly illustrated in Figure 26 which shows data from the ciliate *Metopus palaeformis*. The data are taken from ciliates of all sizes and all physiological states. The volume fraction of methanogens within the ciliates stays relatively constant, at around 1% of that of the protozoan host. This would imply that methanogen production is simply a passive consequence of ciliate growth: the rate of hydrogen production by the ciliate will maintain a certain bacterial biomass growing at a rate which corresponds to that of the host ciliate. But our continuing investigation indicates that the interaction may be more complex. The ciliates seem to exert some subtle control over the methanogens, dictating when the latter undergo what appears to be synchronous cell division. This work continues with the fruitful collaboration of the Marine Biological Laboratory (University of Copenhagen), Helsingør, Denmark.



Figire 26 Relationship between individual cell volumes of the ciliate Metopus palaeformis *and the total volume of methanogen symbionts each ciliate contains.*

Physico-chemical processes in catchments

The transport of radionuclides through the natural environment

Radioactive fallout on Cumbrian lakes

On 26 April 1986, a major accident occurred in reactor 4 of the Chernobyl nuclear power station in the Ukranian Republic of the Soviet Union. Up to 20% of the fission and activation products in the reactor have been estimated to have escaped over a period of the next 11 days, after which time emissions suddenly ceased. The emissions were of two types: small particles of fuel rods with their casings, and gaseous products which either remained in the atmosphere in that form or which condensed to form very fine particulate material. The fuel rod particles contained high concentrations of uranium, plutonium, strontium and ruthenium, as the main components. Since the particles were relatively large they were mainly deposited within 10 km of the plant, although small numbers of particles have been reported from areas as far apart as Sweden and Greece. However, the radioactive cloud which drifted over Europe for several days and eventually reached the UK, consisted of condensation products, mainly 131-Iodine, 137-Caesium, 134-Caesium, 103-Ruthenium and 106-Ruthenium (plus some other very short-lived isotopes).

Although most of the UK received relatively small amounts of deposition, the passage of the cloud of radioactivity over Cumbria on 3 May coincided with very heavy rain, so that the highest levels of deposition in the country were recorded in this region. In conjunction with the Institute of Terrestrial Ecology and the University of Lancaster a programme of work to study the processes of transport of radioactive material through the natural aquatic environment was rapidly developed, starting within a few days of the accident (funded by Her Majesty's Inspectorate of Pollution and later by the Commission of the European Communities (CEC)). Since 131-Iodine has a very short half life (eight days) the majority of the studies used measurements of caesium isotopes, although a small amount of ruthenium data was obtained. However, there are good scientific reasons for studying the transport of caesium as a typical "tracer" element: it has a very simple chemical form (monovalent cation) in solution; although it absorbs onto particles it prefers to be in solution; it is easy to measure in environmental samples; and it is actively taken up by animals and plants as it has very similar properties to potassium.

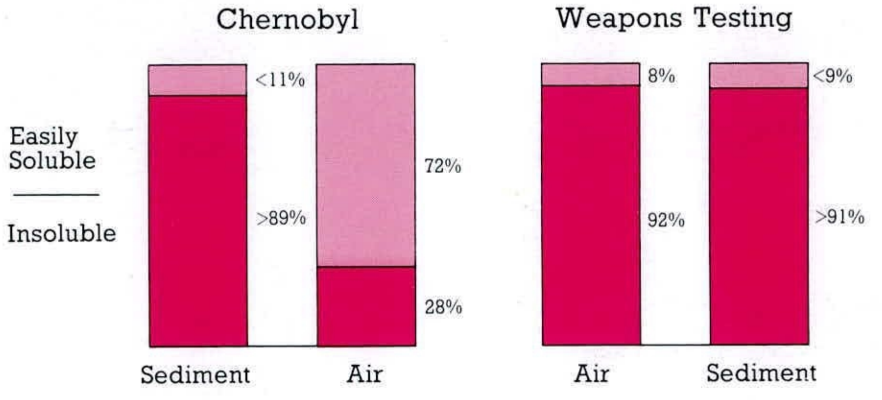


Figure 27 The relative proportions of caesium from different sources which are easily soluble and effectively insoluble in water. The Chernobyl material in air was sampled on 3 May 1986. Weapons test material was a composite sample from 1959. Sediment samples were obtained from different depths in a sediment core taken February 1987.

There was an early impression that the Chernobyl caesium was more readily available than the deposition following atmospheric testing of atomic weapons. In a collaborative programme with the National Radiological Protection Board and the Atomic Energy Authority, Harwell, samples of atmospheric particulate material from the Chernobyl peak and from just before the peak of the weapons fallout (1959) were sequentially extracted using a series of chemical solutions and the chemical forms of caesium were compared. Approximately 70% of the Chernobyl material was found to be soluble in water whereas only 8% of the weapons fallout was soluble (Figure 27). Although definite interpretation of these results was clouded by the possibility that changes had taken place in the weapons test material during its 29 years of storage, this was the first hard evidence of a difference in availability. Another interesting factor was that within nine months of the deposition, less than 10% of the caesium from Chernobyl was found to be easily soluble when sediments from the bottom of Windermere were subjected to the same treatment. It has now been shown that this phenomenon is due to a slow transport of caesium into the middle of clay mineral particles, from where it is very difficult to extract it, ie it is essentially locked in an unavailable store.

Transfer from water to sediment

The major study during the first year after the accident concentrated on measurements in two lakes, Windermere (north basin) and Esthwaite Water. Although the lakes are located within 2 km of each other, the former is a deep (65 m), mesotrophic lake while the latter is shallow (15 m) and hypereutrophic. The change with time in observed activity in the water column of Esthwaite Water is shown in Figure 28. Both lakes behaved similarly, showing a rapid reduction of activity, with levels reducing by 50% within 15 days in Esthwaite and 70 days in Windermere. The patterns of change shown by caesium activity in the deeper (hypolimnetic) and shallower (epilimnetic) water reflect the stratification and mixing of the water. Hence, while activity in the surface fell continuously, activity in the bottom water remained constant from soon after the deposition until the autumn. This was a result of thermal stratification of the water column, which isolated the bottom waters from the removal processes operating in the surface waters.

The removal of radionuclides from the water column resulted from three processes: flushing out from the lake of

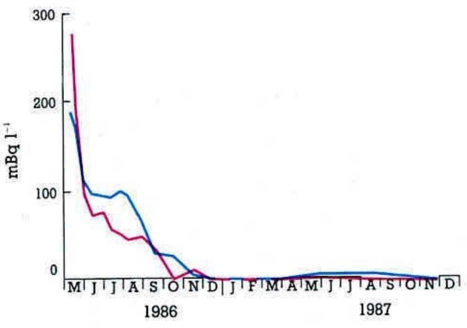


Figure 28 Change in the total concentration of 137-Caesium with time in the surface and bottom waters of Esthwaite Water.

radionuclides by incoming water; adsorption to particles, followed by settlement to the sediments; and direct adsorption onto the sediments. Between 30 and 40% of the total input was lost from the two lakes by hydraulic flushing and about 60-70% accumulated in the sediments by a combination of the two latter processes. Work is continuing to further elucidate the relative importance of the processes of radionuclide removal in different lakes. The research is funded by the CEC, as part of its Radiation Protection Programme, and involves collaboration with 10 laboratories in six European countries, coordinated by the IFE.

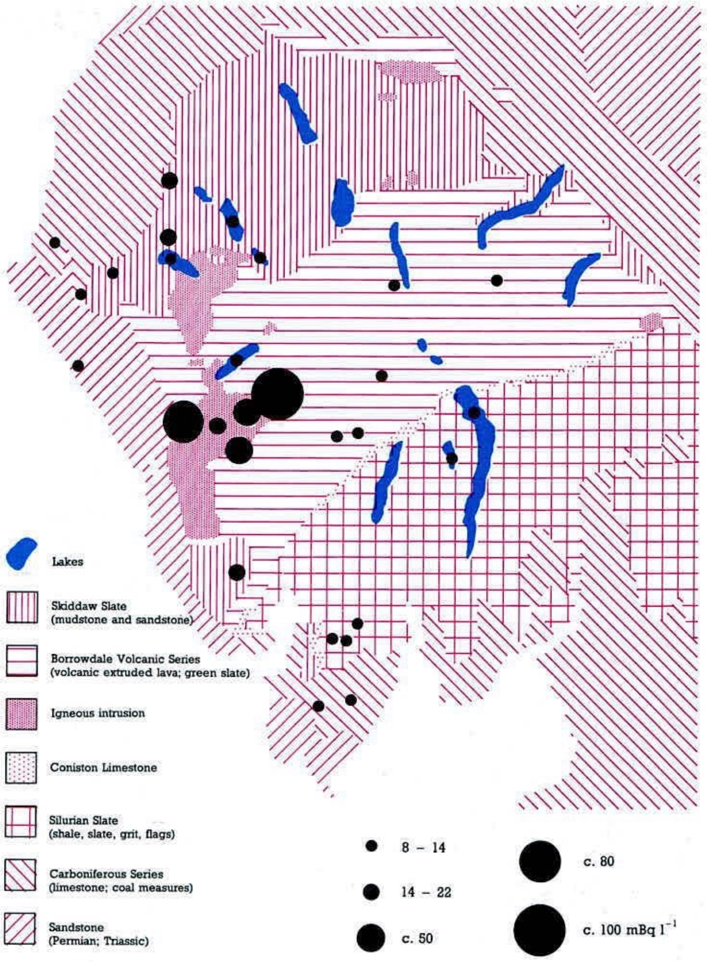


Figure 29 The concentration (mBq l⁻¹) of 137-Caesium in some Lake District waters approximately 2 years after the Chernobyl accident, together with the underlying geology.

The processes of caesium removal from the sediment were sufficiently identified that they could be fitted to a mathematical model to give realistic predictions of particle settling velocities, adsorption coefficients and boundary layer thicknesses. In a collaborative study with the Institute of Hydrology, this information and information gained from studies of fish data (see p. 13) were incorporated into a real-time computer program which predicted the change of radioactivity, specifically caesium, in several aquatic compartments, eg top water, bottom water, sediments, fish and the catchment (land surrounding the lake), given information about the amount of deposition, the size of lake and its catchment.

Subsequent releases into the water

In 1987 a small proportion (0.25%) of the radioactive caesium stored in the sediment was remobilised into the overlying waters when they became anoxic. This was the only source of caesium in Esthwaite Water after April 1987, since the catchments of both Windermere and Esthwaite were found to have retained essentially all of the caesium which had fallen on them. However, a survey of lakes in the Lake District, two years after the initial deposition, showed that several still retained much higher levels than would have been expected. Calculations showed that activity levels should have been reduced to undetectable values, even if the only process in operation was the removal of radioactivity by hydraulic flushing. In fact, activity levels were as high as 100 mBq l^{-1} in some lakes (Figure 29). Studies showed that this must be due to unexpected contributions of radio caesium from the catchments of these unusual lakes. Work in conjunction with the Institute of Terrestrial Ecology, the Ministry of Agriculture, Fisheries and Food, and colleagues in Italy, has shown that this effect is particularly pronounced on catchments which contain areas of waterlogged peat. Further studies are continuing on this particular aspect in a new, joint CEC-Soviet Union research programme which is funded by the CEC and is coordinated by the IFE.

Surface water acidification in the Lake District

There are considerable variations in the water chemistry of streams and small lakes (tarns) in the central part of the English Lake District. Although in all cases the water is relatively poor in dissolved salts, some of the waters are acid (pH<5.5) and have significant levels of the toxic metal aluminium. In order to explain this variability, and to understand the relationships between surface water chemistry and inputs of acid deposition, a modelling study was carried out, drawing on several decades of observations made by workers at the Windermere Laboratory.

The Duddon Acidification Model (DAM)

As its name suggests, DAM was developed originally for the River Duddon and its tributaries, but it is applicable to all catchments on the Borrowdale volcanic series of rocks, which comprise the central part of the Lake District. The model simulates the interactions of rainwater with the plants, soils and rocks of the catchments, and produces streamwater chemical composition as output. The key processes involved and the model structure are shown in Figure 30. In applying DAM, the catchment soils are taken to be uniform, and differences among catchments are assumed to be due only to variations in the weathering rates of the underlying rocks. The greater is the weathering rate, the greater is the supply of base cations (sodium, potassium, magnesium and calcium) to the percolating water, and therefore the higher are the concentrations of these cations in the streams and tarns.

Figure 31 shows plots of present-day pH and dissolved aluminium concentration versus base cation concentration for a number of Lake District surface waters, together with the optimised model predictions. It is seen that the susceptibility of the waters to acidification depends strongly on the ability of the underlying rocks to neutralise acidity and remove dissolved aluminium, by supplying base cations.

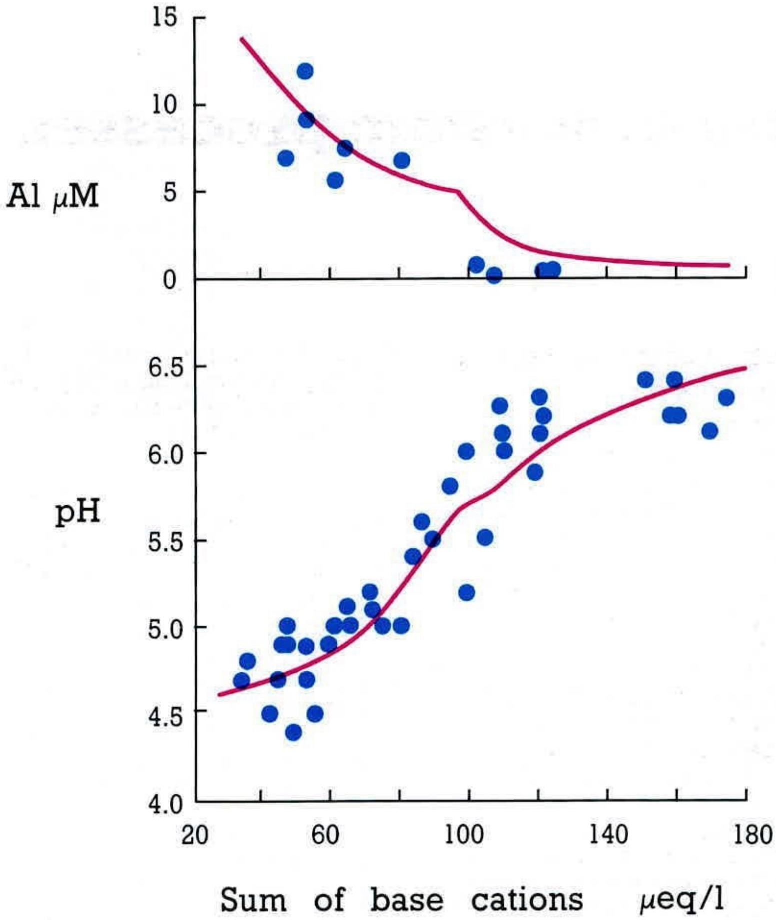


Figure 31 Variations of pH and dissolved aluminium with the sum of the concentrations of non-seasalt base cations for streams and tarns of the central Lake District. The curves show the predictions of the optimised Duddon Acidification Model.

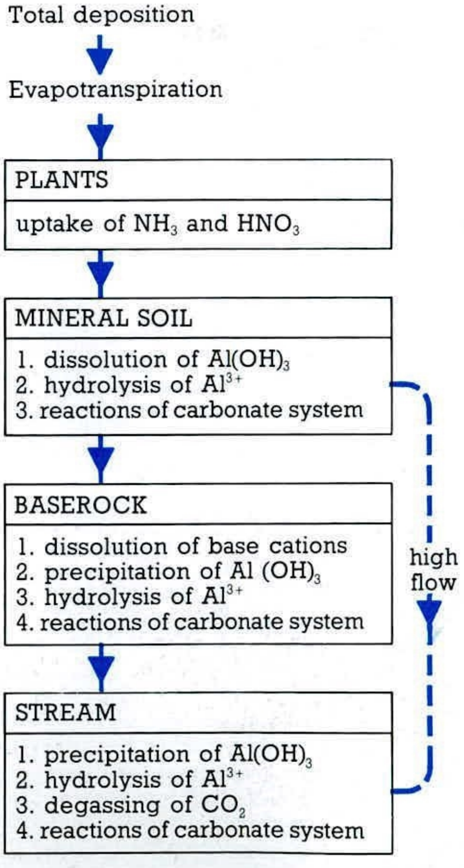


Figure 30 Structure of the Duddon Acidification Model. The arrows indicate the pathways of water.

The past and the future

In order to estimate surface water composition in the past, DAM was run with unpolluted rain as input up to 1850, with a steady increase in acidity between 1850 and 1950, and with observed inputs thereafter. The pH values for two tarns calculated in this way are shown in Figure 32, together with independent estimates obtained by analysis of the remains of diatoms in the tarns' sediments. The pH histories estimated by the two methods are in substantial agreement.

Observations on stream invertebrates and fish indicate that a pH value of 5.5 is critical with respect to the maintenance of an abundant and diverse faunal population; below this pH there is substantial impoverishment. The two tarns of Figure 32 passed through the pH 5.5 barrier in the early years of the 20th century, when acid loadings were only about half their current levels. This gives some idea of the reduction in acid deposition required to allow these waters to recover. For streams, still greater reductions would be required, because they are more sensitive to chemical conditions at high flow, when the neutralisation of acidity by the underlying rocks is less effective.

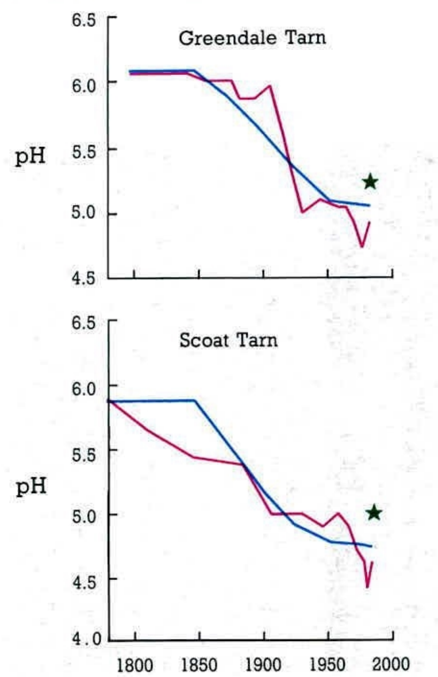


Figure 32 Estimates of past pH values for two Lake District tarns: Duddon Acidification Model; analysis of sedimentary diatom remains; current measured values.

River ecosystem processes

Prediction of phosphate coprecipitation in hardwaters

The loss of carbon dioxide (CO_2) from hard waters by either transfer to the atmosphere or the metabolic activities of algae or macrophytes, may lead to the precipitation of carbonate minerals and coprecipitation of nutrients such as inorganic phosphates. Many reports have documented the precipitation of calcite in lakes having a range of trophic conditions. In streams and rivers the precipitation of calcite usually occurs when a hardwater that is supersaturated with respect to CO_2 loses CO_2 to the atmosphere during its passage downstream. Alternatively, an increase in temperature, possible in pools and marginal areas of a river where flow is reduced, may lead to calcite formation. In lakes the process of coprecipitation is believed to be an important "self-cleaning" mechanism.

The coprecipitation reaction of phosphate during mineralisation is caused by the interaction of organic phosphorus and the calcite surface during crystal growth, followed by the incorporation of some of the adsorbed surface phosphorus into the bulk structure as growth continues (Figure 33). Phosphorus also inhibits the growth process and, depending on the supersaturation of the solution, may stop growth completely.

A simple model has been proposed to enable the prediction of phosphate losses from water by this process and the application of the coprecipitation mechanism to different situations. Certain simplifications to the original model developed from laboratory and field data can be made which permit its application to freshwaters without the need for extensive chemical data. This model requires information about the temperature, the pH and concentrations of calcium and phosphate in the water as well as the conductivity. For waters with pH values between 7 and 9 a comparison with more rigorous expressions for the coprecipitation rate indicates errors of less than 10%. The coprecipitation model has been used to interpret kinetic data from river and lake waters. The environmental conditions in which the coprecipitation of phosphorus is linearly related to calcite have been identified. These can occur in situations when the phosphorus concentration is decreasing as the acidity of the water decreases.

Alien aquatic plants

Concern over the increasingly rapid spread of the Australian swamp stonecrop *Crassula helmsii* in ponds and watercourses of the UK has led to the initiation of studies of distribution of similar, alien water plants, particularly *Myriophyllum aquaticum* (formerly

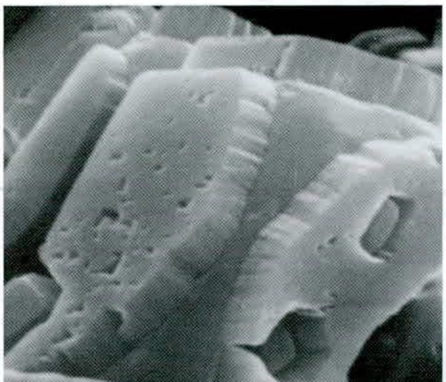


Figure 33 Particles of carbonate showing overgrowth structure obtained in the presence of phosphate. Larger particles are about 3-4 μm in size.

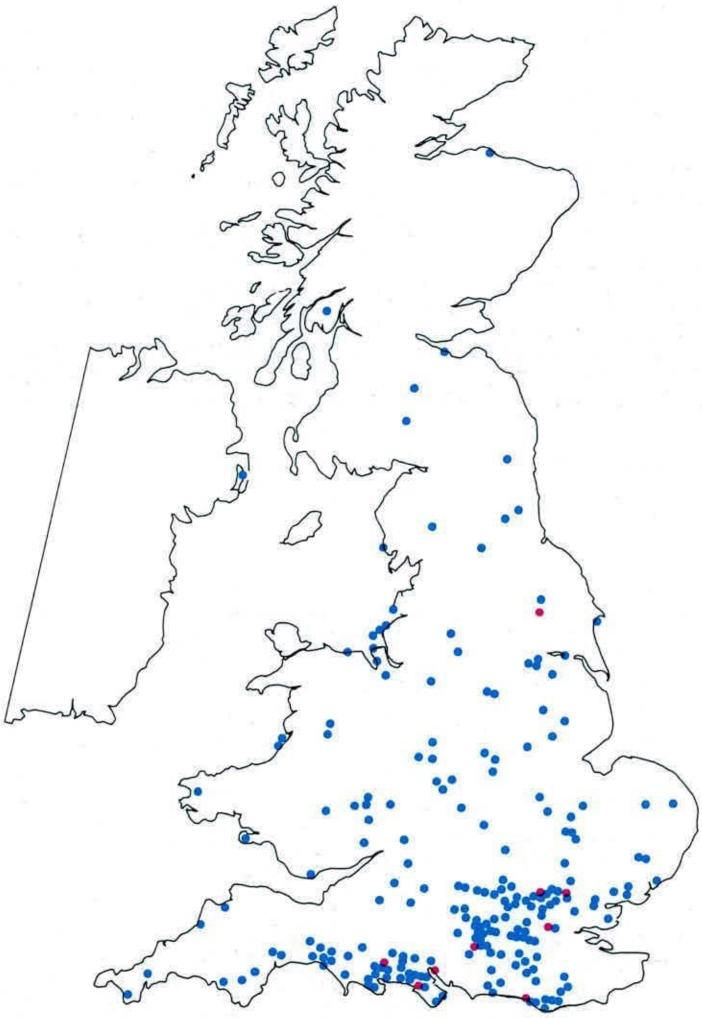


Figure 34 Increase in recorded occurrences of Crassula helmsii *from before 1970 to November 1990.*

M. brasiliense). Sporadic primary distribution to new regions of *Crassula helmsii* (Figure 34) has been ascribed to several, human related, mechanisms; particularly to the intentional, direct transfer of both plants and animals. However, the means of subsequent local or secondary dispersal is less clear but is greatly enhanced by the extreme tolerance to drying of stem fragments and by the amphibious nature of the plant. Concern has been expressed in relation to the plant's ability to tolerate low nutrient levels but to fully utilise high levels when available and to "outcompete" the native flora in certain nutrient poor lochs of Scotland.

Temporal and spatial distribution of the fry of freshwater fishes

The Hampshire Avon, downstream of Salisbury, has long been regarded as one of Britain's best coarse fisheries. In recent years there has been widespread concern that the numbers of coarse fish, particularly roach and dace, may have declined. Such complaints are very subjective and the Freshwater Biological Association, in 1987, surveyed 12 sites on the main river to determine the structure of the coarse fish associations and to provide a data base against which to assess any future changes.

The above survey produced anomalous results, relating to the growth of dace in the Avon (Figure 36), which were subsequently followed up by more detailed observations on the fry of these fish, both in natural populations and in experimental channels. In common with most studies on freshwater fish growth, year-to-year differences were observed. Growth rates of young dace decreased with distance downstream but the trend was reversed in older fish. The variations appear to be due to a complex interaction of temperature and food supply. The possibility of a marked change in diet at around age two requires investigation.

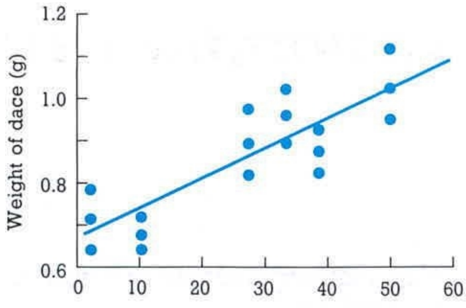


Figure 36 Varying weights of 1988 0 group dace from the Hampshire Avon.

Figure 35 Australian swamp stonecrop Crassula helmsii.

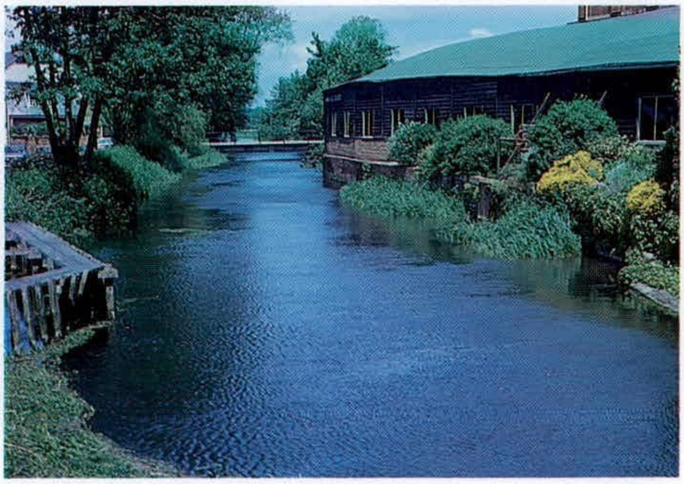


Figure 37 The Hampshire Avon at Fordingbridge.

Laboratory services

The library and information service

This has been a year of consolidations and steady progress for both the library and the information services. Backlogs have been eliminated in all areas except the archives and unpublished collection. At the Windermere Laboratory, the fitting of replacement windows and a ceiling fan to assist air circulation should now enable us to maintain comfortable working temperatures in the library area for staff and visitors.

A personal bibliographic software called Pro-Cite has been brought into use throughout the Institute. We have made extensive progress in being able to provide our Current Awareness Service; profiles from Current Contents on diskette; the results of on-line searches; and the output from searches on CD-ROM in the Pro-Cite format, so that the users can easily add relevant references to their own bibliographic lists.

We have also made some improvements to our Current Awareness Service for external customers and are now able to offer a document delivery service to subscribers. This is also part of a larger package of services available to members of the Freshwater Biological Association. Information on this range of services has been circulated to FBA members during the year and we are now beginning to see the response.

Collaboration with the other libraries within the Terrestrial and Freshwater Sciences Directorate (TFSD) of NERC has continued during the year and a constructive meeting was held with Dr Tinker in October. Following this, agreement was reached between the TFSD librarians on the fields and formats for a database of TFSD publications. It is hoped that a pilot database will be available for testing early next year.

The new phase of our work for the Environmental Chemical Data and Information Network (ECDIN) progressed well and, in collaboration with the Plymouth Marine Laboratory, we prepared summary statements for many of the most important chemicals. These statements will be made available on both the on-line database and the proposed CD-ROM database and should be a great improvement for users of the ECDIN system.

We have maintained our involvement with the Britain and Ireland Association of Aquatic Sciences Libraries and Information Centres (BIASLIC) and with the European Association of Aquatic Sciences Libraries and Information Centres (EURASLIC). We have also continued our input to the United Nations Aquatic Sciences and Fisheries Information Systems (ASFIS).

Developments in electronics and instrumentation

Specialist data loggers

Circuitry developed for the Windermere Profiler instrument has been adapted to provide eight specialist data loggers for monitoring work as part of the Environmental Assessment of Water Courses' project. These are used for long-term monitoring of basic water quality parameters.

Windermere Profiler 2

Some significant developments of this instrument, which records how temperature, light, pH, dissolved oxygen concentration and conductivity vary with depth in lakes, rivers and reservoirs, have been completed. The standard instrument now offers sediment detection,alerting the operator should the probes come within a few centimetres of lake sediment. This can prevent disturbance of the sediment which could seriously affect readings. Also, as an option, the instrument can be supplied with an environmentally-sealed, hand-held computer.

Flow Injection Apparatus

Further development of this equipment has continued both for use by the analytical chemistry laboratory and for sale. Detection levels of better than 1 ppb are expected for nitrite and phosphate and a low-cost package for these and other determinands will be available in the coming year.

Repair work for other Institutes

The department continues to offer a repair service of computer terminals to other NERC Institutes. Thirty such repairs were carried out this year producing a substantial cost saving for NERC. Repairs by the department are carried out to component level, whereas the manufacturers offer repairs to expensive sub-assembly level only.

Personal computer provision

A further 12 personal computers were purchased for the Institute this year. The department continues to coordinate procurement of personal computers and to provide hardware and software support, the latter now being shared with NCS Local Support. A short course on desk-top publishing was presented for staff.

Electrical installation and maintenance

There have been a number of laboratory and office re-fits at the Windermere Laboratory this year together with the more routine repair and maintenance work, and visits to the other IFE sites.

Property, buildings and equipment

During 1990 only two laboratories were re-furbished, one in the Station Cottage area and one in the Ferry House. Some internal re-decoration took place, along with the usual running repairs to the fabric of the site. A "rolling" programme of window replacement was started for the Ferry House and the Pearsall Building. As a means of providing additional space for the Ferry House site, planning permission was obtained to locate a Porta-Cabin between the two buildings, and this is now in use.

As a result of high lake levels and storm erosion it was necessary to repair damage to the foreshore in the vicinity of the pump cell for the hatchery water supply. It is hoped that the new material added will resist further damage for some time.

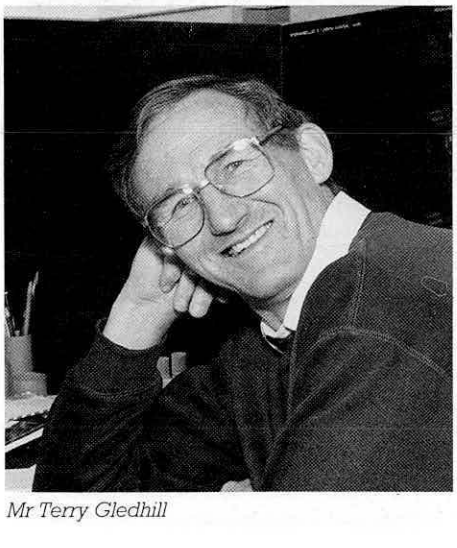
Velia, our main workboat for Windermere, was fitted with a new engine and gearbox this year when it was found that spares were no longer available for the original units. Since the original engine and gearbox were installed 35 years ago the service period does not seem unreasonable.

Staff and external activities

Staff changes

Dr W Davison left in February to take up the Chair of Environmental Chemistry at Lancaster University. Bill Davison had been on the staff of the Windermere Laboratory since 1973 and had done much to influence the direction and the quality of chemistry research within the Institute. He contributed substantially to the basic understanding of chemical processes in lakes and was awarded Individual Merit Promotion for this research. He could also tackle applied problems with new insights and his work on the reclamation of acid sand quarries led to the Award for Pollution Abatement Technology in 1985.

Mr T Gledhill took early retirement during the year. Terry joined the FBA in 1955 as assistant to Dr T T Macan at Windermere. He had developed an interest in entomology and parasitology and had been an Instructor in the Royal Army Medical Corps. Dr Macan encouraged his enthusiasm for taxonomy and he took a particular interest in water mites on which he was to become one of the few acknowledged experts. In 1961 he was the first member of staff posted to the new site for the River Laboratory in Dorset where he started field work from a caravan. There he studied river invertebrates and developed an additional interest in subterranean interstitial animals. In 1971 he was elected MIBiol on the basis of his published papers. He was a keen photographer and this skill was used to much effect within the Institute. In 1983 he moved back to Windermere to strengthen the expertise in invertebrate zoology at that laboratory.



Mr Terry Gledhill

Miss Joan Bird resigned from the Library to take up a more senior appointment at the British Geological Survey. She joined the staff in 1980 and during her ten years as Assistant Librarian she had become well known to many people through her role in providing bibliographic and other information services.

Dr A J Cowling left the CCAP group at Windermere at the end of his contract.

We were pleased to welcome several new colleagues as replacements or as additional members of staff. At the Windermere Laboratory Dr I J Winfield and Dr S C Maberly restored our expertise in fish ecology and aquatic botany respectively and Dr J G Day was appointed Curator of CCAP. Miss H G Orr and Mr M T R Hill also joined the staff. At the River Laboratory invertebrate zoology was strengthened by the recruitment of Mrs J M Winder and Mrs K L Symes and aquatic botany by the appointment of Dr R M K Saunders and Mr A G Shand.

The number of staff in post at 31 March 1991 was $105\frac{1}{2}$.

Honours and promotions

Dr E W Tipping was admitted to the degree of Doctor of Science by the University of Manchester.

Dr W A House was elected to Fellowship of the Royal Society of Chemistry and Mr K H Morris was elected to Fellowship of the Linnean Society of London.

Dr J S Welton was promoted from Senior Scientific Officer to Grade 7; Dr T G Pottinger from Higher Scientific Officer to Senior Scientific Officer; Mrs S M Smith from Scientific Officer to Higher Scientific Officer; and Mr G D Collett from Assistant Scientific Officer to Scientific Officer. Mr G A Richards' post was regraded to Industrial Band 6.

NERC activities

Mr Beaumont was a member of the Executive Committee of the NERC Branch of the Institute of Professionals,Managers and Specialists and also served on the NERC Whitley Committee. Dr Elliott was a member of the Aquatic Life Sciences Grants Committee and Mrs Hurley served on Promotion Panel IV. Professor Jones was on the TIGER II Committee; Dr Tipping on the LOIS Inception Committee; and Dr Reynolds on the Research Councils' Panel on Biomathematics. Dr Hilton was chairman of the Analysts' Working Group and Mr Casey also served as a member. Dr Cranwell was a member of the Organic Geochemistry Mass Spectrometry Advisory Committee and Dr May served on the Computer Users Committee. Dr Dawson was a NERC representative on the MRC Scientific Diving Safety Committee.

The Terrestrial and Freshwater Sciences Directorate (TFSD) of NERC, of which IFE is part, divides its research activities into a series of major programmes. Professor Berrie was coordinator of the Programme on Management of Aquatic Ecosystems and Dr Bailey-Watts, Dr House, Dr Pinder, Dr Reynolds and Dr Wright were members of the Core Group. Dr Elliott was coordinator of the Programme on Freshwater Biology and Chemistry and Dr Davison, Dr Finlay and Dr Ladle were members of the Core Group. Dr Hilton was coordinator of the Programme on Scientific Services and Mr Pettman served on the Core Group. Dr Crisp was a member of the Core Group on The Effect of Man on the Hydrological Cycle; Dr Tipping was a member of the Core Group on Environmental Pollution; Dr Elliott was a member of the Core Group on Population Ecology; Dr Reynolds was a member of the Core Group on Community Ecology; Dr Armitage acted as an adviser to the Core Group on Atmospheric Science and Hydrological Extremes; Dr George was a member of the Climate Change Task Force; and Mr Furse was a member of the Environmental Impact Assessment Task Force.

Mr Pettman acted as chairman of the TFSD Librarians' Group and Dr Tipping was a member of the Catchment Working Group. Professor Berrie represented IFE on the TFSD Marketing Group.

Collaboration with other NERC Institutes

IFE is engaged on several TFSD projects which involve collaboration with both the Institute of Hydrology (IH) and the Institute of Terrestrial Ecology (ITE). These include the Terrestrial Initiative in Global Environmental Research (TIGER); the Acid Waters Monitoring Programme with University College, London; studies on radionuclide transport; studies on upland soils; and studies on the effects of peat extraction.

Joint investigations with IH included studies on organic chemicals in the environment; on the transport and fate of pesticides; and on ecologically acceptable flows in rivers. The two institutes also collaborated on studies of catchments in mid-Wales and on some small contracts for customers.

A major joint project with ITE was the Countryside Survey 1990 which also involved the Soil Survey and Land Research Centre, the Macaulay Land Use Research Institute and the University of Newcastle. We have also continued collaboration on the development of the River InVertebrate Prediction and Classification System (RIVPACS) and on studies of the impact of pesticide spray drift. Other links have involved assessing problems associated with the release of captive bred species and some small contracts for customers.

IFE also collaborated with Institutes in other Directorates of NERC. We have worked with Plymouth Marine Laboratory and the Institute of Oceanographic Sciences on the provision of a data base on environmental chemicals and on the preparation of an aquatic directory. We have assisted the British Geological Survey with studies on colloids in groundwater and collaborated with the British Antarctic Survey on electron microscopy and its application to studies on soil structure in the Antarctic.

Scientific societies

Dr Dawson was elected to the Council of the Institute of Biology and continued as Treasurer of the Wessex Branch, while Mr Mann was a member of the Institute's Water Industry Sub-Committee. Dr Pickup was elected Convenor of the Ecology Group of the Society for General Microbiology and Dr Carling was Treasurer of the British Geomorphological Research Group. Professor Berrie became Hon. Secretary of the Malacological Society of London and also continued as a member of the Executive Committee, the Finance and Administrative Sub-Committee, and the Slapton Committee of the Field Studies Council. Dr Elliott was a member of the Council of the British Ecological Society and Dr Bailey-Watts of the Council of the British Phycological Society. Mr Mann was Vice-Chairman of the Anglian Region of the Institute of Fisheries Management and Dr Hurley was a member of the Committee of the Lancashire/Cumbria Local Group of the Royal Statistical Society.

Other organisations

Professor Jones was a member of the Scientific Advisory Committee of Baikal International Centre for Environmental Research. Dr Crisp was on the European Inland Fisheries Advisory Committee Working Group on Fish Habitat Reinstatement and Dr Hilton acted as Coordinator for the CEC collaborative research programme on Radioactivity in the Aquatic Environment.

For the Department of the Environment (DoE) Standing Committee of Analysts Dr Marker acted as Secretary to the Biological Working Group, Dr Elliott was on the Biological Methods Panel and Dr Dawson was a member of the Test Kits Protocol Panel. Dr Elliott was also a member of the DoE/Health and Safety Executive Advisory Committee on Releases to the Environment and Professor Jones was a member of the DoE/Soap and Detergent Industry Association Technical Committee on Detergents in the Environment.

Dr Ladle and Dr Crisp were members of the National Rivers Authority Regional Fisheries Advisory Committees in Wessex and Northumbria respectively. Dr Reynolds served on the NRA Toxic Algal Task Group.

Dr Armitage was a member of the Biological Standards Sub-Committee of the British Standards Institute. Dr Pinder became the IFE nominated member on the Expert Panel of the Institute of Environmental Assessment.

Mr Pettman was chairman of the Britain and Ireland Association of Aquatic Sciences Libraries and Information Centres; a member of the Working Party of the European Association of Aquatic Libraries and Information Centres; and a member of the Cumbria Environmental Information Services.

Miss Atkinson served as a Secretary of State's appointed member of the Lake District Special Planning Board and as a member of its Development Control Committee, its Park Management Committee, and vice-chairman of its Planning Policy Committee.

Dr Reynolds was a member of the Office of Water Services Consultative Committee for the North West and an adviser to the Institution of Public Health Affairs; and Professor Jones was a member of the Cumbria Environment Forum. Dr Ladle continued as chairman of the Fleet Study Group and was a committee member of the River Allen Association and of the Frome, Piddle and West Dorset Fishery Association.

Editorial commitments

Dr Elliott was Editor of the *Journal of Animal Ecology* and of the *Scientific Publications of the Freshwater Biological Association*. Dr Finlay was Editor of *Archiv für Protistenkunde* and Mr Pettman was Editor of *New Library World*. Professor Jones was Editor of *Freshwater Forum* and Editor elect of *Advances in Microbial Ecology*. Dr Cranwell was Associate Editor of *Organic Geochemistry*, Mr Mann was Assistant Editor of the *Journal of Fish Biology*, and Dr Carling became Joint Editor of *International Geomorphology*.

The following members of staff served on the Editorial or Advisory Boards of journals: Dr Armitage, *Regulated Rivers Research and Management*; Professor Berrie, *Aquatic Conservation*; Dr Crisp, *Hydrobiologia*; Dr Elliott, *Freshwater Biology, Annales de Limnologie* and *Wasser und Abwasser*; Dr Finlay, *Journal of Protozoology, European Journal of Protistology* and *FEMS Microbiology Ecology*; Dr Haworth, *Journal of Palaeolimnology*; Dr Maberly, *Aquatic Botany*; Dr Pickering, *Diseases of Aquatic Organisms*; Dr Reynolds, *Archiv für Hydrobiologie, Journal of Plankton Research* and *Aquatic Sciences*; and Dr Tipping, *Environmental Technology*.

Collaboration with universities

Teaching

Professor Jones is a Visiting Professor in the University of Liverpool and a member of Lancaster University Court. Professor Berrie is a Visiting Professor in the University of Reading. Dr Tipping is a Visiting Reader in the University of Lancaster. Dr Carling is a Visiting Lecturer in the University of Lancaster and Dr House, Dr Ladle, Mr Mann, Dr Pinder and Dr Wright are Honorary Lecturers in the University of Reading. Dr Dawson is a Visiting Research Fellow in the University of Southampton.

A short course in River Ecology was organised at the River Laboratory by Dr House for 16 postgraduate students from the International Institute for Hydraulic and Environmental Engineering, Delft, The Netherlands. Final year students from Reading University spent four days at the River Laboratory with Professor Berrie and Dr Wright as part of a course on freshwater biology. Dr Bailey-Watts gave lectures and seminars to students at the Universities of Edinburgh and Glasgow. Dr Carling gave a course on Sedimentary Oceanography at Lancaster University and Mr Mann contributed to a course on Fisheries at the University of Buckingham.

Members of staff acted as external examiners for higher degrees at the following universities: Adelaide (Dr Reynolds), Birmingham (Dr Bailey-Watts and Dr Tipping), Edinburgh (Dr Hilton), Lancaster (Dr Tipping), Leicester (Dr Reynolds), Liverpool (Dr Wright), London (Dr Wright), Sussex (Dr Ladle) and Wales (Dr Pickup and Dr Ladle).

Research

Dr Armitage carried out joint projects with University College, London, on biological problems of slow sand filters and with Loughborough University on minimum ecological flows. Dr Carling continued his joint research on sediment transport with the University of Berlin and also worked with the University of Lancaster on turbulence and dispersion in the River Severn. Mr Casey collaborated with the Polytechnic South West and with the Chisholm Institute of Technology, Australia on developments of flow injection analysis. Dr Elliott collaborated with the University of Vienna on methods of biological sampling in the River Danube. Dr Finlay continued his joint studies on anaerobic protozoa with the University of Copenhagen and, with Mr Clarke, on the ecology of a sulphide-rich lake system with the University of Valencia, Spain. Dr Haworth carried out joint studies with the University of Liverpool on sediments of Blelham Tarn and on transport and accumulation of caesium in Brothers Water. Mr Morris collaborated with the University of Glasgow on the fauna of Loch Lomond and with the Fish Conservation Centre, Stirling on fish conservation. Dr Pickup and Dr Hall continued joint research projects with the University of Liverpool and Dr Reynolds maintained his liaison with the University of Western Australia. Dr Tipping undertook modelling the effects of liming on organic soils with the University of Newcastle and Dr Winfield collaborated with the University of Wales on studies of rare fish.

Members of staff acted as supervisors for higher degree students registered at the following universities:

Miss E Baroudy (Lancaster - PhD) Effect of eutrophication on Windermere charr populations, with Dr Elliott

Miss P Broadbent (Lancaster Polytechnic - MSc) Nickel resistance in bacteria, with Dr Pickup

Miss S Brown (Liverpool - PhD) The molecular systematics of anaerobic protozoa and their prokaryote symbionts, with Dr Finlay

Miss C Bryant (Edinburgh - PhD) Trace element chemistry in water and sediment of diverse lake systems, with Dr Bailey-Watts

Miss P Campbell (Brunel - PhD) Investigation of the mechanisms underlying the deleterious effects of environmental stress on reproduction in trout, with Dr Pottinger

Miss P S Davies (Leeds - PhD) Competition for phosphorus in the control of phytoplankton community structure, with Dr Reynolds

Mr A D Findlay (Bristol - PhD) The influence of surface chemistry on particle aggregation in natural waters, with Dr Tipping

Miss B Guhl (Konstanz - PhD) Studies on the symbiosis between anaerobic protozoa and methanogens in freshwater sediments, with Dr Finlay

Mr W Hiorns (Liverpool - PhD) Probes for nitrifying bacteria, with Dr Pickup

Mr I D Hooper (Southampton - PhD) River channel vegetation and river discharge analysed by remote sensing, with Dr Dawson

Mr A T Ibbotson (London - PhD) Habitat relationships of freshwater fishes, with Dr Ladle

Mr A Kelsey (Lancaster - PhD) Modelling bedload transport, with Dr Carling

Miss K Lawlor (Liverpool - PhD) Detection of recombinant bacteria, with Dr Pickup

Mr J R Marchesi (University College, Cardiff - PhD) Sorption and biodegradation of anionic surfactants associated with mineral particles, with Dr House

Mr M McGrath (Lancaster - PhD) The biogeochemistry of alkaline earth metals in soft water lakes, with Dr Davison

Mr J A W Morgan (Liverpool - PhD) Survival, transfer and rearrangement of recombinant plasmids in aquatic systems, with Dr Pickup

Mr J Porter (Liverpool - PhD) Detection of specific bacteria, with Dr Pickup

Mr D G Smith (Lancaster - PhD) Wind-induced water movements and spatial patterns in a small eutrophic lake, with Dr George

Mr J Smith (Liverpool - PhD) Modelling the transport of Pb-210, Cs and Am-241 in the aquatic environment, with Dr Hilton

Mr D G Smith (Lancaster - PhD) Wind-induced water movements and spatial patterns in a small eutrophic lake, with Dr George

Mr A J Spink (Glasgow - PhD) Stress, disturbance and competition in submerged macrophyte communities dominated by *Ranunculus* spp, with Mr Westlake

Miss J A Taylor (Dundee - PhD) Immunofluorescence of picoplankton, with Dr Heaney

Mr M R Taylor (Portsmouth Polytechnic - PhD) Characterisation of the microbial community within the digestive tracts of freshwater Insecta, with Dr Ladle

During the year five of our former research students were awarded PhD degrees: Miss E G Berninger (Berlin), Mr P M Reid (Manchester), Miss K J Saxby (Birmingham), Mr J D R Talbot (Reading) and Mr G J C Underwood (Sussex).

International meetings and visits

Professor Jones attended the launch of the Baikal International Centre for Environmental Research at Lake Baikal and visited the Institute for Biology of Inland Waters at Borok, USSR. Dr Pickering was a Keynote Speaker at the Fourth International Symposium on Genetics in Aquaculture in Wuhan, China; at the Aquaculture Symposium in Helsinki, Finland; and at the International Symposium on the Rainbow Trout at Stirling. He also undertook a guest lecture tour to the University of New Brunswick and other centres in eastern Canada.

Dr Armitage was an invited speaker at the Water Resource Symposium in Vittoria, Spain. He was also co-organiser of the International Conference on the Conservation and Management of Rivers held at York at which Dr Wright contributed a paper and Mr Mann and Mr Bass presented a poster. Dr Bailey-Watts spent six weeks in Bangladesh on a Project Identification Fisheries Mission for the Overseas Development Administration. Dr Carling gave an invited paper at an international symposium in Florence, Italy and visited Coblenz, Germany and Montana, USA to discuss and set up collaborative research on sediment transport in rivers.

Mr Casey spent six months in Australia on secondment to the Murray-Darling Freshwater Research Centre where he contributed to several research and advisory projects and introduced flow injection analysis in collaboration with the Chisholm Institute of Technology, Melbourne. He gave talks at the Chisholm Institute, Adelaide University and the CSIRO Griffith Laboratory and also at the New Zealand DSIR Laboratories at Hamilton and Lake Taupo.

Dr Crisp took part in a European Inland Fisheries Advisory Commission working party in Lyon, France. Dr Day presented an invited paper at a meeting on Culture Collections of Algae in Tsukuba, and visited a number of research laboratories and culture collections in Japan. Dr Finlay and Mr Clarke visited lagoons in central Spain to study anaerobic protozoa. Mr Glaister visited Berlin, Germany to complete some joint studies.

Dr Haworth was an invited speaker at the Polish International Phycological Symposium in Poznan, carried out some studies at Warsaw University and presented a poster at the International Diatom Symposium in San Francisco, USA. Dr Hilton attended a conference on Sediment and Water Interactions in Uppsala, Sweden and a CEC coordination meeting in Rome, Italy. Dr House made three visits to Belgium for European Commission meetings on the development of pesticide standards.

Mr Pettman chaired a session at the European Association of Aquatic Libraries and Information Centres meeting in Paris, France. Dr Pickup presented four posters at the International Meeting on Molecular Techniques in Microbial Ecology at Braunschweig, Germany and he visited several laboratories in Japan to establish collaborative links. Dr Pinder visited the University of Chiang Mai, Thailand as a guest lecturer and advisor to their Water Research Centre.

Dr Reynolds gave a Keynote Address at the International Congress of Ecology in Yokohama, Japan and undertook a guest lecture tour of the Universities of Wisconsin and Michigan, USA. He was also UK Rapporteur to a meeting on the Ecosystems Approach to Water Quality Management organised by the United Nations. Dr Tipping visited the University of Oslo, Norway to undertake joint modelling work on acidified catchments. Dr Welton and Mr Beaumont gave a paper at an International Symposium and Workshop on Catch-effort Sampling Techniques at Hull. Dr Winfield attended a Workshop on Ecosystems and Eutrophication in Pallanza, Italy and visited the Institute of Limnology in Nieuwersluis, Netherlands. He and Mr Morris presented posters at the Conference on the Biology and Conservation of Rare Fish at Lancaster.

Looking to the future, Dr Pickering is a member of the Organising Committee for the Second International Symposium on Fish Endocrinology to be held in Brittany in 1992 and of the meeting on Pathological Conditions of Wild Salmonids to be held in Aberdeen in 1992. Mr Mann is on the Steering Committee of the Third Symposium on Ecology of Fluvial Fishes to be held in Warsaw in 1991. Dr Dawson is a Coordinator for the Joint European/American Conference on Aquatic Weeds to be held in Florida in 1992. Dr Winfield is a member of the Organising Committee of Aquatic Birds 91 being arranged by the Canadian Wildlife Service in 1991.

The Freshwater Biological Association

Collaboration between the IFE and the FBA continues to be extremely fruitful. One additional research student has been appointed by the Association, Miss Sian Davies, who will work under Dr Colin Reynolds' guidance on aspects of algal nutrition. The research project is funded by TESCO and has permitted us to expand our collaboration with the University of Manchester.

During the year the FBA launched its new publication, *Freshwater Forum*, which supersedes the Annual Reports of the Freshwater Biological Association, the last one being the 58th report published in June 1990. Henceforth, brief reports from the Director and Council of the FBA, and accounts for the financial year, will be published in *Freshwater Forum*. This new publication will be issued in three parts during its first year, in March, June and November 1991.

Freshwater Forum will act as a bulletin to keep members regularly informed of events and issues of direct concern to members or of wider interest. It will also contain review articles on a wide range of topics relevant to all aspects of the science of fresh waters. Additional material will consist of comments and discussion on articles appearing in *Freshwater Forum* and topical issues concerning human and environmental impacts on the freshwater environment. Brief articles interpreting published material in a new light are welcome. Brief articles incorporating novel findings may be accepted if they are put into perspective, are considered to be timely, and draw attention to points of general interest. The prime concerns are to inform and stimulate further enquiry and comment, rather than providing a vehicle for merely recording facts.

A prize of £50 will be awarded each calendar year for the best article submitted by a full-time undergraduate or research student. Articles should cast an original view on some aspect of freshwater science. They should not exceed six printed pages in length, including tables, text-figures and references, and the text should be less than 2,000 words.

FBA colour poster on blue-green algae

The FBA has published an attractive and informative full colour poster, printed on glossy art paper, size 51 x 76 cm (2 x 3 ft) vertical, which is now available. It contains 12 colour photographs, 10 of them photomicrographs by Dr Hilda Canter-Lund FRPS, together with text by Dr J W G Lund FRS.

Posters cost £2.00 each and are dispatched rolled in cardboard tubes. Each tube will accommodate up to five posters. Postage and packing per tube is £1.00, (£2.50 overseas). Cheque with order please, drawn on a UK bank, to Department DWS, FBA, The Ferry House, Ambleside, Cumbria LA22 OLP.

Further details of FBA publications may be obtained from the same address.

Appendix 1
Finance and administration

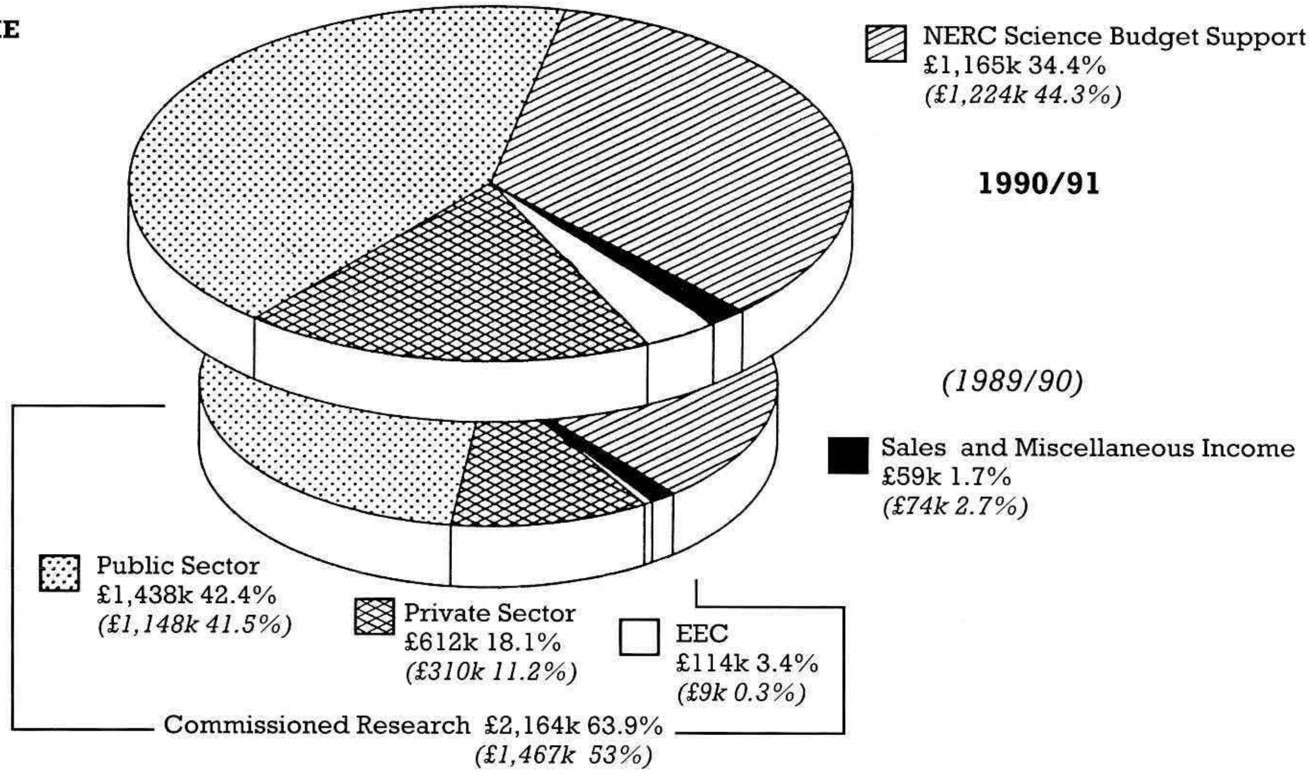
Finance

A summary of the financial accounts for the year ended 31 March 1991 is shown in the pie-charts, together with the comparative figures for 1989/90.

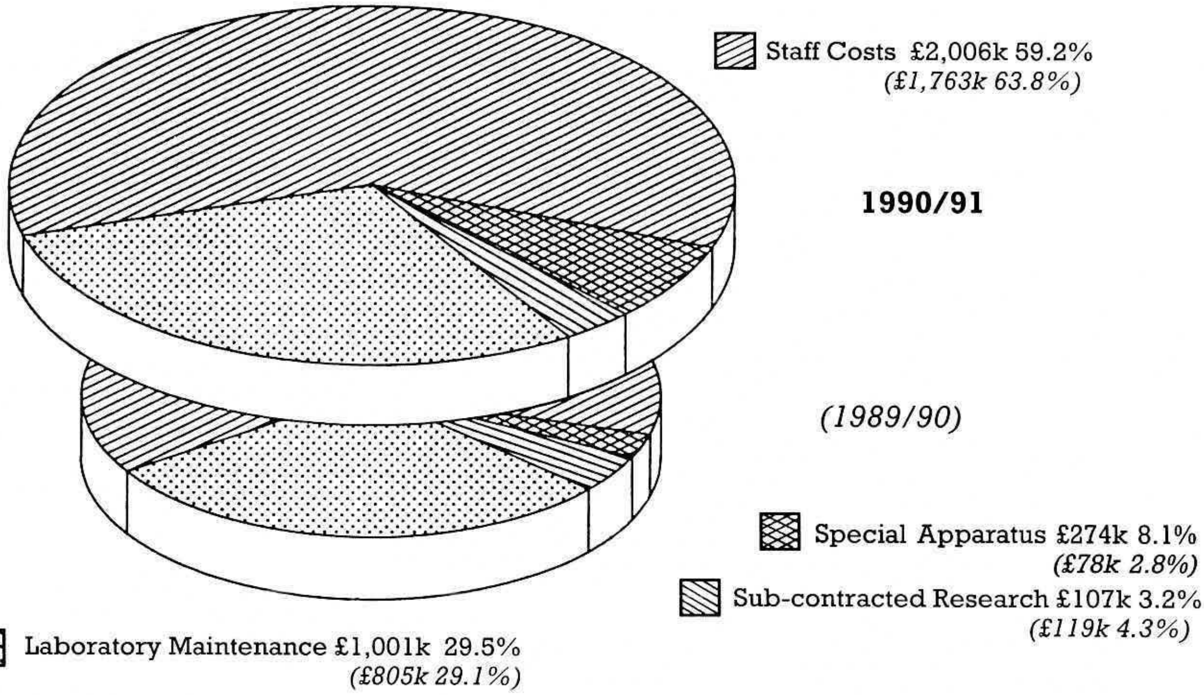
These reflect a notable achievement in that for the first time the Institute's commissioned earnings (£2,164k) significantly exceeded the Science Budget funding for the year (£1,165k).

Together with items of miscellaneous income (£59k), these financed the increased total cash spend of £3,388k (1989/90 £2,765k).

INCOME

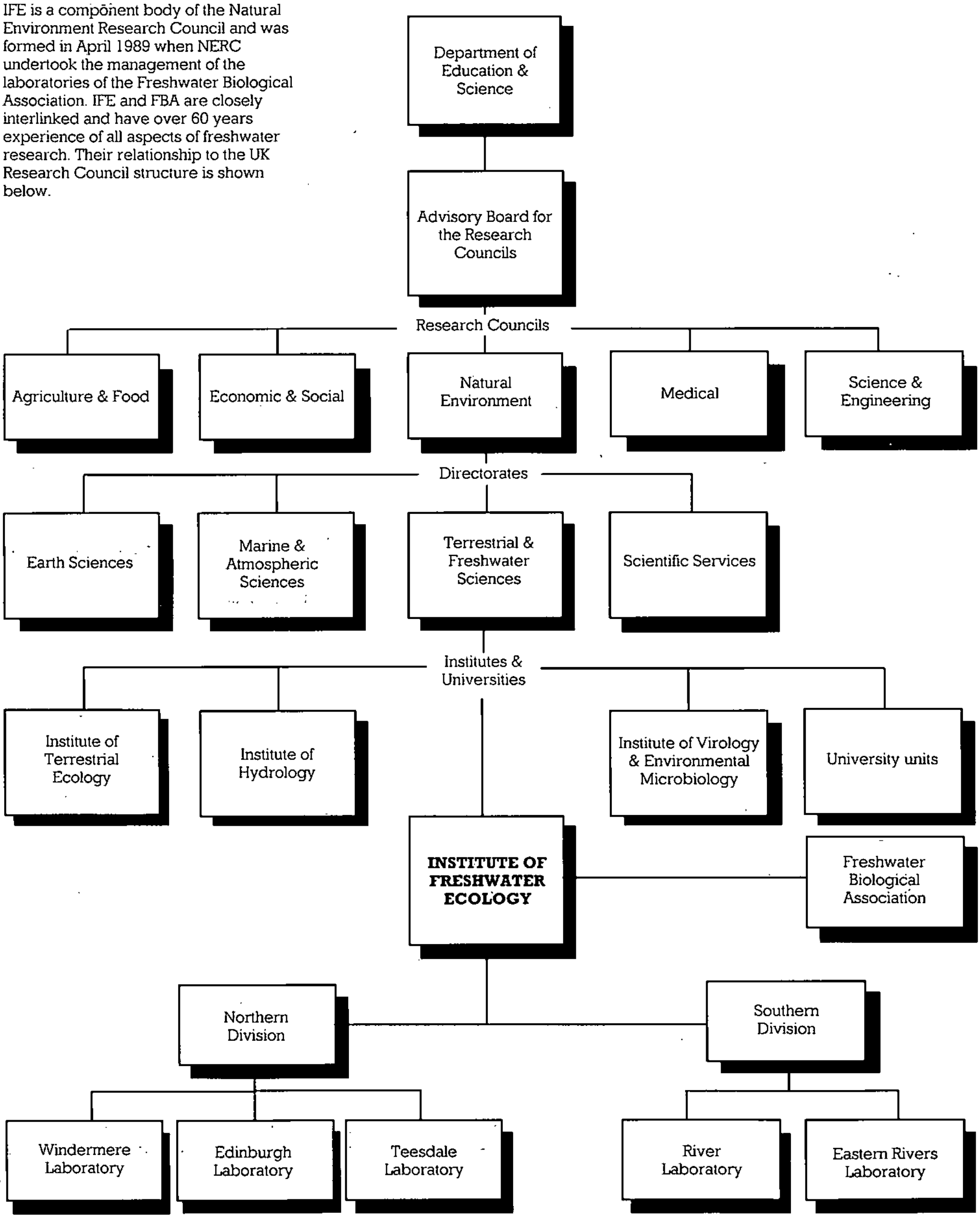


EXPENDITURE



Relationship to UK Research Council structure

IFE is a component body of the Natural Environment Research Council and was formed in April 1989 when NERC undertook the management of the laboratories of the Freshwater Biological Association. IFE and FBA are closely interlinked and have over 60 years experience of all aspects of freshwater research. Their relationship to the UK Research Council structure is shown below.



IFE Management/Administration/Services

- **Prof J Gwynfryn Jones**
  Director (IFE & FBA)
  - **Dr A D Pickering**
    Head, Northern Division
    - **Mr C J Moakes**
      Finance
    - **Miss K M Atkinson**
      Management assistance
    - **Mrs M Thompson**
      Secretarial services
    - **Mr F R Ohnstad**
      Laboratory services
    - **Mr M A Rouen**
      Electronics
    - **Mr I Pettman**
      Library
  - **Prof A D Berrie**
    Head, Southern Division
    - **Mr J Morgan**
      Laboratory services
    - **Mrs D M Morton**
      Secretarial services

IFE Science Panel structure

- **Prof J Gwynfryn Jones**
  Director
  (IFE & FBA)
  - **Dr A D Pickering**
    Head, Northern Division
    - **Dr W Davison** and **Dr E W Tipping**
      Physico-chemical processes in catchments
    - **Dr J M Elliott**
      Fish population dynamics and management
    - **Dr B J Finlay**
      Microbes in the aquatic environment
    - **Dr A E Bailey-Watts**
      Assessment and prediction of changes in the aquatic environment
    - **Dr C S Reynolds**
      Management of lakes and reservoirs
  - **Prof A D Berrie**
    Head, Southern Division
    - **Dr M Ladle**
      River ecosystem processes
    - **Dr L C V Pinder**
      Ecology of large lowland rivers
    - **Dr J F Wright**
      Land-river interactions

Appendix 2
Staff list

Management/Administration

Director	Prof J G Jones	Grade 5
Head Northern Division	Dr A D Pickering	Grade 6
Head Southern Division	Prof A D Berrie	Grade 6
Management assistance	Miss K M Atkinson	HSO
Secretary to Director	Mrs M Thompson	EO
Secretarial services (Windermere)	Mrs S Smethurst	PSec
	Mrs Y Dickens	Ty Pt
	Miss K Ross	Ty
	Miss D Grocock	SB1
(River Laboratory)	Mrs D M Morton	EO
	Mrs V B Palmer	AO Pt
Finance Officer	Mr C J Moakes	SEO
Finance and establishments	Miss P Parry	EO
	Miss B Grant	AO

Management of lakes and reservoirs

Project Leader	Dr C S Reynolds	Grade 6
	Dr D G George	Grade 7
	Dr S C Maberly	SSO
	Dr L May	SSO
	Miss C Butterwick	HSO
	Ms D P Hewitt	HSO
	Dr A E Irish	HSO
	Mr A Kirika	HSO
	Mr A A Lyle	HSO
	Mr K H Morris	HSO
	Miss P S Davies	RS

Assessment and prediction of changes in the aquatic environment

Project Leader	Dr A E Bailey-Watts	Grade 7
	Dr E Y Haworth	Grade 7
	Mrs M A Hurley	SSO Pt
	Mr G H M Jaworski	SSO
	Miss J E Corry	SO
	Mrs J V Roscoe	SO Pt
	Miss C Bryant	RS
	Miss J A Taylor	RS

Ecology of large lowland rivers

Project Leader	Dr L C V Pinder	Grade 7
	Dr A F H Marker	Grade 7
	Mr R H K Mann	Grade 7
	Mr J A B Bass	SSO
	Mr D V Leach	SO
	Mr G D Collett	SO
	Mr A C Pinder	ASO
	Dr G H Copp*	RF

Land-river interactions

Project Leader	Dr J F Wright	Grade 7
	Dr P D Armitage	Grade 7
	Mr M T Furse	Grade 7
	Mr J H Blackburn	HSO
	Mr R J M Gunn	HSO
	Mrs J M Winder	SO
	Mrs K L Symes	ASO

Fish population dynamics and management

Project Leader	Dr J M Elliott	Grade 6
	Dr D T Crisp	Grade 7
	Dr T G Pottinger	SSO
	Dr I J Winfield	SSO
	Mr P R Cubby	HSO
	Mrs P A Tullett	HSO Pt
	Miss J M Fletcher	SO
	Miss T Moran	SO
	Miss E Baroudy	RS
	Miss P Campbell	RS

Microbes in the aquatic environment

Project Leader	Dr B J Finlay	Grade 7
	Dr G H Hall	SSO
	Mr B M Simon	SSO
	Dr R W Pickup	SSO
	Mr K J Clarke	SSO
	Mrs R M Hindle	SO Pt
	Mrs H E H Mallinson	ASO
	Miss P Broadbent	RS
	Miss S Brown	RS
	Miss B Guhl	RS
	Mr W Hiorns	RS
	Miss K Lawlor	RS
	Dr J A W Morgan*	RF
	Mr J Porter	RS
Culture Collection for Algae and Protozoa	Dr J G Day	SSO
	Miss S Brown	SO
	Miss M M Deville	SO
	Ms J Tompkins	AO Pt
	Mrs A Cook	ASO Pt

Physico-chemical processes in catchments

Project Leaders	(Dr W Davison	Grade 6
	(Dr E W Tipping	Grade 7
	Dr P A Carling	Grade 7
	Dr P A Cranwell	Grade 7
	Dr J Hilton	Grade 7
	Mr T R Carrick	SSO
	Mr C P Woof	SSO
	Mrs J P Lishman	HSO Pt
	Mr E Rigg	HSO
	Mr M S Glaister	SO
	Mr M T R Hill	SO
	Mr J B James	ASO
	Miss H G Orr	ASO
	Miss P Southern	ASO
	Mr A Kelsey	RS
	Mr M McGrath	RS
	Mr J Smith	RS

River ecosystem processes

Project Leader	Dr M Ladle	Grade 7
	Mr H Casey	Grade 7
	Mr R T Clarke	Grade 7
	Dr F H Dawson	Grade 7
	Dr W A House	Grade 7
	Dr J S Welton	Grade 7
	Mr I S Farr	SSO
	Mr W R C Beaumont	HSO
	Mr P Henville	HSO
	Dr R M K Saunders	HSO
	Mrs S M Smith	HSO
	Mr D R Orr	SO
	Mr A G Shand	SO
	Mr I D Hooper	RS
	Mr A T Ibbotson*	RS
	Mr J R Marchesi	RS
	Mr A J Spink	RS
	Mr M R Taylor	RS

Laboratory services

Windermere Laboratory	Mr F R Ohnstad	SPTO
	Mr P V Allen	HSO
	Mr M A Rouen	HSO
	Mr T I Furnass	GO
	Mr B M Godfrey	PTO
	Mr D I Aspinall	PTO
	Mr J Crompton	PTO
	Mr P M Hodgson	PTO
	Mr G Gregson	Ind
	Mrs J Gregson	Ind
	Miss N Lund	Ind
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	Miss J V Bird	ALib
	Miss S Scobie	ALib
	Mrs K Crompton	AO
	Mrs K J Pearson	AO Pt
	Mrs J H Dobson	SO Pt
	Miss A Benning*	RF

Fritsch Collection of Algal Illustrations

Honorary Curator	Dr J W G Lund*	
	Mrs E G Devlin*	
	Mrs E Monaghan*	

River Laboratory	Mr J Morgan	HPTO
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	Mr S C Shinn	PGSE
	Mr G A Richards	Ind
	Mrs J Whitmarsh	Ind Pt

Abbreviations:

ALib	Assistant Librarian
AO	Administrative Officer
ASO	Assistant Scientific Officer
EO	Executive Officer
GO	Graphics Officer
HPTO	Higher Professional & Technical Officer
HSO	Higher Scientific Officer
Ind	Industrial
PGSE	Process & General Supervisory E
PSec	Personal Secretary
Pt	Part-time
PTO	Professional & Technical Officer
RF	Research Fellow
RS	Research Student
SB1	Support Band 1
SEO	Senior Executive Officer
SLib	Senior Librarian
SO	Scientific Officer
SPTO	Senior Professional & Technical Officer
SSO	Senior Scientific Officer
Ty	Typist
*	FBA - not IFE establishment

Appendix 3
Project list

Management of lakes and reservoirs

Project T04050-5 at Windermere and Edinburgh Laboratories
Programme TFS4 Management of aquatic ecosystems
Leader C S Reynolds
Funding Science budget/commission/miscellaneous consultancies
Objectives To obtain greater resolution and experience in all biological aspects of stored-water quality, including methodology development, tracing physical water movements, chemical recycles and pelagic population dynamics. To develop computational methods for predicting and applying state-of-the-art knowledge to practical problems.

Assessment and prediction of changes in the aquatic environment

Project T04051-5 at Windermere, Edinburgh and River Laboratories
Programme TFS4 Management of aquatic ecosystems
Leader A E Bailey-Watts
Funding Science budget/commission
Objectives
a) The acquisition of physical, chemical and biological data from diverse aquatic ecosystems with the primary purpose of identifying and quantifying environmental changes associated with man's activities, distinguishing man-made change from natural variations and trends and giving early warning of undesirable effects.
b) To seek a better understanding of organisms and fundamental processes within the aquatic environment and to identify particular variables, processes and aquatic environments which are sensitive to change.
c) To develop qualitative and quantitative models for the assessment and prediction of change in aquatic ecosystems as influenced by catchment perturbation.
d) To apply the knowledge to the mitigation and preferably prevention of problems attributed to cultural eutrophication, acidification and other results of human pressures.

Ecology of large lowland rivers

Project T04052-5 at Eastern Rivers and Windermere Laboratories
Programme TFS4 Management of aquatic ecosystems
Leader L C V Pinder
Funding Science budget/commission
Objectives The broad objectives are to quantify the physical, chemical and biological interactions within large lowland river systems and to develop models that describe these interactions and are capable of predicting the effects of changes in factors such as management and levels of pollution.
Immediate, specific objectives include:-
a) Development of a model of flow relating hydrological and morphological properties of channels in order to predict sedimentation and transport of particulates, dissolved pollutants and dynamics of phytoplankton.
b) Determination of seasonal and spatial patterns of abundance of invertebrates and larval and juvenile cyprinid fish in the Great Ouse and relating these to factors such as channel morphology, vegetation, water velocity, management, recreational pressures and pesticides.
c) Examination of the effects of changes in light climate, due to turbidity, on the growth and development of macrophytes and phytoplankton in the Great Ouse.

Land-river interactions

Project T04053-5 at River and Windermere Laboratories
Programme TFS4 Management of aquatic ecosystems
Leader J F Wright
Funding Science budget/commission
Objectives This project, which is heavily commissioned, includes strategic and applied research in river management, conservation, the impact of land-use on river biota and environmental impact assessment. The relationship between catchment features/land use and the river biota is being addressed through collaborative work with the Institute of Terrestrial Ecology (ITE) and also through a new commission on headwater streams.
Current objectives include i) research on river management and pollution assessment which is responsive to the requirements of the National Rivers Authority; ii) studies to provide the Nature Conservancy Council with information on river biota, techniques for site appraisal and methods for detecting the impact of river management procedures; iii) provision of a freshwater component to the 1990 Countryside Survey; iv) examination of the behaviour of pesticides in running waters and the impact of these and other pollutants on the fauna; v) development of a database on the biota and environmental conditions in British rivers to service various sub-projects and ensure the availability of the data for future uses (e.g. environmental impact assessments, long-term monitoring, climate change studies).

Fish population dynamics and management

Project T11050-5 at Windermere, Edinburgh, River and Teesdale Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader J M Elliott
Funding Science budget/commission
Objectives
a) To obtain quantitative information on variations in numbers, biomass, growth rates, mortality rates, production rates, movements and feeding of fish and their food organisms in streams, rivers, lakes and reservoirs. To identify the extrinsic and intrinsic factors affecting these variables and to develop mathematical models that can be used to predict quantitative changes in these variables. Particular emphasis is placed on populations of brown trout, pike, perch, charr and the rare coregonids (schelly, vendace).
b) To elucidate the basic physiological and endocrinological changes that occur when fish are subjected to acute and chronic environmental stress, with special emphasis on survival, disease resistance, growth and reproduction. To investigate methods for controlling the stress response by modifying the fish's environment or by selecting, for breeding purposes, fish with low sensitivities to environmental stress.
c) To interpret and apply the results of the above work so that they can be used for the scientific management and conservation of stocks of freshwater fish and their environments, especially in relation to human perturbations such as eutrophication, acidification, changes in land use and changes in climate.

Microbes in the aquatic environment

Project T11051-5 at Windermere Laboratory
Programme TFS11 Freshwater biology and chemistry
Leader B J Finlay
Funding Science budget/commission
Objectives
a) To investigate the identity, diversity, distribution and functional role of microbes and microbial processes in aquatic (especially freshwater) environments.
b) The innovative exploitation of aquatic microbes with biotechnological potential, especially algae, protozoa and free-living prokaryotes.

Physico-chemical processes in catchments

Project T11052-5 at Windermere and River Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader W Davison and E W Tipping
Funding Science budget/commission
Objectives
a) To investigate the pathways and transformations of particulate and soluble chemical components in catchments.
b) To further understanding of the fundamental physical, chemical and biological processes operating in soil waters, rivers and lakes.
c) To develop quantitative models of individual processes and of physical and chemical ecosystems.

River ecosystem processes

Project T11053-5 at River and Windermere Laboratories
Programme TFS11 Freshwater biology and chemistry
Leader M Ladle
Funding Science budget/commission
Objectives This project includes strategic and applied research into river ecosystem processes. The study area ranges from procedures designed to measure the kinetics of chemical transport processes at the particle/water interface; through physical, chemical and biological investigations designed to improve management and understanding of plant communities in running waters; studies of the environmental impact of management activities including control measures for insect pests such as the Blandford Fly; development of techniques for the determination of runs of migratory salmonid fishes and for the validation of fish counting installations; establishment of the natural patterns of recruitment and resource utilisation by coarse fishes and the solution of problems of classification, identity, distribution and population genetics in a wide range of aquatic organisms.

Appendix 4
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The FBA continues to run a programme of basic research under the guidance of its Council. It also continues to provide services for its corporate and individual members and they are notified separately as to how the changes may affect them.

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