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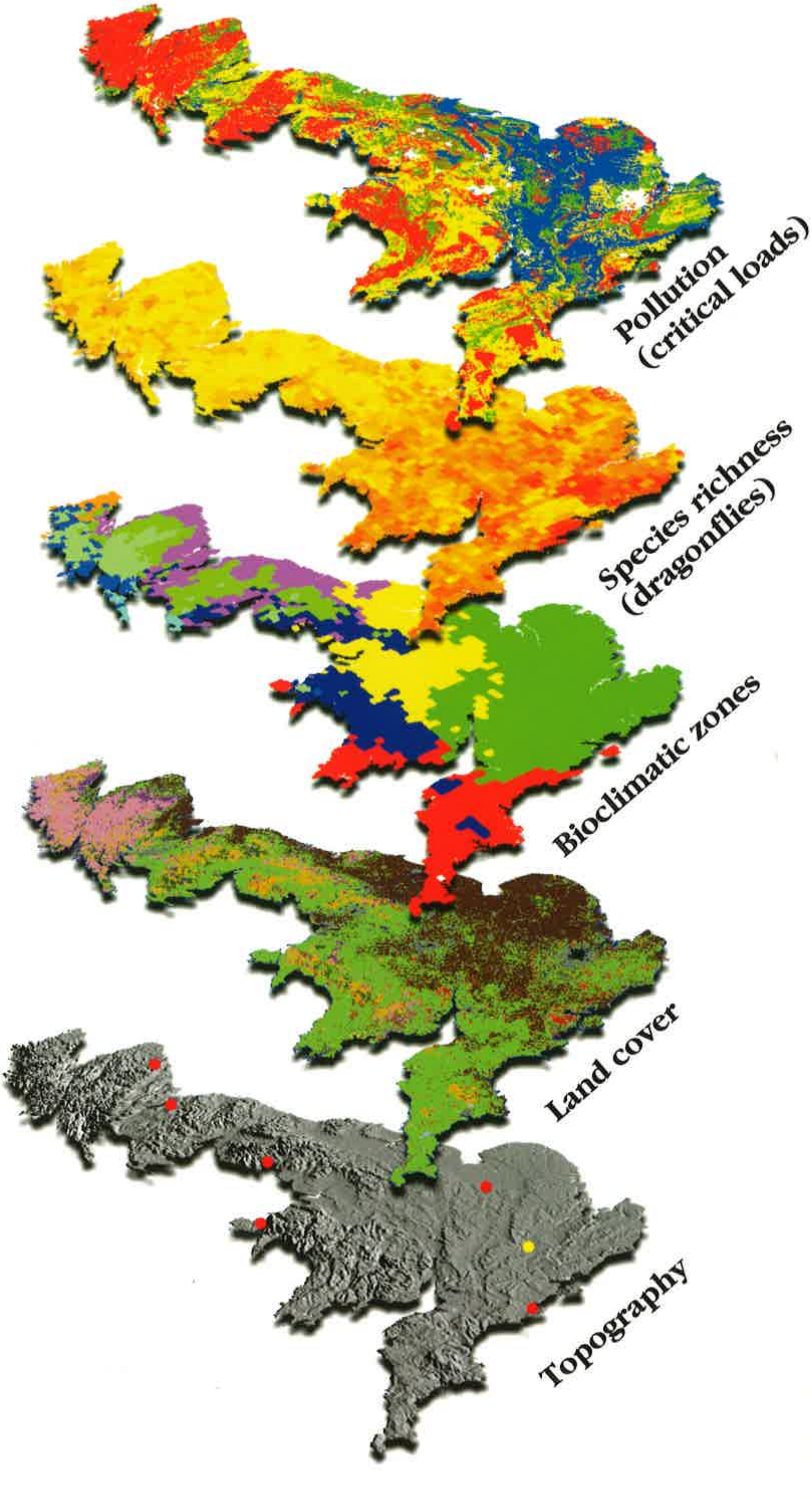

Institute of Terrestrial Ecology

Scientific Report 1997–98

Centre for Ecology and Hydrology

Natural Environment Research Council

Silver Jubilee – Silver Jubilee – Silver Jubilee – Silver Jubilee – Silver Jubilee –

ITE's mission statement

The Institute of Terrestrial Ecology will develop long-term, multidisciplinary research and exploit new technology to advance the science of terrestrial ecology, leading to a better understanding and quantification of the physical, chemical and biological processes of the land.

Priority is placed on developing and applying knowledge in the following areas:

- the factors which determine the *composition*, *structure*, and *processes* of terrestrial ecosystems, and the *characteristics* of individual plant and animal species

- the dynamics of *interactions* between atmospheric processes, terrestrial ecosystems, soil properties and surface water quality

- the development of a sound scientific basis for *monitoring*, *modelling* and *predicting* environmental trends to assess past, present and future effects of natural and man-made change

- the securing, expansion and dissemination of ecological data to further scientific research and provide the basis for impartial advice on environmental protection, conservation, and the sustainable use of natural resources to governments and industry.

The Institute will provide training of the highest quality, attract commissioned projects, and contribute to international programmes.

ITE will promote the use of research facilities and data to enhance national prosperity and quality of life.

Twenty Fifth
Scientific Report of the
Institute of Terrestrial Ecology
1997–1998

Edited by:
T M Roberts, K Threlfall, and J Sheail

Centre for Ecology and Hydrology
Natural Environment Research Council

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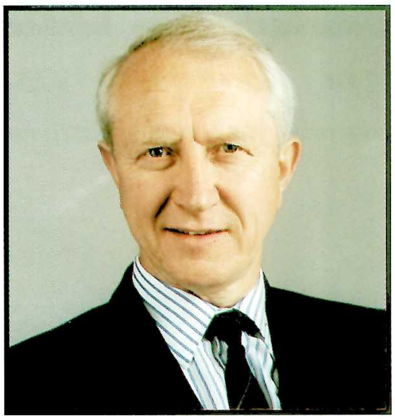


The environmental agenda has shown no diminution during the year. Issues such as deforestation, dryland degradation and climate change persist. Natural disasters, resulting from flood, drought and forest fires, have caused disruption to the lives of millions of people and many deaths worldwide. Man-made disasters, resulting from pollution or other causes, are all too evident.

Foreword by CEH Director

Internationally, there is a growing political will to address such problems as those mentioned above. The United Nations Framework Convention on Climate Change, aimed at stabilisation of greenhouse gases in the atmosphere, has taken its first historic steps towards achieving this goal through the 1997 Kyoto Protocol. Nationally, with a change in government, we have seen environmental issues move up the agenda. The Right Honourable Michael Meacher, MP, Minister for the Environment, in presenting the 1998 Natural Environment Research Council (NERC) Lecture, showed both his personal and the government's commitment towards sustainable management.

To address such issues a multi-disciplinary approach is needed and the Centre for Ecology and Hydrology (CEH), with one of the strongest capabilities in the world for undertaking holistic research in the terrestrial and freshwater sciences, is well placed in this respect.

NERC places a high value on our science and has shown a willingness to invest in the future of CEH through a programme of rationalisation and restructuring. The first step has been to approve a £2.86 million extension to CEH's Wallingford site. I am confident that investments at other CEH sites, rising from the package approved by Council last year as part of the so-called 'Prior Options' Review, will be made during the coming years.

The impact of the rationalisation and restructuring activity has caused some uncertainty amongst staff during the year. However, our staff are highly skilled, innovative and well motivated, and it is to their credit that, during these uncertain times, they have not only maintained scientific output but increased it in some areas. For example, CEH peer review publications have increased by 21% this year over last.

Under the leadership of its Director, Professor Mike Roberts, CEH's *Institute of Terrestrial Ecology (ITE)* has had an excellent year to mark its *Silver Jubilee*. During the year, the Institute has contributed fully to the Centre's 10 Science Programmes and has joint research projects in place with all of the other CEH Institutes. Descriptions of these scientific activities are presented in this report. Within the report there are also articles from past Directors and these present an intriguing insight into the development of the Institute's science over the last 25 years.

Professor Mike Roberts is also the Deputy Director of the Centre and I would offer my personal thanks to him for his full support in developing CEH policy and strategy during the past year.

This year's annual reporting follows the arrangement established last year, whereby the CEH Annual Report provides an overview of our scientific progress and principal achievements, while the Scientific Reports of the Centre's component Institutes:

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

present more detailed reviews of the science.

I commend this Scientific Report from the *Institute of Terrestrial Ecology* to you, together with the overview CEH Annual Report and the complementary reports from the other CEH Institutes.

NERC places a high value on our science and has shown a willingness to invest in the future of CEH through a programme of rationalisation and restructuring.

Prof W B Wilkinson

This 1997–98 Scientific Report marks the Silver Jubilee of the formation of the Institute in 1973. Prior to 1973, ITE was the Research Branch of the Nature Conservancy.

Introduction by ITE Director

Achievements have been set against a background of major organisational changes in the management of research in the UK and the rapid evolution of environmental policy.

This report documents the achievements of the major scientific programmes over the last 25 years. They are set against the background of major organisational changes in the management of research in the UK and the evolution of environmental policy. The current management team (Plate 1) have contributed in a major way to these achievements.

The striking feature of ITE's early development was the rapid *diversification* from conservation ecology to broadly-based environmental science. This trend has culminated in the incorporation of ITE into the Natural Environment Research Council's (NERCs) Centre for Ecology and Hydrology (CEH) and the development of productive interdisciplinary science programmes.

The initial diversification was partly driven by the need to increase commissioned research following the transfer of research funds to government departments under the 'Rothschild Principle'. More recently, the Institute has been so successful in expanding the user community base that this has fuelled a modest expansion and investment programme. In the last decade, ITE has doubled the output of high quality publications in refereed journals and trebled the commissioned research income (in real terms). The Institute was honoured to present a summary of these outputs during a visit of the then Prime Minister, John Major, to ITE Monks Wood in 1996 (Plate 2).

A further feature of ITE's development has been the *resilience* derived from the foresight of the initial research strategy. The early strategy sustained projects on community ecology, population biology and ecotoxicology in support of the conservation of wildlife. Increased emphasis was given to research on:

- land use
- nutrient cycling
- radionuclide and airborne pollutants
- genecology.

This has provided a robust base from which to develop new initiatives in response to policy needs. There has been conflict over:

- land use policies
- impacts of pesticides on wildlife
- the 'acid rain' debate
- the Chernobyl accident
- climate change impacts
- ozone depletion
- the Biodiversity Action Plan
- the development of agri-environment policies.

The long-established expertise in genecology has been pivotal in the expanding ecological research on the risk assessment of genetically modified organisms (GMOs). More recently, there have been new initiatives on global change, urban environmental science and soil sustainability.

It is difficult (and perhaps a little unfair) to highlight specific *achievements* when science is incremental in nature and progress in the environmental sciences is so dependent on interdisciplinary research and teamwork. However, there are 12 major achievements that can be identified. These provide an interesting mix of strategic and applied research. In most cases, the strategic research has been developed to provide support for major government policies on environmental issues. In several cases, the achievement has depended upon effective collaboration with other Institutes or Universities.

1. Collaborative research in the International Biological Programme developed the first element budgets for UK moorland and woodland ecosystems and explored the role of soil organisms in nutrient cycling.

2. A major land use programme has produced an integrated method for estimating land use at the national scale using sample-based field survey and mapping by remote sensing. The resulting 'Countryside Surveys' have monitored land use change from 1978 to 1998. This information has been used to inform a range of land use policies.

3. Statistical research has developed ordination techniques for vegetation analysis used extensively by ecologists to assess the relationships of species in communities and the influence of environmental factors.

4. Sustained long-term population studies of numerous vertebrates have provided knowledge of the effects of behaviour, social organisation, density-dependent processes and predator-prey interactions. This knowledge has been used to develop predictive models of abundance and dispersal, and to thereby support a range of conservation policies.

5. Invertebrate research has described the biology and adaptations for coexistence of large blue butterflies (*Maculinea* spp.), the specific ant hosts and parasitiod species and incorporated the interactions into a model of population dynamics. The understanding of population ecology has been applied to the successful reintroduction into the UK of this species.

Plate 1. The ITE Management Group as at 31 March 1998. (Left–right) Professors Melvin Cannell, Mike Hornung, Alan Gray, Mike Roberts and John Good, Mrs Jane Parsell, Drs Steve Albon, Barry Wyatt and Lloyd Anderson

6. Silviculture research has developed techniques for the regeneration of tropical forest trees. The procedures for genetic selection, propogation and the use of soil mycorrhiza have been transferred to developing countries.

7. Research in community ecology has developed a range of techniques for establishing species-rich communities and restoring habitats of conservational importance. These techniques have considerably advanced the wildflower seed industry and helped mitigate the ecological impact of major civil engineering schemes (such as the M3 extension at Twyford Down).

8. Basic research on the ecology of natural populations of crop relatives has been incorporated into a science-based assessment of the risks of releasing GM crops. This research has underpinned the development of the UK's 'Fast Track' GMO Regulations.

9. Ecotoxicological research demonstrated the impact of organochlorine pesticides on birds of prey and established the mechanisms (egg-shell thinning and direct mortality). This research guided statutory controls over use of these pesticides. Further research has monitored the rates of recovery following statutory controls.

There are 12 major achievements that can be identified. These provide an interesting mix of strategic and applied research.

Plate 2. Visit to ITE Monks Wood of the Rt Hon John Major MP in July 1996

Plate 3. Elliot Morley MP (right), Parliamentary Secretary, Ministry of Agriculture, Fisheries and Food (Minister for Fisheries and the Countryside), with Mike Roberts during a visit to ITE Monks Wood in March 1998

The current vitality of the Institute has only been reached through the resolution of the management teams, as well as the flexibility and commitment of staff at all levels.

Plate 4. Environment Minister, the Rt Hon Michael Meacher, MP

10. Research on radionuclide pathways produced the first national map of the distribution of radionuclide fallout from the Chernobyl accident and established the mechanisms of long-term persistence in upland soils. This research underpinned the government response to managing the impacts of the fallout on upland agriculture.

11. Air pollution studies have quantified the parameters for dry and wet deposition of acid pollutants and incorporated the values into spatial models of the 'Critical Loads' for these pollutants. This research help to determine government policy on emission reductions for acid pollutants.

12. Global change research has developed methods to measure the fluxes of trace greenhouse gases at the national and regional scale and to model the effects of climate change at the biome scale. These studies have been used in inter-governmental negotiations on carbon emission limits.

The continuing drive towards diversification and interdisciplinary research throughout ITE's evolution has generated several phases of *reorganisation and restructuring*. The current vitality of the Institute has only been reached through the resolution of the management teams, as well as the flexibility and commitment of staff at all levels. The 1980s saw a major expansion in the physical sciences to meet the challenges of ITE's expanding pollution programmes. During the 1990s there was a major expansion of information technology to meet the growing priority of environmental monitoring and access to environmental data. The Institute is currently expanding molecular ecology to meet the basic research opportunities in this new area and develop risk assessments for GMOs.

The expansion of ITE's science base in urban ecology has been accelerated by successful proposals into the NERC 'Urban Regeneration (URGENT)' Thematic Programme. Research is underway on urban air pollution, restoration of contaminated soils and the patch dynamics of wildlife. Increased NERC support has also been secured for research on the ecological dynamics of genes and soil biodiversity.

The breadth of disciplines in ITE has been further enhanced by the incorporation of NERC's Remote Sensing Application Development Unit into the Section for Earth Observation at ITE Monks Wood. A Service Level Agreement with NERC has resulted in the expansion and re-equipping of the Stable Isotope Facility at ITE Merlewood to serve expanding application in both the Institute and the University sector. The refurbishment of the climate change research facilities at ITE Bangor has also been completed.

In the past year, the current phase of staff restructuring has been completed and the focus has moved to investment in infrastructure and laboratories, resulting in plans for laboratory mergers that will sustain the national distribution of research sites. Expansion of environmental chemistry is planned as part of an overall CEH strategy. The trend towards greater collaboration with the university sector continues to strengthen the national capability in terrestrial ecology.

The contribution of ITE's land use research to the development of agri-environment policy was highlighted in the visit of the Agriculture Minister, Mr Elliot Morley, to ITE Monks Wood in March 1998 (Plate 3).

On 9 March 1998, Environment Minister, Michael Meacher (Plate 4) announced that the Department of the Environment, Transport and the Regions (DETR) and NERC had agreed to undertake a major new survey of the British countryside. ITE, in collaboration with eight government departments and agencies, had spent the previous year planning the fourth Countryside Survey. Mr Meacher stated "The £4.5 million survey will establish new techniques and break new ground in the integration of field-based and satellite observation of the earth's surface. It will provide us with essential information to help us develop our policies for the next Millennium."

Prof T M Roberts

Since its creation in 1973 ITE has observed many changes in structure and research. Sir Martin Holgate, John Sheail, Bill Heal and Mike Roberts take a look at this in more detail, from ITE's creation, to the current high standing in the research community.


Annual reports for the years 1974, 1989–90 and 1996–97

Twenty five years of ITE research

The formative years

Sir Martin Holdgate

Quite a lot of people thought that the creation of ITE was a mistake. To understand that, you have to look at what went before. The scientific and managerial challenges of the past 25 years, and the stature of ITE within the Centre for Ecology and Hydrology (CEH) today, both reflect changing national and international attitudes towards the environment, and evolving views on the contribution of ecology to the conservation and sustainable use of natural resources.

The Nature Conservancy was conceived in 1949 as a biological service. Its creators believed that ecology should be the foundation both for science-based land use and for the conservation of nature, which they regarded as a priceless cultural asset as well as an irreplaceable resource. Although the Conservancy was not given a mandate to guide planners, farmers and foresters in the wise use of the total rural environment, it was broadly based, doing ecological research as well as establishing nature reserves and promoting understanding of the need for conservation. It also had its ear to the ground of environmental concern, for example, Monks Wood Experimental Station examined the interaction of agriculture and ecosystems in the intensively farmed lowlands of England. Its Toxic Chemicals and Wildlife Section headed by Norman Moore began to study the effects of persistent pesticides on wildlife several years before Rachel Carson startled the world with her book 'Silent Spring' (Carson 1963).

The Conservancy had the status of an independent Research Council until 1965. Then the creators of the Natural Environment Research Council (NERC) saw the merits of combining it with the Geological Survey and with institutes and units working on hydrology, freshwater biology and marine science. This provided scientific underpinning for a wide range of environmental policies. But while NERC was obliged by statute to maintain a Committee called "The Nature Conservancy" and to support its conservation functions, the latter jarred on many Council members and Headquarters staff. It was not surprising that after a Secretary of State for the Environment was appointed in 1970, and the Stockholm Conference drew the eyes of the world to the environment in 1972, those then leading the Conservancy concluded

The creators of the Nature Conservancy, in 1949, believed that ecology should be the foundation for science-based land use and the conservation of nature.

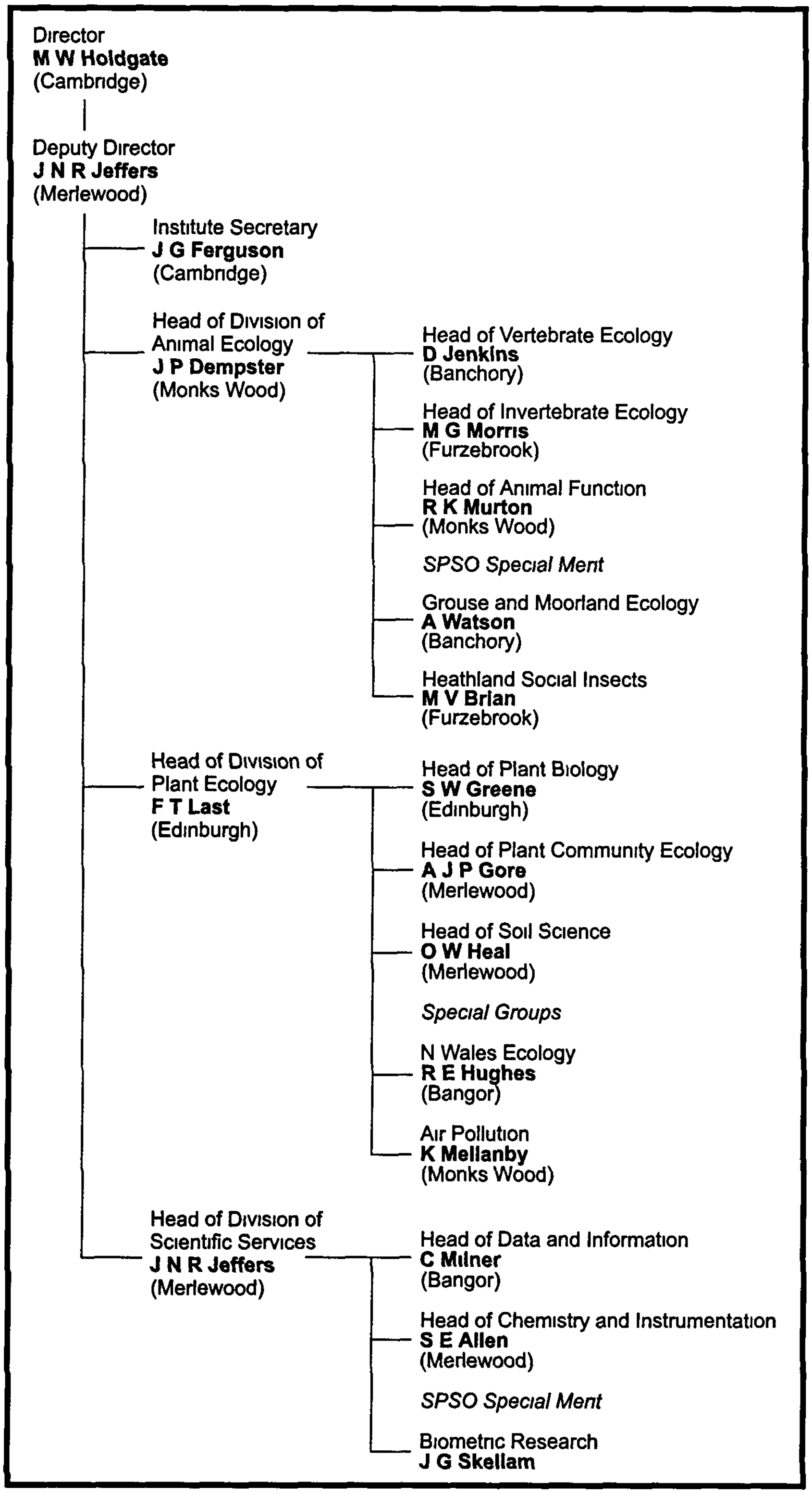


Figure 1 Staff structure taken from the first ITE Annual Report (1974)

that it should be removed from NERC and made answerable to the Department of the Environment (DOE)

NERC did not like this proposal They argued that half the staff of the Conservancy were researchers, and fitted well within a Research Council context Many of the research staff themselves were uneasy about the political interference that could come from subordination to a policy department The outcome was 'the split' in which the conservation branch of the Conservancy was severed as the Nature Conservancy Council (NCC), established by Act of Parliament in 1973, while the research branch stayed in NERC and became ITE The reconstruction was easier to rationalise because Lord Rothschild, then Head of the Central Policy Review Staff (the 'think tank' in the Cabinet Office) had just produced his celebrated report outlining the 'customer-contractor principle', and this seemed a good way to provide the new NCC with research support Funds would be transferred to it, in the expectation that it would purchase much of what it needed from ITE

I had been Deputy Director (Research) in the Nature Conservancy from 1966 until 1970, serving under Max Nicholson and Duncan Poore, and alongside Bob Boote as Deputy Director (Conservation and Management) Between 1970 and 1974, I was part of DOE as the first Director of the Central Unit on Environmental Pollution, and watched these convulsions from my Whitehall desk I supported the argument that conservation policy fitted alongside town and country planning, river conservation, water supply and pollution prevention in DOE But I was not a great believer in Rothschild, and felt that NCC should retain the blend of research and its application that had been a unique attribute of the old Conservancy But ITE was *a fait accompli*, and in the spring of 1974 after long discussions with Professor (now Sir James) Beament, Chairman of NERC, and with Ray Beverton, NERC's Secretary, I became its first Director

The challenge was evident and daunting Over 300 staff, at twelve widely separate locations, had to be welded into a new entity with a new culture Three components – the NERC Institute of Tree Biology (ITB) at Penicuik near Edinburgh, the Antarctic Bryology Unit based at Birmingham, and the Culture Centre for Algae and Protozoa at Cambridge (added a bit later) had not been part of the Nature Conservancy at all. At the same time, the new Institute had to earn its keep in Rothschild's world – for NCC had to deploy their research funds wherever they could get the knowledge they needed, and there could be no guarantee that they would pay for all the things the ITE scientists wanted to do.

John Jeffers, Deputy Director of the Institute, Fred Last (formerly Director of the ITB and now our Director of Plant Sciences), Jack Dempster (who had succeeded Kenneth Mellanby as the senior officer at ITE Monks Wood and became ITE's Director of Animal Ecology) and I formed a tight Management Group which met monthly. We had three priorities:

- to define the objectives of the new Institute
- to weld it into a coherent body
- to encourage research of high scientific quality which at the same time earned the Institute its living.

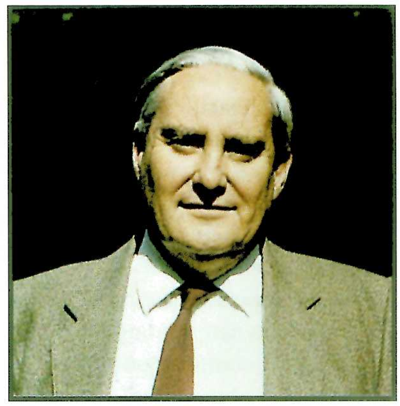
We discussed two alternative structures. One would have been primarily geographical, with each station run as a unit and with cross-cutting disciplinary (or multidisciplinary) teams to promote professional linkage. Alternatively, the thematic groupings could be made the primary units in the hierarchy. At that stage in our evolution we thought that the first priority was to link the scattered groups, many with strong local loyalties, into as integrated an Institute as possible. We, therefore, created three primary Divisions (Animal Ecology, Plant Ecology and Scientific Services) with subdivisions for:

- Vertebrate Ecology
- Invertebrate Ecology
- Animal Function
- Plant Biology
- Plant Community Ecology
- Soil Science
- Data and Information
- Chemistry and Instrumentation.

Together with some smaller specialist teams, most of them led by outstanding people promoted on grounds of individual merit (Figure 1). We did not want to give any particular research laboratory the superior status that might come from locating our HQ there (even if there was room, which there was not). We expected in the long-term that the HQ would be placed on the Monks Wood campus. We, therefore, rented offices in Cambridge for the Director, and John Jeffers remained the senior officer at Merlewood, Jack Dempster at Monks Wood and Fred Last in Scotland. It was not an ideal structure. It meant that people were brigaded into groupings that seldom met. However, we hoped that it would none the less be a unifying force. We expected that smaller multidisciplinary teams would be pulled together to address specific projects, and that all the research of the Institute would be project-based.

In our first year we had nearly 400 projects in the register. All were the subject of written plans approved by the Management Group and all had critical path diagrams with key stages (and dates) that were entered by John Jeffers into the Merlewood computer so enabling him to monitor progress stage by stage and month by month. Nowadays, such monitoring by cost centres, and regular checking of out-turn against budget seems commonplace. However, it was new then and there was considerable hostility to John Jeffers' disciplined management on the part of those (including some members of NERC) who believed that the first duty of research directors was to provide support for the creativity of free intellects.

Perhaps we were hesitant about our organisational model, for we emphasised in the First Annual Report of ITE (1974) that "organisation for its own sake has little merit and, in scientific research, administrative tidiness is no substitute for intellectual creativity". The aim of ITE was said to be "to make it easier for staff of the Institute to do good research, to



Professor John Jeffers, Director of the Merlewood Research Station 1968, Deputy Director of ITE 1973, and Director 1976–86

The challenge was evident and daunting. Over 300 staff, at twelve widely separate locations, had to be welded into a new entity with a new culture.

follow creative careers, and respond individually and collectively to the national need" What need? "Britain needs a research Institute like ITE because we need ecological understanding if we are to use our environment wisely", we argued We set two objectives

- "to improve understanding of the factors determining the structure, composition and processes of terrestrial ecological systems and the abundance and performance of individual species and organisms"

- "to provide a sounder scientific basis than is presently available for predicting and modelling future environmental trends, especially those resulting from man's activities, hence permitting a more critical assessment of the need for, and likely benefits of, specific measures to protect and manage the environment "

This was the time of 'the environmental explosion' Worldwide concerns about the pressure of human populations on natural resources, the destruction of wild habitats and species, the impacts of intensive agriculture and the blighting impact of pollution had come to a global focus at the Stockholm Conference of 1972 OECD had set up its Environment Committee in 1970 The European Community had adopted its first environment programme in 1974 All four of us in the original ITE Management Group had been involved in international environmental activities, not least in the International Biological Programme (IBP) of 1964–1974, to which the NC had contributed major studies at Meathop Wood, Moor House, Snowdonia and Loch Leven We were clear that ITE had a 'launch window' of opportunity to provide the ecological understanding that should inform agriculture, forestry and town and country planning (although we accepted a special responsibility to support the Nature Conservancy Council) And we stressed that ITE's expertise gained value because it was a component of NERC's multidisciplinary array

But however innovative our aims, the fact remained that we took over a disparate group of ecologists recruited primarily to back nature conservation – to which many of them were deeply committed A look at the early ITE Annual Reports demonstrates how much of our initial effort went on insect, bird and mammal ecology, plant community dynamics, and the methodology of survey The work on pesticides and wildlife was, however, of direct relevance to contemporary demands for tighter action against pollution The projects inherited from the ITB had obvious application in the improvement of forestry in the developing world as well as the UK We were also doing special projects of habitat characterisation in the Isle of Man, Shetland, Maplin Sands (proposed site of London's third airport) and the Wash – the last three very much geared to assessing the environmental impact of major proposed developments

As time went by, we deliberately broadened the spectrum of activities In 1974 we held a joint conference with town and country planners – only to be looked at askance by some conservationists who felt that we were getting too close to the developers We also emphasised the need for numeracy – again not without cultural resistance from some able researchers who had doubts about modern modelling techniques By 1977, nature conservation accounted for only 33% of the work of the Institute (a change partly forced on us by NCC who were clearly looking to diversify their sources of research), while 20% of the work was relevant to land use planning, 25% to pollution and the rest to habitat management and restoration

By the time I left ITE to return to DOE as Chief Scientist in 1976 – much earlier than I had planned and much sooner than was right – these changes were only beginning In the following decade they were pressed forward under the directorship of John Jeffers The Institute became more tightly integrated and multidisciplinary projects gained emphasis I have watched the evolution of the Institute with fascination and a good deal of admiration Its work is no less important today than in the beginning, and I now believe that the separation from NCC has proved an asset, because it has allowed the work to broaden and serve a very wide range of users in Britain and abroad This process will continue, and I hope and trust that the next 25 years will prove even more rewarding than those since 1973 which this report celebrates

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As time went by, the Institute became more tightly integrated and multidisciplinary projects gained emphasis.

Development of environmental research and government policy

Prof John Sheail

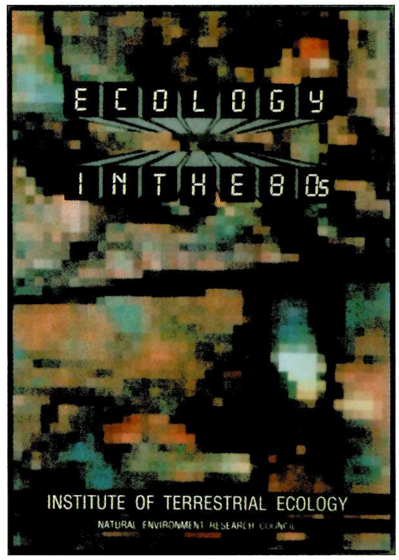
Responding to an invitation from the Director of ITE, John Jeffers, to write on *Ecology in the 1980s*, Lord Flowers, the physicist and Rector of the Imperial College of Science and Technology, recalled how, like most people, he had first become aware of ecology in the late 1960s (Flowers 1984). The dramatic surge of interest in pollution, conservation and other environmental issues had caused 'ecology' to become a household word almost over night. If on the one hand, the word had come to embrace a variety of disparate attitudes and beliefs, too often charged with political and emotional overtones, the science of ecology had itself changed, partly through the expansion of empirical knowledge and partly through the development of more sophisticated theories. Much had been learnt since ecology 'came of age' in the 1960s, but a great deal of knowledge of quite fundamental importance was still required before many ecological problems could be solved. Continuing priority had to be given to ecology, if it was to secure adequate resources. None was more anxious to prove the value of committing those resources than ITE.

The ITE research strategy: food, fibre and fuel

The priority of the early years of ITE was to develop a Strategy which was both relevant and distinctive in the way it addressed current needs and anticipated those that would attract mounting public concern over the coming decade. The ITE Strategy, published in its fifth Annual Report of 1978, foresaw three principal pressures on the environment, arising from increasing shortages of food, fibre and fuels. Arable farming would intensify, and stock numbers in the uplands increase. A shortage of wood fibre and timber would encourage large-scale afforestation. There would be increasing concern for the ecological systems upon which many sources of renewable energy depended. Although the situation had improved through greater knowledge and the imposition of standards, pollution remained one of the most significant and unpredictable ways in which human activity affected the natural environment.

Whilst careful not to exaggerate the claims made for ecology, the ITE Strategy saw ecological characterisation, namely the survey and mapping of land use, habitats, organisms and resources of the terrestrial environment as the basis for environmental policies. A base-line was provided for monitoring and interpreting changes in the inter-relationships between plants and animals, and between those organisms and the physical environment, including modifications instigated by human activity. ITE's Terrestrial Environment Information System had already begun to demonstrate the potential for integrating the considerable volume of information that existed (and which might be anticipated), that had been collected for a range of purposes at different scales. Besides making use of modern methods of handling and storing such data (and anticipating much greater advances in such technology), careful synthesis, aggregation and analysis were required in determining the key ecological variables or attributes. Not only might ecological survey be improved by more effective design, but the development of advanced mathematical and computational techniques meant data could be used more intensively. It would be possible to examine ecological variation more systematically through the development of models of spatial variation.

In the Annual report for 1979, John Jeffers wrote of how, in pursuit of the ITE Strategy, NERC had approved important changes to meet the anticipated requirements of existing and potential customers for commissioned research, while maintaining a healthy balance of fundamental ecological research. There would be increased concentration of research on the ecological consequences of changes in land use, actual or potential. Greater effort would be made to respond to the growing interest in ecological research in many overseas countries. In so far as financial constraints permitted, it was the wish of Council that ITE should maintain and develop the nine research topics



John Jeffers brought together a range of views on the principal ecological problems of the 1980s in this ITE publication of 1984

The dramatic surge of interest in pollution, conservation and other environmental issues had caused 'ecology' to become a household word almost over night.

outlined in Table 1 One of the major advantages of ITE putting forward such a large, integrated programme of research, was that ITE contained a wide range of expertise in terrestrial and freshwater ecology

During each parliament, ITE was asked through NERC to submit evidence to a range of enquiries The extraordinary impact of Marion Shoard's book, *The theft of the countryside* (Shoard 1980), reflected both her skills as a polemicist and growing unease at what was happening to the countryside Concern was raised by the losses of amenity and wildlife reported during the promotion of the Wildlife and Countryside Bill of 1981, and highly publicised clashes over the future management of such areas as the Somerset Moors and Halvergate Marshes in Norfolk The respective role of the Research Councils came under close scrutiny, when the House of Lords' Select Committee on Science and Technology investigated the case for greater coordination between agricultural and environmental research The Committee's report of July 1984 highlighted the imbalance between the former, which had an obvious customer and commercial importance, and environmental research that, as one witness put it, was a 'polyglot entity that ranges widely over a number of disciplines' The Committee believed that, as well as studying the consequences of current management practices, there should be joint initiatives to forecast and mitigate any adverse environmental effects from new crops, the further intensification in some parts and perhaps withdrawal of such farming methods from others (Parliamentary Papers 1984) Determined to press ahead as quickly as possible with the research it had long advocated, NERC made 'Agriculture and the environment' the largest of its Special Topic Awards in 1986 ITE Stations played a prominent role in both that initiative and the research supported by the later inter-research councils' Joint Agriculture and Environment Programme By that time, important developments had occurred both in the research field of pesticides and pollution and in the wider organisation of NERC science

Table 1 The nine research topics identified by ITE in 1979 for maintenance and development within its general programme of research (ITE 1979)

1 Theoretical and applied studies of land classification and land use change An existing research theme given increased emphasis as a result of the predictions of rapid forest expansion, increased upland grazing and energy sector developments

2 Effects of radionuclides on terrestrial and freshwater ecosystems Although a relatively new field of research for ITE, public interest in the highly emotive topic made it essential that decisions were based on facts not conjecture

3 Effects of sulphur, fluorine and other airborne pollutants Sufficient research had been carried out to indicate the need for better evaluation of the interacting effects of various airborne pollutants

4 Toxicology of organic pollutants and heavy metals in terrestrial and freshwater systems There was need to relate a more exacting understanding of the effects of such pollutants to dynamic changes in the physiology of organisms

5 Synoptic limnology, such research to be carried out in collaboration with other NERC Institutes

6 Cycling of plant nutrients, with particular emphasis on woodland and grassland ecosystems The understanding of nutrient and pollutant pathways in ecological systems represented ITE's principal contribution to a wide range of practical applications in ecology

7 Plant demography and the dynamics of plant communities, with reference to the management of woodlands and grasslands Such studies were fundamental to the understanding of change in ecological systems, and to the management of rural areas

8 Physiology and population dynamics of invertebrate and vertebrate animals As for plants, the inter-relationships between animals and their environment provided the basis for control of pest species, conservation of wildlife, and prediction of change

9 Genecology and the implications of variation in natural and man-made ecosystems Reproductive strategies of plant and animal organisms played an important role in the management of crop and semi-natural systems ITE placed considerable emphasis on expanding knowledge of the genetics and variation of such species

Pesticides and pollution

ITE's earlier management and administrative structure based on three Divisions, namely of Plant and Animal Ecology, and its Scientific Services, was replaced in 1982 by one more directly centred on the individual Stations, with the research of the Institute coordinated by the Assistant Directors (ITE 1982) This facilitated the rapid diversification that proved vital in securing the financial future of ITE

Of all the research challenges faced by the environmental scientist, none was more public than the increasing concern over pollution Scientists had to react, and be seen to be responding, to growing public anxiety The decision of the earlier NC to focus on the long-term implications of using organochlorine insecticides had meant British ecologists were able to play a key role in identifying what proved to be the most dangerous side-effects (Sheail 1985) Besides monitoring the numbers and breeding success of vulnerable species, ITE's monitoring programme (beginning in 1962) provided a check on the effectiveness of successive restrictions in organochlorine use, together with information on long-term and geographical patterns of environmental contamination

The decision of NERC, in December 1974, to establish a Committee for Atmospheric Pollution Effects Research (CAPER) had far-reaching implications The annual study-meetings of CAPER brought together scientists from the component bodies and universities (CAPER 1994) Such rapport anticipated the opportunities for collaborative research under the Commission of the European Communities It also meant the UK environmental sciences were well placed to respond to mounting concern in the 1980s over the effects of emissions from coal-fired power stations on the natural environment of other countries, particularly Scandinavia ITE had already begun to acquire information as to the totality of acid deposition and the processes by which it occurred, and the assessment of the impacts on soils, vegetation and watercourses. From field observation and experimental data, models were devised to explain how acidity was transferred from the atmosphere to water, either directly or through plants, soils, and from snowmelt. Spatial analysis of the areas impacted by acid deposition (the "Critical Loads" approach) underpinned the response of the UK government and industry sector to increasing international pressure for emission controls.

For ITE, the pollution research agenda rapidly expanded through the 1980s. As the NERC Annual Report for 1986–87 remarked, the accident in the Russian Chernobyl nuclear power station shook public confidence. Serious deficiencies were exposed not only in the control of industrial technologies, but in forecasting and dealing with the effect of pollution, once it had occurred. At the Council meeting of July 1986, tribute was paid to ITE in producing the first maps defining the extent and magnitude of deposition in the UK (Sheail 1992). Previous research on the soil chemistry of radionuclides in Cumbria had made its counting facility the largest outside the nuclear industry. ITE was accordingly well placed to explain the persistence of such radioactivity in the vegetation and sheep of upland pastures.

The terrestrial and freshwater sciences

To mark its 25th anniversary in 1990, NERC published a booklet entitled, *Our changing environment*. It recounted how concern about various issues had moved the environment to centre stage in the politics and economics of the 1980s. These issues outlined the possible changes in the world's climate and destruction of the rain forests, and more domestically the implications of the Common Agricultural Policy and exploitation of the nation's finite resources. It was increasingly recognised that the earth was not an infinite 'reservoir' – ecosystems were fragile (NERC 1990).

If NERC was to respond to such renewed opportunity, a new flexibility was required in its organisation to secure multi-disciplinary working and across-boundary cooperative effort between its component Institutes and the universities and polytechnics (NERC 1987). Council had established three principal Directorates, namely for the Earth, Marine, and the Terrestrial and Freshwater Sciences. The Strategy for the Terrestrial and Freshwater Sciences, *The green light* (as drawn up by its Director, Bernard Tinker) identified three main fields of research:

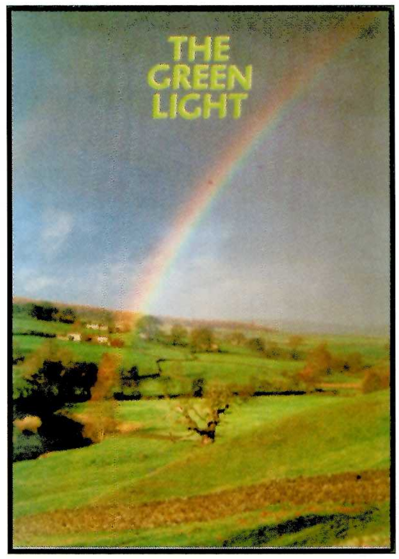
- the development of land and natural resources
- the maintenance of environmental quality (as it related to pollution)
- the principles that underpinned environmental management and conservation (NERC 1989).

Within that context, ITE emphasised its own threefold objective of:

- improving understanding of ecosystems and species
- providing a sounder scientific basis for predicting and modelling environmental trends
- disseminating the results of such research (ITE 1990).

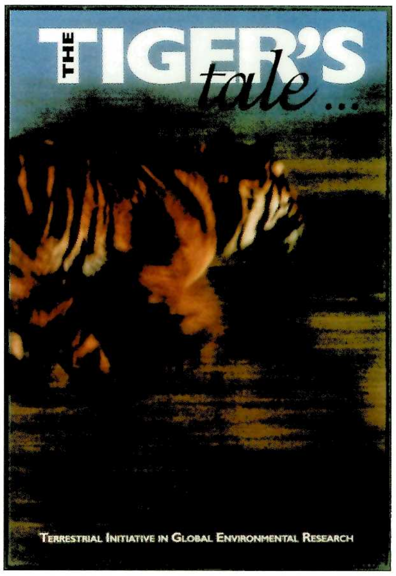
As a component body of the new Directorate, ITE had been divided into two parts, North and South (in December 1985) with Bill Heal and Jack Dempster respectively as their Director. Their Annual report of 1986–87 recorded how, during the previous three years, the level of the Science Budget allocated to the Institute had fallen in real terms, with a consequent reduction in effort on basic scientific research. The decline in such support had, however, been compensated by an increase in commissioned research to the point where it now represented a third of ITE's total budget. That income had come mainly from work on radionuclides, atmospheric pollution and environmental impact assessment. With the Science Budget likely to decline further, still more income had to be found from other sources.

If the positive and dynamic qualities of *nature conservation* had enabled ecologists to catch the political imagination in the decade of the 1940s, the words *sustainable development* represented a further major advance in understanding in the 1980s. The United Nations (UN) appointed a World Commission on Environment and Development (WCED), as an independent body in 1983, under the Chairmanship of the Norwegian Prime Minister, Gro Harlem Brundtland. Its report of April 1987, *Our common future*, powerfully advocated the concept of sustainable development. Significantly too, it demanded more rigorous definition of how that goal might be met (WCED 1987). Of more immediate significance in British politics was the concern expressed by the Prime Minister, Margaret Thatcher, first before the Royal Society of London and then at the General Assembly of the UN. At the Annual Conservative Party conference in October 1988, she spoke of how 'no generation has a freehold on the earth', and continued 'all we have is a life tenancy – with a full repairing lease'.



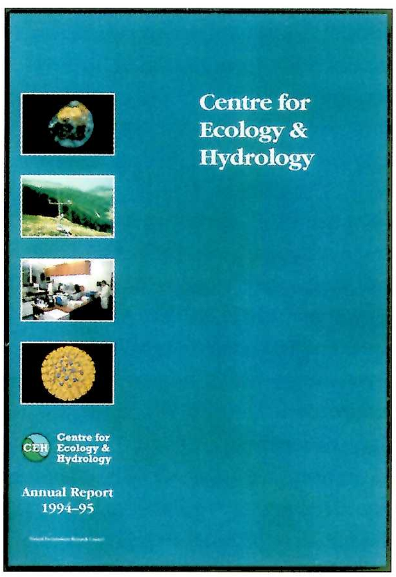
The NERC Strategy for Terrestrial and Freshwater Sciences, published March 1989

The year 1990 marked not only the Environment Protection Act and the introduction of a system of integrated pollution control, but the publication of 'Britain's first comprehensive White Paper on the Environment', *This common inheritance*. Never before had government acknowledged so explicitly the extent and depth of public anxiety over the natural environment. As well as setting out a vision for the 1990s, the report made 350 commitments and proposals for action. It emphasised the



ITE contributed significantly to the achievements of the NERC Climatic Change Research Programme in the 1990s

The UN Conference on Environment and Development, held in Rio in June 1992, succeeded in taking the sustainable development debate across a further threshold in political perception.



The first CEH Annual Report published in 1995

need to base policies on fact. The role of research and long-term monitoring was emphasised (Secretaries of State 1990). The ITE Annual Report for that year described how increasing weight was being given to research on the impacts of climate and land use change, the forest sciences and water quality, and atmospheric pollutants (ITE 1990). The Institute played a key part in planning and implementing, in 1992, both an Environmental Change Network (ECN) and a major NERC community research programme, the Terrestrial Initiative in Global Environmental Research (TIGER). Beyond their obvious timeliness in understanding land-water-atmospheric processes, such programmes offered further opportunity for ITE scientists to work with colleagues in the other NERC Institutes, as well as universities and other 'centres of excellence'.

The UN Conference on Environment and Development, held in Rio in June 1992, succeeded in taking the sustainable development debate across a further threshold in political perception. The Earth Summit and signing of a Biodiversity Convention were treated with a seriousness previously reserved for Summit Conferences on disarmament and the plight of the world economy. As a topic where the UK claimed much expertise and experience, it was a chance to display leadership on the world stage. As an exemplar to others, the UK was among the first to publish (in January 1994) Action Plans for Biodiversity and Sustainable Development (Secretaries of State 1994a, 1994b) and to launch the Darwin Initiative. It was also the first to publish (in December 1995) costed targets and action plans for an initial tranche of key habitats and threatened, or endangered, species (UK Steering Group 1995). ITE was well placed to support this policy initiative through the extensive biodiversity databases that had been brought together in the Environmental Information Centre (EIC) in 1989.

Policies were fast expanding on the domestic front. The National Parks and Access to the Countryside Act of 1949 had given statutory recognition to protecting landscape and wildlife, and promoting outdoor recreation, as a third force alongside farming and forestry. The Agriculture Act of 1986 became another milestone, in the sense of giving Agriculture Ministers a responsibility for securing greater balance between those various user interests. For the first time, the agriculture budget could be used for such purposes as the promotion of Environmentally Sensitive Areas.

This more holistic vision found the ITE well prepared. It had already embarked on a series of rural inventories, the most recent being the Countryside Survey of 1990. The countryside was increasingly perceived by ecologists as a mosaic of intensively-managed land and of semi-natural habitats. Although the effects of individual management-practices had been much studied, little was known of the effects of the mosaic itself on wildlife. How were habitats colonised following local extinctions? How far might changes in the mosaic affect the dynamic interactions of different organisms, which constituted different food chains? A theoretical framework was required, within which an experimental approach could be adopted, combined with field observations. Both the geographical scale and rapidity of changes in the use and management of the countryside afforded outstanding opportunities for ecological study at the landscape and more detailed levels.

There was a coming together of domestic, European and international agendas, as government, business and conservation bodies sought increasingly to adopt an integrated approach to resource use. The Minister of Agriculture joined the Environment Secretary in publishing a White Paper, *Rural England – a nation committed to a living countryside*, in October 1995. Its overall purpose was to identify ways in which it could remain 'a living working place', without harming the environment. A separate White Paper was published on *Rural Scotland* and another for Wales, by their respective Secretaries of State (Scottish Office 1995, Welsh Office 1996). With its scientists located in each of the three parts of the UK, ITE could be particularly sensitive to the aspirations and circumstances of each, in terms of providing the underpinning science required

The Centre for Ecology and Hydrology

NERC and its component bodies were required to take close note of government policy in both the environmental and science sectors The White Paper, *Realising our potential – a strategy for science, engineering and technology*, reaffirmed NERC as the lead organisation for research, survey and training across the full breadth of the environmental sciences (Chancellor of the Duchy of Lancaster 1993) With the other five research councils, NERC was charged with placing special emphasis on the themes of wealth creation, quality of life, partnership in science and technology, and the establishment of closer links with its 'user community'

The further requirement placed upon NERC to promote and support long-term environmental monitoring confirmed the wisdom of sustaining and initiating such national data bases as ITE's Biological Record Centre (BRC), Land Cover Map and the national critical loads data base They were essential not only for defining environmental characteristics and as resource inventories, but as baselines against which to monitor the effectiveness of policies As the ITE Annual Report for 1993–94 emphasised, an important feature of ITE policy was to collaborate in establishing information networks that allowed reciprocal access to environmental data bases and provide a common vehicle for analysis

The government also launched an 'Efficiency Scrutiny' and a 'Prior Options Review' which affirmed, in January 1997, that NERC establishments should remain in the public sector, and retain their separate identity The new 'Realising our Potential' agenda, along with pressures for improved efficiency and effectiveness, called for a greater integration of the existing NERC Institutes In 1995 NERC replaced the three Science Directorates with four Centre/Surveys and ITE became a component of the Centre for Ecology and Hydrology (CEH) The new Director, Brian Wilkinson, was charged with greater coordination of the research programmes across the four component Institutes

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

ITE North and South, with their combined staff of 270 distributed between 6 sites, became once again a single Institute With Bill Heal's retirement, Mike Roberts (who had been appointed Director of ITE South in 1988) became the Director of the Institute as a whole Through some 20 research groups of critical mass, ITE was well placed to contribute to the ten closely-defined scientific programmes established by CEH It provided a sound basis from which the CEH network might expand in realising the potential of the inter-disciplinary approach required of the NERC sciences (NERC 1998)

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In 1995 NERC replaced the three Science Directorates with four Centre/Surveys and ITE became a component of the Centre for Ecology and Hydrology.

Professor Bill Heal, Director of ITE North, 1986–94

ITE progress in the 1990s

Prof Bill Heal

Resilience, diversity, adaptation and evolution are terms that come to mind when contemplating ITE in the 1990s. These are the characteristics of the Institute which mark its success and its future. These strengths become apparent when considered against the science and policy changes that have affected it over 25 years. The Institute has been adaptable – the science and management structures have evolved to match the dynamic changes in function. The resilience of the organisation has been the result of the foresight of the first Management Group as well as the vitality and flexibility of the staff.

The series of science and policy changes over the 25 years resulted in major initiatives which now feature strongly in the ITE portfolio and performance in the early 1990s.

ITE was founded against the background of the increasing recognition of global environmental issues, and the demand for greater input from science to 'users' – the United Nation Stockholm Conference in 1972; Lord Rothschild's report introducing the 'customer-contractor' principle, the restructuring of research within NERC. The vision of the first Director, Martin Holdgate, with his management team of John Jeffers, Fred Last and Jack Dempster, established an Institute designed to strengthen basic ecology and focus understanding on environmental management. The regional distribution of the research stations provided access to ecological diversity, whilst the flexibility of matrix management enabled integration across stations to meet changing issues.

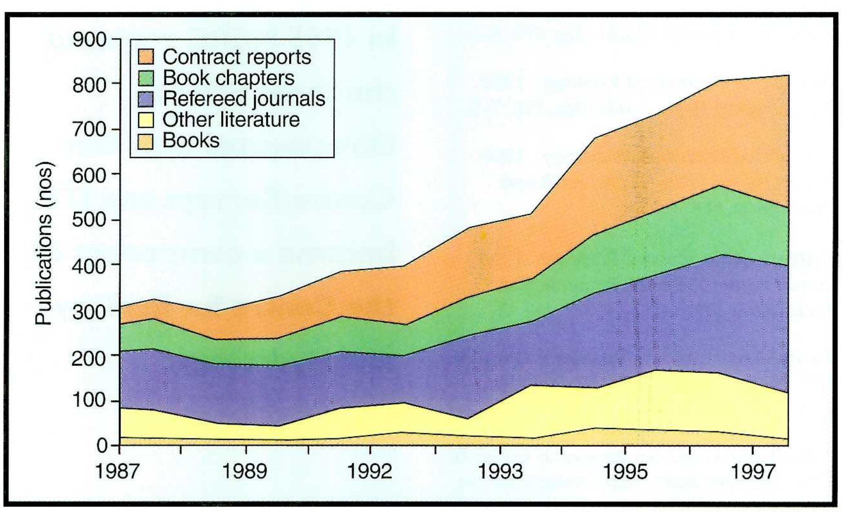


Figure 1. Trends in output of ITE publications from 1987 to 1997–98

The 1990s were ushered in on three major policy events, with strong echoes of the 1970s:

- publication in 1990 of the first comprehensive 'White Paper' on the environment, *This Common Inheritance* (Secretaries of State 1990)
- the United Nations Conference on Environment and Development (UNCED) in Rio in 1992 with emphasis on Climate Change, Biodiversity and Sustainable Development
- the restructuring of UK science in 1993 to increase exploitation of research, *Realising our Potential* (Chancellor of the Duchy of Lancaster 1993).

Scientific management in NERC paralleled these changes. Firstly, the establishment of the strategy for NERC Terrestrial and Freshwater Sciences in 1989 (*The Green Light* – NERC 1989) focused on three key themes – land use and natural resources, environmental quality, and environmental management and conservation. The themes embraced 11 Programme areas spanning the four Institutes and University interests of the Terrestrial and Freshwater Sciences Directorate (Table 1). Secondly, incorporation of ITE into the Centre for Ecology and Hydrology in 1994, created greater opportunities for interdisciplinary research.

The series of science and policy changes over the 25 years resulted in major initiatives which now feature strongly in the ITE portfolio and performance in the early 1990s.

- Emergence of new priority subjects – climate change impacts, conservation of Biodiversity, and the embracing concept of sustainable development.
- Application of new technologies – molecular biology, stable and radioisotopes, chemical techniques based on mass spectrometry, widespread use of computerised databases, geographical information systems (GIS) and global positioning systems (GPS).

- Dramatic adjustment to new external and open funding mechanisms with the decline in Science Budget compensated by the highly successful diversification of external funding (15% of income in 1984, 40% in 1990 and 50% in 1997, plus NERC Thematic Programmes providing 15% in 1997) Total income rose from about £8 m in 1984 and 1990 to almost £14 m in 1997 (at constant prices)
- Rising rate of publications – 175 in 1974, 400 in 1990, and 800 in 1997, with a steady rise in numbers of journal papers in addition to the expansion of contract reports (Figure 1)

Despite the dynamic changes there has been a marked degree of stability and continuity

- Basic ecology remains the backbone of ITE (the per cent of journal papers on basic ecology may have halved since 1974 but the total numbers have doubled!) This has underpinned land use, conservation, pollution, policy and management studies as originally envisaged by Martin Holdgate
- As befits an Institute, strategic research including long-term studies and development of national data bases, has been a key investment generating intellectual capital which now reaps considerable dividends In this area the vision of John Jeffers of the role of computers, information technology and modelling has been critical
- Funding has always been a challenge Martin Holdgate referred to 'scarce public money' in the first ITE Annual Report (1974), related to the declining Science Budget of 1974–75 As the Institute entered the 1990s "the finances continue to be delicately balanced" (see ITE Annual Report 1990–91) However, diversification of the core research expertise has increasingly brought ITE's science closer to the user community (Figure 2) As a result, staff numbers have not changed (294 in 1974, 294 in 1997) although the balance has changed (reduced senior management and administrative support, increased scientific and technical support)

Table 1 The seven priority areas for ITE, as drawn up in response to The Green Light – the NERC strategy for Terrestrial and Freshwater Sciences, published in March 1989 (ITE 1990)

1	*Land use and remote sensing* The expected rapid changes in land use in the UK and Europe, and the huge values involved in land, demand rapid development of techniques and concepts in this multidisciplinary subject There is a need to expand research on remote sensing, Geographical Information Systems, data base development and land use capability
2	*Atmospheric pollutants* Studies of acid rain, its components and effects should continue, but work on nitrogen oxides and ozone needs expansion The exchange of 'greenhouse' gases with surfaces of soil and vegetation is very poorly quantified and is very relevant to understanding climate change effects The experience of the Chernobyl accident has shown us that much still needs to be learnt of the atmospheric transport and pathways of radionuclides
3	*Water quality* The chemical quality of water bodies is a central issue of our time The consequences of chemical pollution episodes or other perturbations for water quality over time and space, and effects on biota, cannot be predicted with sufficient accuracy Strategic studies are needed on sediment interactions, micro-organisms, ecotoxicological principles, organic pollutant behaviour, chemical speciation and natural organic contaminants
4	*Forest science* Demands for afforestation and new sources of timber at home and overseas can be met only by an expansion of research The underpinning strategic research will be long-term, covering physiological, genetic, ecological and pest and disease studies
5	*Population biology* This is a core subject within ecology for understanding, managing and conserving all biological resources that need long-term increased support Research is needed on modelling to predict the behaviour of single species (both plants and animals) in relation to environmental variables, and multi-species communities, and new techniques such as genetic fingerprinting
6	*Environmental microbiology* New techniques of detection and identification of micro-organisms are first priority, using new ideas now coming forward Measurement of gene transfer between organisms, dispersion rate of organisms, biochemical interactions between them, and the problems of growth rates in the natural environment are all urgent research topics Development of improved strains for environmentally beneficial purposes is a real possibility
7	*Climate change impacts* There is great urgency in establishing research on impact and quantification *before* serious effects are seen The unstated assumption that the mean climate remains constant is no longer acceptable Mathematical modelling is an essential tool in forecasting the extent and impact of impending climatic change on the environment and man It is essential to have accurate long-term records, so that the time trends can be identified, quantified and modelled Resources are needed to develop research on greenhouse gases, long-term reference sites and impacts

So, what are the key features of ITE in the 1990s that will form the basis for the 21st century? These are illustrated by brief views of some of the current topics – biodiversity, molecular biology, pollution, and climate change, plus data bases and the underpinning basic research

Biodiversity: a new angle on conservation

Tropical deforestation put conservation firmly on the Global, European and UK agendas of the 1990s Recognition that species extinction is occurring at an ever increasing rate, not only in the tropics, captured the public and political imagination 'Biodiversity' is now a social, economic, management and moral issue locally, nationally and internationally Stimulated by the 'Darwin Initiative' and the International Geosphere-Biosphere Programme (IGBP), ITE has increased research on biodiversity assessment and sustainable management of tropical forests A further impetus is expected to arise from the return of the UK into UNESCO in 1997

The official reopening of ITE Banchory in 1994 following a serious fire. (Left to Right) Professor Bill Heal, Mr Robert Malpas (Chairman of NERC), Professor Brian Staines, Sir Hector Munro MP (Scottish Minister for Agriculture and the Environment) and Mr George Kynock MP at ITE Banchory

Despite the dynamic changes in structures and funding, there has been a marked degree of stability and continuity in the research programmes.

Within the UK, ITE scientists continue to use the large data resources in the Biological Records Centre (BRC) and the Land Use Surveys to answer key questions such as "What is the rate of loss of species, where and why?" "What are the management and policy options to reduce loss?" The Countryside Survey was designed in the 1970s to define the amount and distribution of vegetation in Britain. It is an efficient statistical sampling of major land types and was planned, to be repeated. The surveys of 1978, 1984 and 1990 have generated detailed quantitative data on change in plant species, habitats and land use for the country. The Countryside Survey 2000 is underway and will form a major part of the Biodiversity Action Plan. This is a classic example of how an Institute can implement large-scale and long-term strategic research. It also utilised the regionally dispersed forces of ITE as a whole, even during the period when ITE North and South were managed as separate units. The data from the Countryside Survey represent a major capital of ITE and the Department of the Environment, Transport and the Regions (DETR) which are now widely available through the Countryside Information System.

The extensive 5–10 year national Countryside Survey does not stand alone. It is now linked to two more recent strategic initiatives:

- The Land Cover Map generated by ITE in 1990 from satellite observations (and repeated for 2000) provides a complete census of land and vegetation cover of Britain which can be repeated at shorter intervals or for particular areas.
- At the opposite end of the spatial and temporal scales, the Environmental Change Network (ECN) with its 11 terrestrial and 42 freshwater sites, provides detailed information on an integrated series of climatic, pollution, flora, fauna and water variables over daily and annual periods. ECN is a consortium in which many government and related organisations participate, with ITE in a co-ordinating role.

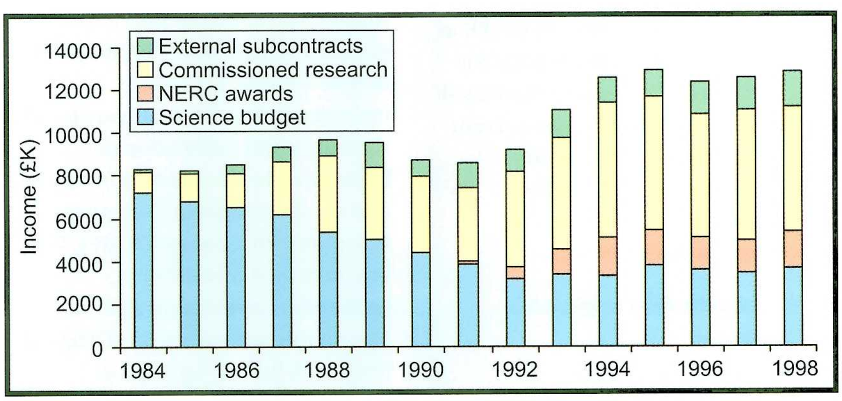


Figure 2. Trends in ITE income (at constant prices – 1984–98 using gross domestic produce indicies

The combination of census (Land Cover Map), extensive (Countryside Survey) and intensive (ECN) sampling now provides ITE and the UK with probably the best structured system for detecting terrestrial ecological change in the World. But such strategic data needs the understanding of population and community dynamics and of their response to change in order to evaluate the specific causal factors and inform policy options. It is here that the detailed ecological research comes into play, for example, in the intensive upland study to assess the relative importance of land management and predator control in maintaining biodiversity on different grouse moors (Redpath & Thirgood 1997) and in the analysis of bird diversity in relation to woodland size, structure and connection in the landscape (ITE 1994) In both cases there are sensitive economic, social and policy issues It is the strength of the combination of long-term national survey data and detailed ecological knowledge which enables ITE to contribute fully to the current series of conservation issues embraced in the term 'Biodiversity'

Molecular biology: application of new technology

Genetic sequencing and manipulation have provided major new opportunities for population ecology as well as generating environmental concerns over genetically modified organisms (GMOs) The new technologies became part of the ecologist's tool kit in the 1990s as methods became routine, reasonably priced and interpretable The variety of questions which can be addressed when the technology is integrated into the science are illustrated in the three specialised laboratories of ITE (Banchory with Aberdeen University, Merlewood and Furzebrook)

In vertebrate ecology, development of genetic markers allows identification of individual animals from blood, feathers, fur and faeces Collaboration between ITE Banchory and Aberdeen University has extended research on three important conservation issues

- To what extent do family relationships in red grouse (*Lagopus lagopus*) influence the density of nesting birds and population cycles?
- What are the home ranges of otters (*Lutra lutra*) and how is this affected by environmental features, including the presence of related animals in the local population?
- What are the habitat and meta-population characteristics of water voles (*Arvicola terrestris*) which determine their ability to recolonise habitats vacated during recent decline in numbers?

Microbial ecology has been severely limited by the ability to culture only a small fraction of the organisms in soil Combinations of molecular enzyme markers with carbon isotope labelling is being used at ITE Merlewood to identify, and isolate, those methanotrophic bacteria which can oxidise low concentrations of methane This addresses the question of the extent of methane removal from the atmosphere by oxidation in soils which is a key element of the global methane balance

Genetic manipulation of crop plants is now routine Molecular techniques and field experiments are being used at ITE Furzebrook to improve risk assessment by quantifying the probability of spread of manipulated crops in the wild and gene flow into populations of native plants Oilseed rape (*Brassica napus*) can establish feral populations, and early experiments indicate that while modified insect resistance might increase seed output of feral rape, it is unlikely to increase its persistence Gene flow from genetically modified brassica crops could confer enhanced insect resistance in populations of wild cabbage (*B oleracea*) Analysis of variation in compounds conferring 'natural' insect resistance indicates that plants with increased resistance might produce more seeds However, studies of seedling demography suggest that seed production is not a limiting factor in the growth and persistence of wild cabbage populations Studies such as these, combined with more extensive knowledge of genetic structure and ecology of natural populations, provide input to the developing regulatory policies

Environmental pollution: continuing issues

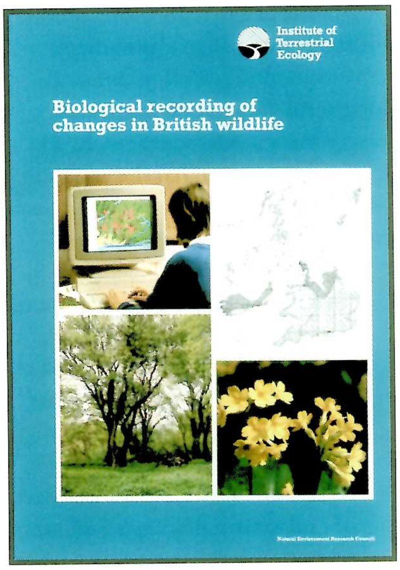
A growing strength of ITE has been its research on pollution impacts which has been pivotal in the formulation of emission control policies in the UK and Europe The continued production of new industrial and agricultural chemicals keeps researchers and legislators in a dynamic interaction Probably more than any subject, environmental pollution demands long-term, large-scale and multi-disciplinary strategic research The evidence is strong that the capabilities of ITE have provided the appropriate response in the following areas

- *Long-term research*
  The slow and variable decline of pesticide residues and the persistence of polychlorinated biphenyls (PCBs) over 30 years The unexpected food-chain cycling of radionuclides from Chernobyl and the redistribution of radioactive discharges in Arctic ecosystems, the emergence from 'acid rain' research to address the complex sensitivity of ecosystems to accumulated nitrogen (N saturation)
- *Large-scale research*
  The mapping of Critical Loads to define sensitivity of ecosystems to long-range atmospheric deposition across Britain and Europe The accumulation of radionuclides from Chernobyl and reprocessing in Arctic ecosystems
- *Multi-disciplinary research*
  Atmospheric physics, organic and inorganic chemistry, plant, animal and soil ecology and physiology, and mathematical modelling have all been essential to unravelling the pollution problems

Probably more than any other subject within ITE, the success of pollution research has depended on capital investment in high quality facilities (eg analytical chemistry laboratories, open-top chambers, solardomes and radionuclide laboratories) and collaboration with Universities and other Institutes

Climate change: a major new priority

It was in 1986 that climate change first appeared on the ITE agenda when the Department of the Environment (DOE) initiated a desk study, the same year in which the IGBP on global change was launched In 1990 it was identified as a major environmental problem by the government in *This Common Inheritance* (Secretaries of



Proceedings of a conference in March 1990 that celebrated the 25th anniversaries of the Biological Records Centre and the Natural Environment Research Council

The rapid expansion of computing capability, open access to environmental information and increased emphasis on process modelling have all been features of the 1990.

State 1990). At that time ITE had 27 relevant projects in hand and NERC launched the major community research programme, TIGER. It was the experience in air pollution and its effects, combined with the extensive knowledge of the ecological influence of climate, that enabled ITE to play both an important role in planning and advice and to develop a major research programme. It was the realisation of Fred Last's vision in the early 1980s that ITE should develop an interdisciplinary approach to the 'Pollution Climate'.

The 1990s have seen a rapid development of the topic with increasing emphasis on the coupling of land-atmosphere processes and determining feedback effects on:

- the interaction between species
- the ecological consequences of the interaction of climate with land use and other environmental factors
- regional variations
- options for mitigation.

Above all, climate change has forced a major change in the research approach, with much greater emphasis on the future. Questions of 'What will happen if?' have challenged the ability to produce quantitative predictions, forecasts and scenarios which account for the variability in the terrestrial environment.

The DOE and NERC have been key funding sources for climate change, but the content has certainly not been domestic. The European dimension has included participation in networks to explore changes across environmental gradients as part of the EC Environment and Climate Programme and contribution to the European Environmental Agency. At the global level, IGBP has provided a stimulating international community for the understanding of underlying processes, comparative analysis and data exchange.

Data bases: expanding capacity and emerging uses

The rapid expansion of computing capability, the demand for open access to environmental information and issues of intellectual property rights, have all been features of the 1990s. The application of old data to new issues has proved particularly valuable.

The geographical distribution of some 10 000 taxa based on more than 6 million records within BRC is a classic example of a strategic activity which has increased in value since its establishment in 1964. Supported by the conservation agencies, these data are now contributing to the Biodiversity Action Plan and also being used to assess past and potential changes in response to climate change – new questions of old data.

BRC is one example. Land Classification, Countryside Survey, Land Cover Map, Pollution Monitoring, Critical Loads, Biogeographic Zones and Environmental Change Network, plus a variety of individual long-term data sets, represent other primary and derived data sets. These are now coordinated through the Environment Information Centre at Monks Wood as one of NERC's Designated Data Centres.

The challenge is not only to make these data readily accessible, but to strengthen the capacity for their analysis and synthesis. The use of existing data is an increasing option in developing and testing hypotheses as a complement to field observation and experiment. The inclusion and access to European and Global data sets has been a further major development which will expand the scientific capability.

Basic ecology: a continued priority?

Has basic ecology declined or disappeared under the pressures to win external funding and the demands of customers? This is debatable. It depends on the definition of 'basic' ecology. The key question is whether the research improves understanding of the factors determining the structure, composition and processes of terrestrial ecological systems, and the abundance and performance of individual species and organisms It is this understanding which provides an improved basis for prediction and modelling future environmental trends and critical assessment of measures to protect and manage the environment

Evidence for the depth and quality of ITE's continuing scientific credibility includes

- continued international standing of research on animal population dynamics, plant genecology, and land-atmosphere interactions
- the awarding of Individual Merit Promotion to 8 members of staff during the 1990s
- doubling the rate of publication in high quality refereed journals (to nearly 300 refereed journals papers in 1997)
- an increase in multi-authored journal publications (60% of publications were with external co-authors in 1997)
- success in open competition for awards in NERC Thematic Programmes and EU grants (each comprised over 10% of ITE's income in 1997)

Reasons for the sustained strength in 'basic' ecology stem from

- the importance given by NERC to the quality of science reflected in the criteria for Thematic Programmes and the CEH Core Science Programmes
- the ITE management policy of maintaining core expertise in plant and animal ecology and biogeochemistry, whilst extending the capability through extensive external collaboration
- adoption of new technologies which expand existing knowledge (particularly in computing science, analytical chemistry and mathematical modelling)
- collaboration with Universities and the high level of involvement of post-graduate students (currently c 100) in research programmes
- targeting of contract proposals towards those that require new understanding of mechanisms and processes (a feature of many Department of the Environment, Transport and the Regions (DETR), Ministry of Agriculture, Fisheries and Food (MAFF) and EC contracts) and maintain continuity of core capabilities

There may be less freedom to follow personal instincts and interests but even this is debatable when reconsidering the function of ITE 25 years ago What is clear in the 1990s is that ITE continues to make a significant contribution to basic ecology both nationally and internationally

Conclusions: what makes ITE function after 25 years?

ITE in the 1990s has shown its pedigree that owes much to the vision of its founders Despite the vicissitudes of funding and of reorganisations the principles that they laid down have been retained

- The role of an Institute and the need to focus on understanding long-term and large-scale trends has been justified The issues of the 1990s have increasingly needed such information
- The key issues of the 1990s – biodiversity, global change, environmental pollution and sustainable development – challenge our ability to integrate information across disciplines They call for a holistic and synthetic approach Here, the range of expertise in ITE and the ability to generate multi-disciplinary research teams, often in collaboration with researchers at other Institutes and Universities, has been a strength
- The dispersed nature of ITE has retained its value in providing understanding of regional issues and of the varied environments of the UK The dramatic improvements in electronic communication have minimised the limitations of geography
- Participation in international research and policy is a normal part of ITE's activities, also enhanced by improved communications Research extends from the Tropics to the Poles The importance of such efforts has increased greatly in the 1990s with the recognition of the environmental interactions at the European scale, the increased importance of global markets in natural resources, and the increase in international policies on global issues

Why is ITE strong in the 1990s? The answer lies in the visionary structure and function laid down by the founding Directors (Martin Holdgate and John Jeffers) and the energy, flexibility and resilience of their staff

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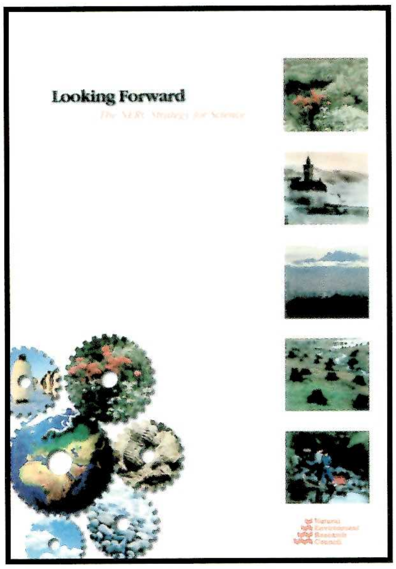

Plate 1. The NERC strategy for environmental sciences over the next 5–10 years

Investing in a sustainable future

Prof Mike Roberts

Introduction

"As we approach a new Millennium, the challenge for NERC is to provide an holistic approach to the environmental sciences, by moving from description to prediction based on understanding processes and integration of large data sets into models" (NERC Strategy for Science 1998) (Plate 1).

The key element of this challenge is prediction based on an holistic and integrated approach. The UK's atmospheric, terrestrial and freshwater science community has internationally recognised skills that will be able to meet the challenges of this strategic statement. The challenges to the Centre for Ecology and Hydrology (CEH) will be to provide large-scale and long-term environmental information, advance technological developments and contribute to interdisciplinary studies of processes and model development.

The key element of NERC's Strategy for Science is prediction based on holistic and integrated approach to Earth System Science.

The ITE management strategy during the 1990s (Table 1) has been to broaden those disciplines which now contribute to the strength of CEH's interdisciplinary research capability, (particularly molecular ecology, mathematical modelling and information technology). This strategy has also been successful in other important aspects:

- increasing the quality of ITE's ecological research (publications in refereed journal papers have doubled)
- increasing links to a broader user community (commissioned research income has doubled)
- greater integration with NERC's scientific objectives (the number of grants won by ITE staff has trebled)
- greater support for education, training and public awareness of science (through increased support for research fellows, postgraduates, undergraduates and schools).

Table 1. The ITE Management Strategy

- Maintain geographical distribution to provide integrated national projects whilst exploiting regional opportunties.
- Increase breadth of disciplines and flexibility to form interdisciplinary teams through a staff restructuring programme.
- Improve services to the research community through access to national databases and large-scale facilities.
- Accelerate utilisation of new technologies (particularly molecular techniques, mathematical modelling and information technology).
- Maintain strong links between research projects and strategic needs of government policy, the EU and international agencies.
- Develop collaboration with the industrial sector.

A key element of this success has been to focus on the individual scientist's contribution to the objectives of coherent research teams. The research teams have been encouraged to interact with the broader research community in CEH, the UK universities and overseas. In the market place for environmental science (Figure 1), ITE is now seen as a valued collaborator and a strong competitor.

The Strategic Framework

The trend in recent years has been for the research community to work within a defined national strategic framework. NERC has responded to national priorities such as those identified in the Foresight Programme (Office of Science and Technology 1998) by focussing on six environmental and natural resource issues (NERC 1996).

- Biodiversity
- Environmental risks and hazards
- Global change
- Natural resource management
- Pollution and waste.

Within these six issues the NERC Terrestrial and Freshwater Sciences Board has identified six priority areas (Table 2). Along with Polar Science and environmental data, these form the framework for evolution of the ten CEH strategic science programmes which were established in 1996 (CEH Annual Report, 1996). These programmes have been the mechanism for integrating the research capability during the commissioning phase of CEH. It is clear that the programmes need to be dynamic and subject to continuing review and development.

In particular, many of the difficult topics at the interface of science disciplines (eg environment and health) have still to be addressed Several aspects of the ITE strategy will need to be modified and strengthened to meet the future challenges for large-scale interdisciplinary research A primary objective will be to develop the appropriate mix of ecological and technical disciplines to provide a flexible base to respond to strategic research opportunities

The objective is for each CEH programme to provide a long-term and large-scale national capability for survey and monitoring, technology development, process-based research and predictive model development For some CEH programmes this strategy is fully realised, in others it is still an aspiration For example, ITE plays a major role in the full breadth of these activities in the comprehensive and mature Land Use Change, Pollution and Biodiversity Programmes In the Global Change Programme, integrated research on large-scale biome modelling is developing rapidly In the Soils Programme, arrangements are in hand to expand national monitoring of soil quality through analysis of physical properties, pollutant residues and biological characteristics A new CEH Science Urban Programme has been launched and has been successful in securing support from the NERC 'URGENT' Thematic Programme

Future Challenges

There is more cause for optimism in the future of the terrestrial and freshwater sciences than at any time in ITE's history The long period of efficiency scrutiny and performance appraisal during the 1990s has produced a lean and hardened approach to delivery of excellent, relevant and independent science to a broad range of customers (Figure 2) Staff have learned that change creates opportunities as well as threats The arrival of a new Millennium is generating a renewed emphasis on ecological aspects of sustainable development within the Research Councils and government departments (DETR – Opportunities for Change 1998) The opportunities

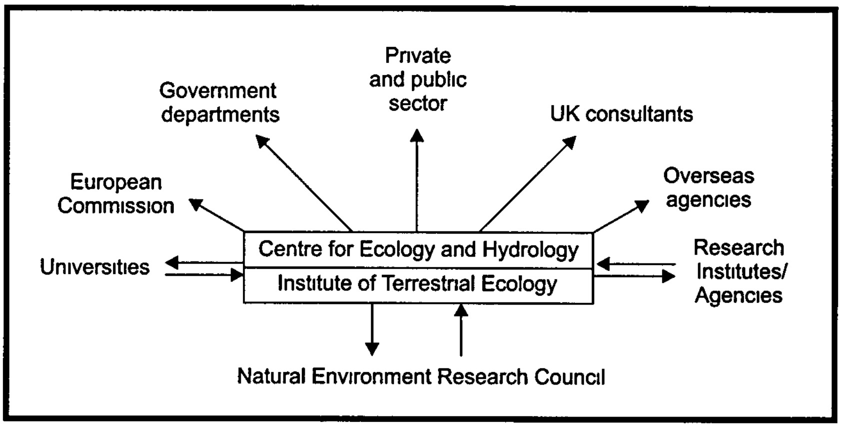

Figure 1 The role of CEH and ITE in delivery of ecological research to NERC and a broad user community

within Europe will expand through the emphasis on strategic environmental research to support sustainable development in the European Union's Fifth Framework Programme which commences in 1999 and the European Environment Agency The UKs return to UNESCO will give added impetus to support research and technology transfer to improve the economic well-being and the quality of life in developing countries

The amalgamation of ITE's research capability within CEH has enhanced the opportunity to deliver an integrated environmental science capability to NERC and the user community Nevertheless, the future will bring new challenges The pressure for amalgamation of management structures and more efficient administration will continue apace The twin imperatives of delivering research of the highest quality whilst ensuring relevance to a broad user community will continue unabated

It can be anticipated that a more transparent customer-contractor relationship between NERC and the Centre/Surveys will emerge This will have the advantage of a more business-like approach to the full range of deliverables provided to NERC by research staff (Figure 2) It will also generate the need for a more flexible and adaptable response from the science base to emerging national priorities The challenge for management to match scientific capability to the changing funding profile will continue to intensify The trend is for 'headroom' to be redirected by NERC whilst the user community base will continue to diversify and fragment

Expanding Horizons

The optimal strategy within CEH will be to sustain a broad disciplinary base whilst ensuring mechanisms are in place to form interdisciplinary research groups ITE will need to maintain the core research disciplines to meet current objectives whilst enhancing research capability in expanding areas such as

Genetic and molecular ecology

This expertise will

- quantify genetic variation in natural

Table 2 Priority Topics for the Terrestrial and Freshwater Sciences in NERC and CEH

NERC Theme	CEH Programme
Biodiversity	Biodiversity and Population Processes Pest Disease Control and Risk Assessment for GMOs
Global Change	Global Change
Hydrological Processes	Freshwater Resources
	Environmental Risks and Extreme Events
Human Impacts	Pollution
	Land Use Science
	The Urban Environment
Microbial Ecology	Soils and Soil-Vegetation Interactions
Earth Observation	Integrating Generic Sciences
Polar Sciences	Arctic Initiative
Environmental Data	Environmental Information Centre

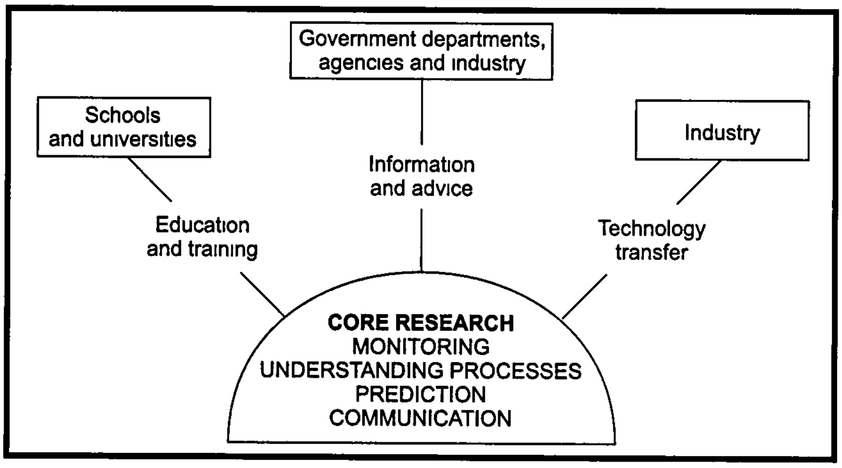

Figure 2 ITE's services to the user community

populations of selected plants and animals and its consequences
- investigate mechanisms of population differentiation and speciation
- develop and apply genetic markers to studies of breeding biology, dispersal, gene flow and population structure
- apply the research to GMO risk assessment and conservation policy

The priority will be to expand expertise in molecular biology and invest in modern laboratory facilities

Population Ecology

This discipline aims to
- elucidate the factors and processes (including the performance of the individual) that determine the distribution and abundance of organisms
- develop methods to estimate relevant population parameters at different spatial and temporal scales
- identify mechanism that enhance or limite spread of species (eg philopatry)
- assess the evolutionary responses to changes in selection pressures generated by land use change
- use the knowledge to model and predict the impact on wildlife populations of environmental change, to underpin strategies for wildlife conservation and for the control of invasive pest species

The priority will be to sustain the existing high level of ecological expertise whilst increasing mathematical modelling and molecular applications

Community Ecology

This discipline will
- determine mechanisms underlying patterns and process in terrestrial communities
- establish the functional significance of community structure and biodiversity
- develop models to describe species assembly, plant/animal interactions, co-evolutionary host/parasite systems and successional processes
- based on this understanding, to develop and improve methods for community management, restoration and conservation for a broad user community in the conservation, consultancy and land use sector

This will require a stronger theoretical base, greater field experimentation and better integration between community ecologists and soil scientists

Landscape ecology

This discipline will
- develop scale techniques for integrated monitoring of environmental effects of land use change
- integrate data, including land cover, climate and topographic features to predict species distribution, abundance and community structure
- relate the dynamics of metapopulations and communities to landscape structure, including linear and fragmented features
- model the impacts of land use change on animal and plant populations and communites
- apply techniques for environmental assessment of land use change for a broad user community and develop indicators of sustainable management

The priorities will be to improve techniques for recording by remote sensing, spatial integration and ecological modelling at the landscape scale

Soil Sciences

This discipline will
- improve understanding of the interaction between physical and chemical processes in soils and soil biodiversity (including soil fauna, fungal and microbial populations)
- advance knowledge of biologically-mediated soil processes which are significant in biogeochemical cycling
- develop research on rhizosphere processes which determine soil-plant interactions
- develop a framework for monitoring changes in physical, chemical and biological parameters
- provide information in support of national policies for the sustainable management of soils

These objectives will require expansion of the existing interdisciplinary capability through investment in molecular microbiology, stable isotope facilities and advanced organic chemistry

Air Pollution

Research in air pollution will
- monitor gaseous and particulate pollutants (including radionuclides) and determine the deposition, uptake, flux impacts on key processes in terrestrial ecosystems
- assess the sensitivity of ecosystem components to pollutant impacts and exposure, and identify the consequences of any changes

- determine the effects of interactions with other environmental factors
- develop techniques for mapping the sensitivity of terrestrial ecosystems and modelling at the local, national and international scale
- provide advice to the industry and regulatory sectors on emission control strategies based on the critical loads approach and predictive modelling

The priorities will be to sustain the strong interdisciplinary skills whilst strengthening the application to urban and human health issues

Ecotoxicology

Research in this area will

- monitor the environmental trends in persistent pollutant residues and to quantify the transfer processes
- study the bioavailability of organic and metal contaminants to a range of organisms
- investigate biomarkers as a means of assessing exposure and predicting effects
- relate the impacts of a pollutant on the individual to those at the population level
- evaluate the significance of interactive effects of pollutant mixtures
- improve hazard and risk assessment methods that can be applied to sensitive species and habitats at the appropriate temporal and geographical scale for the regulatory and industry sectors

The existing strong interdisciplinary capability will need additional support from organic chemists, environmental pharmacologists and mathematical modellers

Earth System Sciences

In this areas ITE will contribute to

- reducing uncertainty in the global budgets of greenhouse gases by quantifying the sources and sinks of CO_2, CH_4 and N_2O
- improving understanding of land/ atmosphere interactions and incorporate dynamic interactive models of global biomes into global change models (GCMs)
- assessing effects of climate change on the structure and function of terrestrial communities and to predict the dynamics of changes in species abundance and distribution
- providing support on the optimal methods for mitigation of global change and to advise on the most effective adaptive strategies

This is an expanding area (see Inter-Agency Committee on Global Environmental Change Report, 1996) and will need further strengthening of the biome-scale modelling skills and greater integration with earth observation expertise

Interdisciplinary Research

It is noteworthy that the UN Convention on Sustainable Development, promulgated at the 1992 Rio Conference, should be setting the cross-sectoral policy agenda into the new Millennium This is primarily due to the difficult interdisciplinary (social, economic and environmental) issues which have emerged as regulatory action has progressed at global, European and national level The DPSIR (Drivers – Pressures – State – Response) framework has emerged as a conceptual structure which continually requires interdisciplinary solutions For example, this approach is essential in

- Global change regulation to resolve mitigation/adaptation strategies
- Pollution control to formulate adequate risk assessments and cost-benefit analysis
- Land use policy to optimise agri-environment strategies
- Conservation policy to develop integrated land-use management
- Urban planning to enhance the quality of life

There is also growing pressure for environmental science to contribute to policy solutions resulting from the introduction of new technologies The most immediate will be to enhance the ecological inputs to risk assessments for genetically-modified organisms Major shifts in land use policies (such as CAP Reform) will also require a broad disciplinary coalition to predict the socio-economic and environmental consequences The move towards renewable energy sources will expand the requirements for broad-based environmental assessments

In future, the extensive contribution of Institute scientists to the advisory procedures for the government regulatory process will become more visible and demanding Across a broad spectrum, risk assessment procedures will need to be more quantitative Transparent indicators of sustainable development have still to achieve universal acceptance (British Government Panel on Sustainable Development 1998)

CEH has established internal mechanisms to support interdisciplinary research and produce new research alliances across the research sites (Table 3) There may be opportunities to strengthen this commitment through the formation of a unit to focus on integrated research across the terrestrial and freshwater sciences The current commitment to in-house socio-economic expertise will require strengthening to ensure that extensive external networking is realised For example, the significance of the scientific advisory role could lead to a greater commitment to research on integrated environmental policy analysis

Infrastructure Investment

Whilst it has been possible to improve the scientific capability during the last decade, the fragmentation of the funding base has made it more difficult to sustain investment in the infrastructure The science in ITE is becoming increasingly dependent on information technology and analytical techniques, with the consequence that some sites have difficulty in sustaining the requisite fit-for-purpose well-found laboratories Investment is essential if facilities are to match scientific aspirations of the new generation of scientists In addition to molecular laboratories, improved support for advanced analytical chemistry and the computing infrastructure will be continuing priorities

Improvements in communications through advances in computer networks has been one of the major factors contributing to the effectiveness of ITE research across the geographical spread

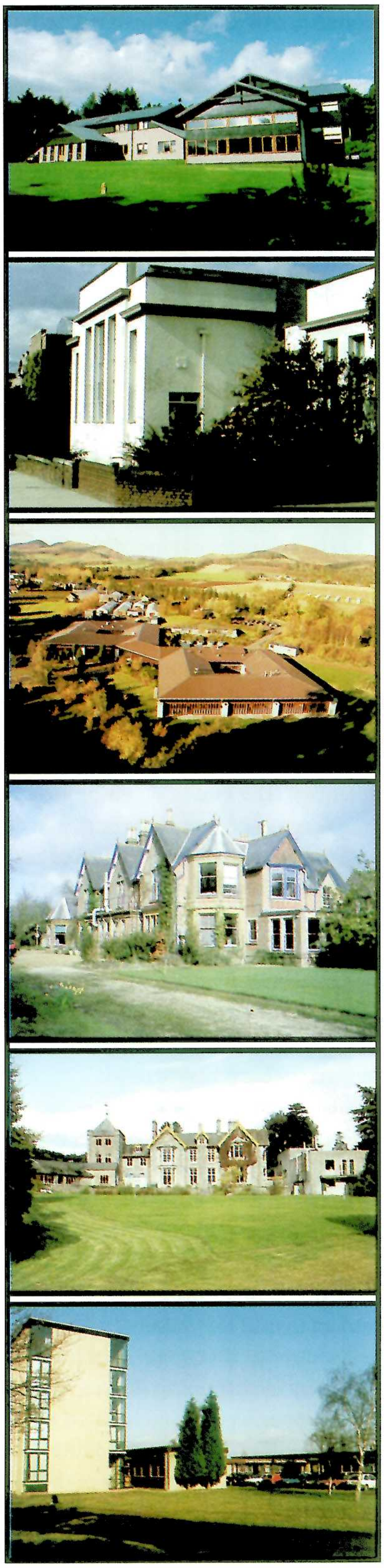

Plate 2. The geographical capability of ITE research. Banchory Research Station, Kincardineshire. Bangor Research Unit, Gwynedd. Edinburgh Research Station, Midlothian. Furzebrook Research Station, Dorset. Merlewood Research Station, Cumbria. Monks Wood, Cambridgeshire

Table 3. Contribution of ITE Stations to CEH Strategic Science Programmes

CEH programme	Monks Wood	Merlewood	Furzebrook	Edinburgh	Banchory	Bangor
Soils	-	•	-	-	-	•
Land use	•	•	•	•	•	•
Urban environments	-	-	-	•	-	•
Freshwater resources	-	-	-	-	-	-
Biodiversity	•	-	•	•	•	-
Biocontrol	-	-	•	-	-	-
Pollution	•	•	-	•	-	•
Environmental risks & hazards	-	-	•	-	-	-
Global change	•	•	•	•	•	•
Generic enabling science	•	•	-	-	•	-

of sites (Plate 2). Techniques for further improvements in networking, such as video-conferencing, use of the Internet and data sharing across secure networks will continue to create opportunities for more effective collaboration on CEH programmes. Access to high performance computers will create new opportunities for innovative science.

One of the major changes in the last decade has been the recognition of the importance of the Institute's role in safeguarding NERC's environmental data resource. The responsibility and resulting resource implications can only increase. In many ways, ITE's currency is environmental information. However, with the pressure mounting for free access to environmental data, it has proved difficult to realise this asset without constraining the many applications. Dedicated resources will be needed to implement successfully new initiatives for open networking such as the National Biodiversity Network.

Investing in People

ITE has surmounted past challenges through the commitment of staff to a mission for broad-based ecological research established 25 years ago. As we move into a new Millennium, the mission will expand further and the science will develop even more rapidly. Management will need to ensure appropriate investment in people and facilities to match the commitment of a second generation of ITE scientists, administration and technical support staff.

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