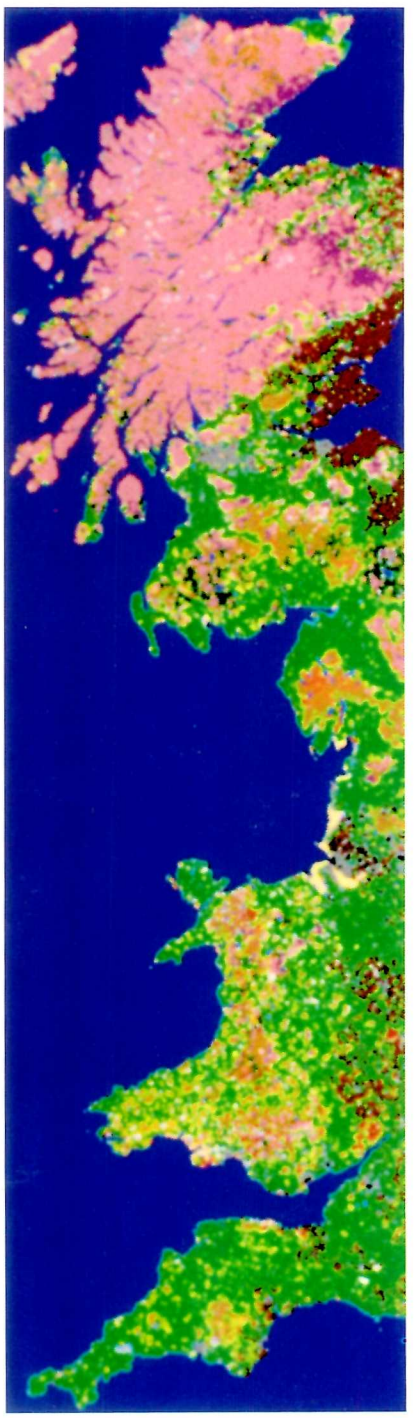
1992—1993
REPORT



Institute of Terrestrial Ecology

Natural Environment Research Council

The ITE mission

The Institute of Terrestrial Ecology will develop long-term, multidisciplinary research and exploit new technology (molecular ecology, information technology, and modelling) to understand the science of the natural environment, with particular emphasis on terrestrial ecosystems

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 *modelling* and *predicting* environmental trends arising from natural and man-made change
- the *dissemination* of this research to decision-makers, particularly those responsible for environmental protection, conservation, and the sustainable use of natural resources

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

By these means, ITE will seek to increase scientific knowledge and skills in terrestrial ecology, and contribute to national prosperity and prestige

Front cover illustration
An overview of the ITE land cover map of Great Britain

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Report of the Institute of Terrestrial Ecology 1992–93

Natural Environment Research Council

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Foreword by Director of TFS

The first three months of my appointment as Director of NERC Terrestrial and Freshwater Sciences have been among the most demanding, enjoyable and exciting times of my entire life! Trying to come up to speed with the exceptionally wide spectrum of Directorate activities is clearly a task for a lifetime rather than 100 days. Added to this has been the anticipation of the publication of the UK government's White Paper on science and technology – a review that will undoubtedly have wide-ranging implications for research in NERC, government institutes and Higher Education Institutions (HEI).

My initial impressions, based on such a short time in post, are perhaps inevitably more general than specific. The first of those is the breadth of TFSD science. ITE is a microcosm of this, with ITE North and ITE South bringing together, in an inter- and multidisciplinary way, an exceptionally wide variety of techniques and approaches. To have achieved this so successfully reflects great credit on the staff and management of ITE.

My second impression is of quality. Here I must seek the forgiveness of those many staff who have made significant advances in their science, often with external recognition, if I mention just one. Dr Ian Newton was elected a Fellow of the Royal Society. This is, of course, a considerable and well-deserved personal honour, but I believe that Ian would not object if we all shared in it to some small extent. It is good for NERC and good for ITE to have its science recognised in this way, and I am also pleased to see field-based studies given such a high profile by our premier science body. I am delighted that the work of many other members of staff has also been recognised, and details are given in this Report.

The quality of our science must be the bedrock on which all our work is built and, whatever the changes in policy or structures that may occur in the future, our science will endure if it is good enough. How is quality measured? In general, the merit of all scientific work is judged by peer-review, for both publications in learned journals and in bidding for funds to support research projects. With regard to the latter, all new Science Budget-funded projects in ITE are subject to peer-review and subsequent assessment by NERC's Terrestrial and Freshwater Sciences Committee. In this way, the ITE science programme is maintained at the highest quality, in a manner directly comparable with that used to maintain research standards in HEIs. It is a matter of concern to me that the Science Budget in ITE has declined over the period 1982–92 (see the graph in the Directors' Introduction, p8). I regard it as a high priority to halt this decline and, if possible, to reverse it. It is of the greatest importance that we retain an underpinning of our activities with a strong and vigorous programme of basic research.

Science Budget funding to ITE has been supplemented by successful bids into Community Programmes (eg the NERC Terrestrial Initiative in Global Environmental Research – TIGER), which involves a welcome collaboration with other NERC institutes and universities. This research networking is a major strength which will be continued and developed, with a recognition of the increasing importance of industrial collaboration and wealth creation.

Publications of all types continue at a buoyant level, with an increase in contract reports being particularly marked over the past five years. In HEIs, peer-reviewed papers in high-quality journals are a major output indicator. The same is true for ITE, and there is considerable evidence of achievement in this area. However, contract reports to customers also indicate a substantial and important science effort, the importance of which cannot be emphasised too highly, especially to colleagues in the HEI community.

I should like briefly to comment on three other areas of ITE activity, which I personally have found to be of particular interest. A number of national data bases are maintained by ITE, for example the Biological Records Centre, land cover map, countryside information system, and CORINE (Co-ordinated Environmental Information in the European Community). These data bases are crucially important for policy development and monitoring, and a substantial part of the Science Budget is used to fund them. Long-term data collection is central to NERC's mission and this role must be safeguarded.

ITE research interests range from studies of the organism via communities and populations, through to local,

regional and global issues Many activities in these areas feature in this Report, but a recent and important development is the Environmental Change Network, which ITE manages on behalf of a consortium of research councils, government departments and agencies

As this Report shows, ITE is actively involved in a range of collaborative projects overseas I am particularly pleased that a number of our younger scientists are gaining the experience of working in ecosystems very different from those found in the UK, and that overseas visitors come to ITE to learn techniques applicable to applied problems in their home countries

Finally, let me return to the forthcoming White Paper, which I believe will place considerable emphasis on wealth creation, industrial competitiveness and quality of life A continuing task for us all in TFSD will be to demonstrate the value and relevance of our research to wealth creation and wealth preservation I am entirely confident that ITE is well placed to meet these challenges

C Arme

Director of Terrestrial and Freshwater Sciences
Natural Environment Research Council

Introduction by Directors of ITE

Senior ITE staff
Back row: Dr Melvyn Cannell (Edinburgh), Dr Brian Staines (Banchory), Ian Smith (ITEN Administration Officer), Dr John Good (Bangor), Prof Mike Morris (Furzebrook), Prof Mike Hornung (Merlewood), Dr Stuart Dobson (Monks Wood). Front row: Jane Parsell (ITES Administration Officer), Prof Mike Roberts (Director South), Prof Bill Heal (Director North)

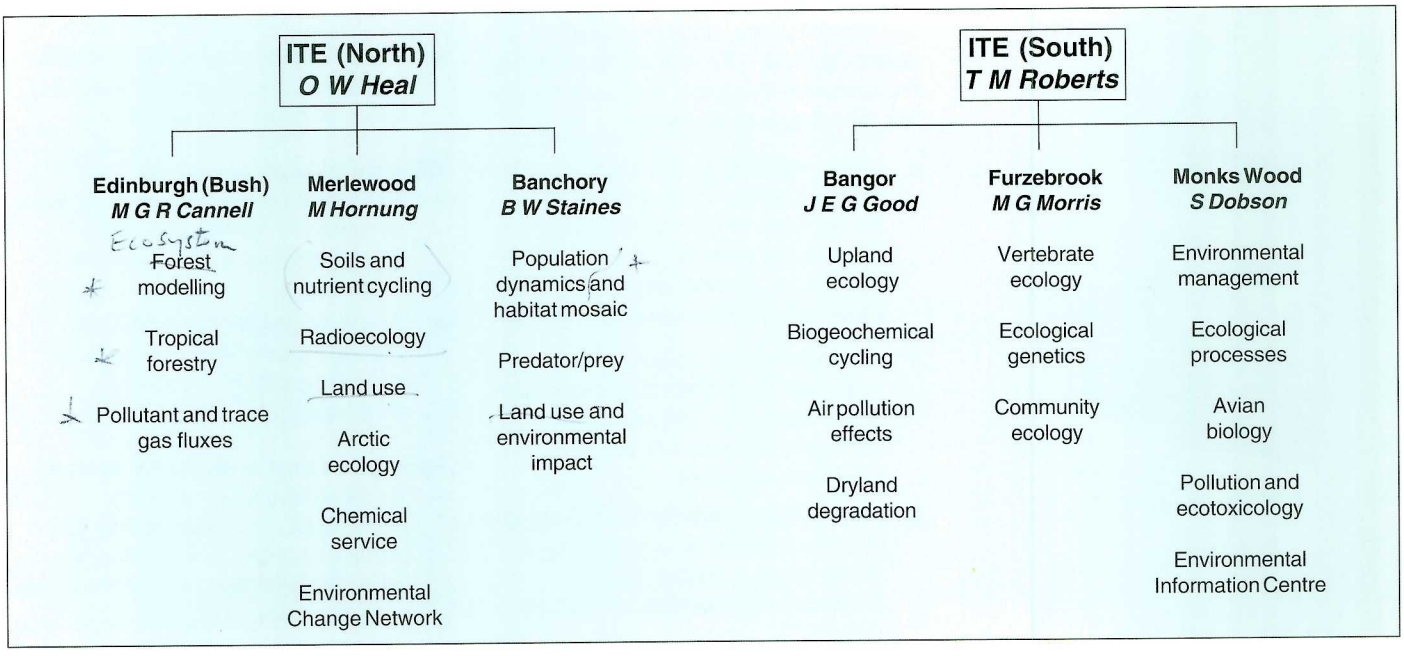
The year 1992–93 saw a continuation of the trend towards more integrated interdisciplinary research directed to international and national priorities. Strategic research throughout the Institute continued to be strongly related to UK government policy and requirements of the industrial sector. Analysis of ITE's performance in 1992–93 shows a further increase in numbers of scientific publications, commissioned research (contract) reports and collaboration with the university sector.

Research trends

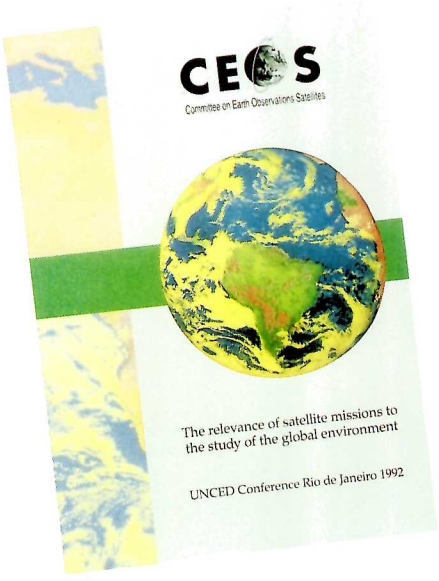
The global dimension

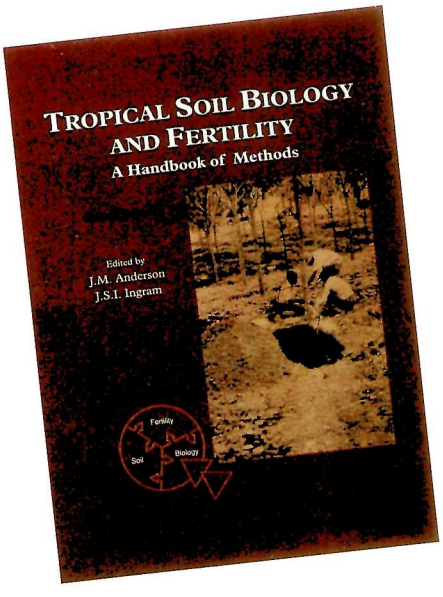
International policies were dominated by the United Nations Conference on Environment and Development (UNCED), held in Brazil during 1992. The resulting action plan for sustainable development into the 21st century (Agenda 21) called for 'integration of environment and development which will lead to fulfilment of basic needs, improved living standards, better protection and management of ecosystems and a safer more prosperous future'. The UK science base has an important role in formulating the national sustainable development strategy being prepared by the Department of the Environment (DoE) for the new UN Commission on Sustainable Development (CSD). The Biodiversity Convention formulated at UNCED placed continued emphasis on the preparation of a UK Action Plan on Biodiversity. The Climate Change Convention also called for the development of scientific understanding and consensus through the continuing deliberations of the Inter-Governmental Panel on Climate Change (IPCC).

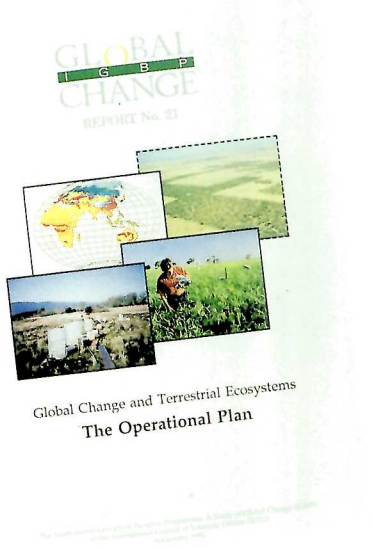
ITE contributes to global change issues in a number of ways. At a truly global scale, ITE is involved in improving the general circulation models (GCMs) which predict the earth's present and future climate. The flux of water and energy between vegetation and atmosphere is a basic ecological process



Current organisation within ITE







Examples of international development

which responds to increasing levels of CO_2 and changes in climate. Modelling of vegetation dynamics is necessary if GCMs are to give more accurate predictions of the 'greenhouse effect', and researchers, mainly at ITE Edinburgh, are exploring the global application of interactive vegetation models with the UK Meteorological Office and with other research groups overseas. Participation by ITE is also targetted through international programmes designed to understand the ecological processes which characterise the major biomes and the consequent implications for sustainable management. For example, there is active collaboration in the Arctic through the International Tundra Experiment (ITEX), and in the tropics through the Tropical Soil Biology and Fertility (TSBF) programme of UNESCO. An alternative contribution is focused on particular environmental impacts rather than regions, as in the hazard assessment of chemicals for the World Health Organisation's international programme on chemical safety.

The European dimension

The Commission of the European Communities (CEC) programme Towards Sustainability, accepted at the Edinburgh 'Summit' in late 1992, identified the main features of the CEC Fifth Action Programme on Environment. The priority issues identified at the European scale were climate change, air pollution and acidification, depletion of natural resources and biodiversity, pollution of water resources, deterioration of the urban environment and coastal zones, and the control of waste disposal. ITE staff are involved in collaborative European research through the following mechanisms:

- participation in global change projects within the Environment Programme of the Third Research Framework (covering acid deposition, climate change impacts, biodiversity and coastal processes);
- extension of the CORINE (Co-ordinated Environmental Information in the European Community) 'biotopes' data base to six eastern European countries;
- Europe-wide definition and mapping of 'critical loads' for acid pollutants under the auspices of the UN Economic Commission for Europe (UN-ECE);
- involvement within the European Conservation Research Institute Network (CONNECT) in collaborative research on climate change, biodiversity, land use change and ecotoxicology;
- training of European scientists in terrestrial ecology through the CEC Capital and Mobility Programme.

The UK dimension

The year was dominated by the consultation stage of the government's review of the role of science and technology in the future development of the UK. The outcome had not been announced by the end of the 1992–93 reporting year, but it was clear that there would be a restructuring of the Research Councils and a greater emphasis on wealth creation. The NERC submission to the Office of Science and Technology stressed the importance of an holistic, interdisciplinary approach to environmental research. The research programme areas within the Terrestrial and Freshwater Sciences Directorate of NERC reflect this integrated approach to strategic 'directed-mode' research. ITE research projects are making a significant contribution in the following areas.

Forest sciences

- To determine how best to conserve forest ecosystems and biodiversity from boreal lands to the tropics.

Land use and remote sensing

- To exploit modern information technology to ensure land use data are comprehensive and accessible.
- To develop the capability to predict the environmental consequences of major changes in land use.

Climate change processes

- To determine the production of trace 'greenhouse' gases, and water/energy exchange over terrestrial surfaces.
- To assess the impact of climate change on land-based processes, and the response of sensitive ecosystems and rare species.

Population and community biology

- To determine ways in which populations and assemblages of plants and animals become established, interact and respond to stress.
- To develop the ability to predict and manipulate the dynamics and diversity of ecosystems.

Environmental pollution

- To determine the transport, fate and effects of environmental pollutants on ecosystems and sensitive organisms.

Community science

The 'core' science programme in the Institute is increasingly integrated with university research through Community Programmes, Special Topics and joint studentships. In 1992–93 the Joint Agriculture and the Environment Programme (JAEP), which was co-sponsored by the Agricultural and Food Research Council (AFRC), the Economic and Social Research Council and NERC, came to an end. ITE participated in each of the three programme areas in collaborative projects. The science concentrated on the dynamics of plant and animal populations in relation to habitat structure. These fundamental studies in population and landscape ecology provided an important theoretical basis for land management and, in the case of the socio-economic component, for identifying how farmers will respond to management incentives. A more limited Special Topic explored the wildlife and socio-economic aspects of Farm Forestry in parallel with JAEP and also ended in 1992–93, with a conference to disseminate the results.

Whilst some Community activities ended in 1992–93, others developed. ITE played a significant role in establishing the final element of the NERC Community Programme entitled Terrestrial Initiative in Global Environmental Research (TIGER), which covers the effects of climate change on terrestrial ecosystems. The approach has been to build up an understanding through studies covering ecophysiology, population dynamics and species interactions at a hierarchy of scales – ecosystem, landscape and biome. The Programme has been enhanced by the transfer of research facilities from the National Power Technology and Environmental Centre to the TIGER community. In particular, the solar dome climate change facility has been transferred to ITE Bangor. Research facilities were also being developed at Monks Wood to optimise free-air CO_2 exposure (FACE) and outdoor UV-B exposure systems.

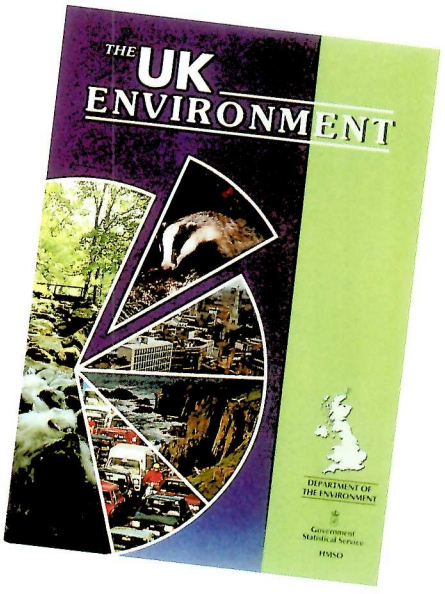
In 1992–93, NERC launched the multidisciplinary Land–Ocean Interaction Study (LOIS) – a long-term Community research project which seeks to understand the flux of materials across the coastal zone. LOIS consists of four linked parts, the River – Atmosphere – Coast Study (RACS), the Shelf Edge Study (SES), the North Sea Modelling Study (NORMS) and the Land–Ocean Evolution Perspective (LOEPS). The RACS study will be focused on the coastal zone between Berwick-on-Tweed and Great Yarmouth. ITE has responsibility for understanding the biological determinants of intertidal fluxes. This project will incorporate four site-specific studies of saltmarsh and mudflat fluxes and spatial extrapolation using remote sensing and geographical information systems (GIS). Close collaboration is planned with the University of Hull and the National Rivers Authority.

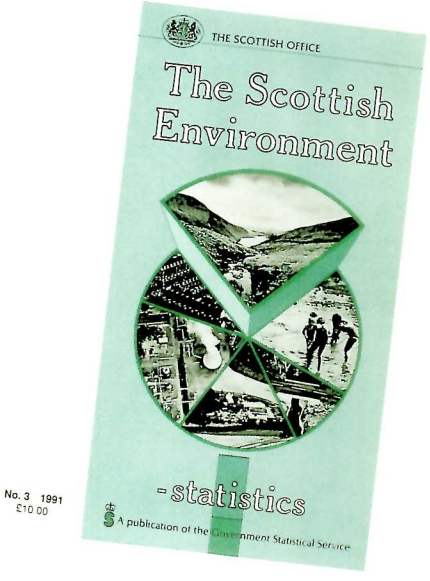
The government White Paper *Coastal zone protection and planning* highlighted the need for integrated coastal zone management. ITE contributed to a major NERC Conference on the scientific underpinning of coastal defence, offshore resources, pollutant flux and the conservation of estuarine ecosystems. ITE is also developing research for the Ministry of Agriculture, Fisheries and Food (MAFF) on options for 'managed retreat' in the coastal zone.

Collaborative research with the university sector through the Special Topic programmes has become increasingly significant. In 1992–93, research was completed on Geographical Information Systems as well as Farm Forestry. New programmes have been initiated on Wildlife Diseases and Remote Sensing–ATSR, as well as through Special Topics in support of TIGER and LOIS. ITE supports nearly 40 CASE (Co-operative Awards in Science and Engineering) studentships and 20 'sandwich' course students. Institute staff were also successful in bidding for NERC Industry Targetted Studentships on information technology for environmental assessment.

Strategic research and government policy

One criterion for assessing the value of Institute 'directed-mode' research is the extent to which it can be applied. An enormous amount of information is needed for formulating policy to underpin government decisions, and then for implementing and monitoring the consequences. In recent years, ITE has made considerable progress in





Examples of UK strategy documents

One of a series of lysimeter trenches in the northern Pennines, under construction. These trenches will be used by ITEN to study the impacts of climate change

developing commissioned research to complement the baseline science programmes. In 1992–93, policy-related research was carried out in the following areas.

Environmental impacts

- Air pollutants and acid deposition
- Climate change
- Radionuclide pathways

Risk assessment

- Integrated pollution control
- Hazardous chemicals
- Genetically manipulated organisms

Contingency planning

- Hazardous chemical incidents
- Industrial accidents
- Oil spills

Land use

- Monitoring of land use change
- Key habitat mapping and monitoring
- Long-term set-aside management
- Management of Environmentally Sensitive Areas (ESAs)
- Managed retreat/coastal setback

Conservation

- Biodiversity – mapping and monitoring
- Rare species recovery
- Management of invasive species
- Management of Nature Reserves

Planning

- Environmental information
- Environmental impact assessment (EIA)
- Habitat loss and fragmentation
- Habitat restoration techniques

A major part of the commissioned research of ITE is related to the development of 'core' science in ITE and its application to environmental policies. The list of nearly 200 contract reports given in Appendix 4 shows that research is required at three scales – local, regional and global.

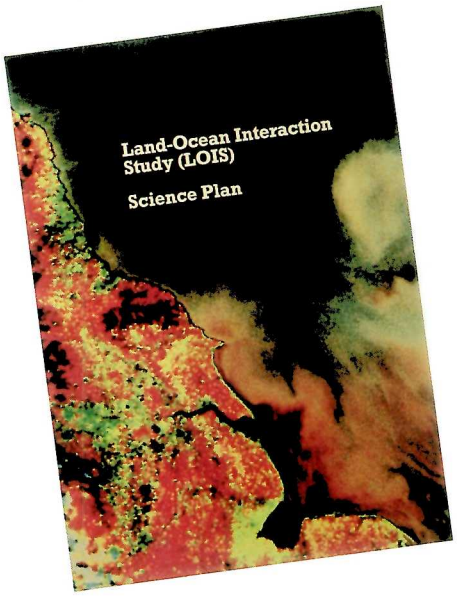
Local or site-specific policies

Implementation of environmental policy requires assessment of the likely impact of developments, whether through formal EIA or because of general concern by the relevant agencies. In these studies, the wide range of experience within ITE is therefore focused on site-specific issues – either for developer or planner. An increasingly important component in these studies is the identification of management practices which both ameliorate damaging impacts through habitat rehabilitation and enhance biodiversity, recreational or amenity potential in an area.

A distinct set of site-specific issues relates to environmental accidents, such as the oil pollution from the *Braer* on Shetland, or investigations into toxic chemical pollution under the Control of Industrial Major Accident Hazards (CIMAH) regulations. Remote sensing data and geographical information systems have been exploited to develop new approaches to environmental impact assessment procedures for industrial and road developments.

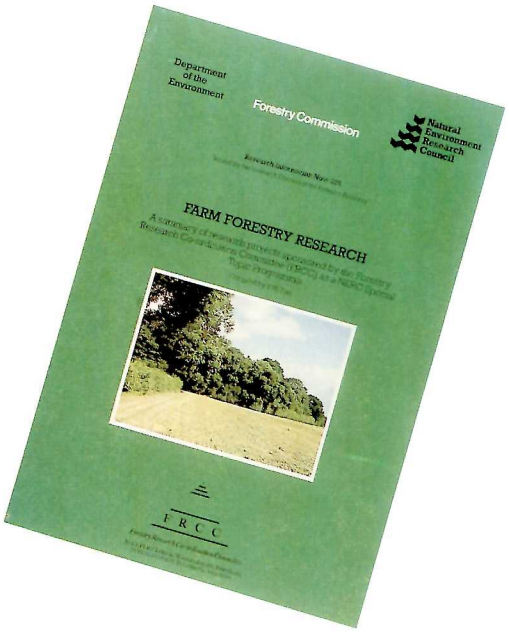
National and regional policies

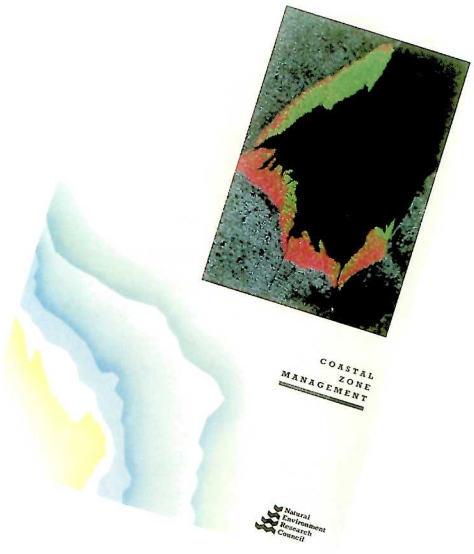
Research input to government departments and the CEC is directed to the formulation and monitoring of policies. Concern over the sources and levels of pollution, particularly atmospheric pollutants, is clearly represented. The pollutants vary greatly from industrially derived trace gases,



Key NERC publications

Key NERC publications





radionuclides, fertilizers, pesticides, and other organic compounds, to derived products such as ozone and naturally produced gases like methane and CO_2. Despite the variety, there are common features in the research required for policy-making. ITE contributes mainly in the definition of the transport, deposition and toxicity of pollutants from various sources. This information has been used to identify acceptable levels in relation to sensitive conditions, areas or species. Policies such as Integrated Pollution Control require the assessment of risk in relation to options, and increasingly include locational information which benefits from the predictive capability of geographical information systems.

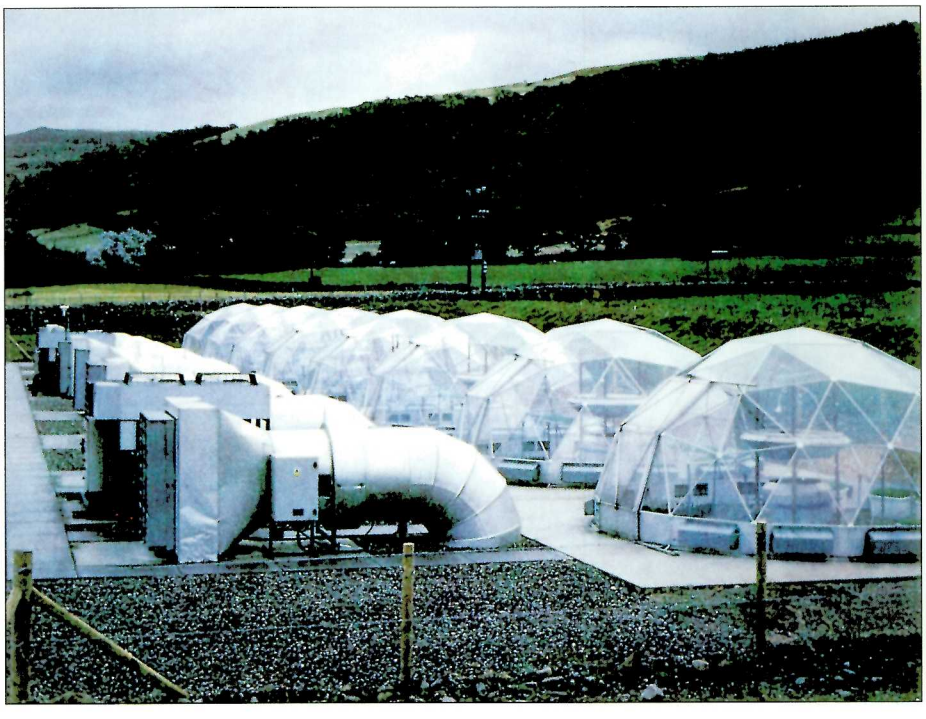
Policies related to land use and conservation require a detailed basis of information, not only of the current distribution and change of species but on the mechanisms by which change can be controlled, either directly through targetted protection policies or indirectly through land management. Again, the assessment of options and identification of sensitive locations require analysis of conditions across the country. Hence, research has focused on the combination of mechanistic studies leading to management prescriptions and the development of major national geographical data bases.

The national data bases, such as those in the Biological Records Centre, the UK land cover map, the countryside information system and CORINE, are critical, not only to define locational characteristics and resource inventories but in providing the essential means for monitoring the effectiveness of policies. Increasingly, the national data bases must be integrated with those at regional level. A major achievement in 1992–93 was the completion of the land cover map derived from remotely sensed information, together with full documentation of data from the 1990 Countryside Survey. These data bases underpin ITE's capability to address land use issues at the national scale. This capability has been used to develop policies on long-term set-aside, management of ESAs, and conservation responses to climate change.

Global policies

ITE research supports the development of global policies through the provision of data and information to major assessments of global conditions, such as IPCC. ITE research under TIGER has been incorporated into the global change and terrestrial ecosystems project of the International Geosphere–Biosphere Programme (IGBP). It is from this scientific base that target emission levels are negotiated. Plans are also being formulated for a Global Terrèstrial Observing System (GTOS), which will incorporate the UK's Environmental Change Network (ECN) managed by ITE staff.

At a more specific level, many of the Institute's projects are directed by the UK Overseas Development Administration (ODA) towards the implementation of policies concerned with the protection and regeneration of tropical forests or of individual products, such as mahogany. ITE staff also produced a major review paper on *Global forest assessment* in the context of environmental change issues for the United Nations Environment Programme and the Food and Agriculture Organisation.. In response to developments at UNCED, ITE staff have also contributed to a new strategy for research on dryland degradation.

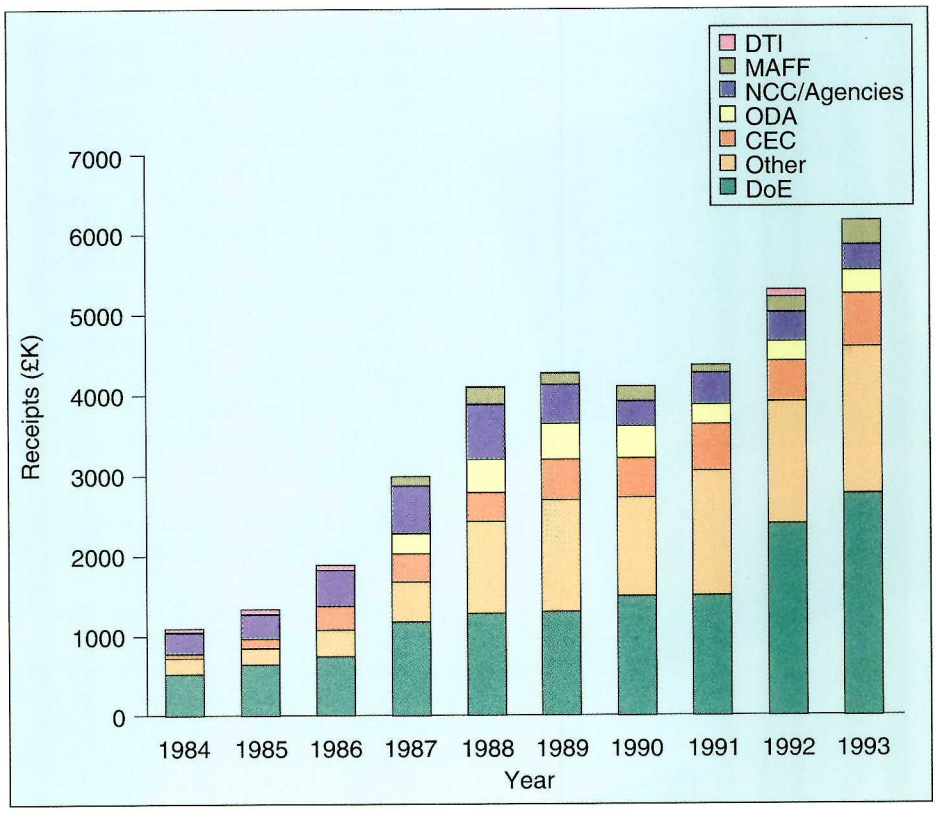


The solar dome research facility, recently transferred to ITE Bangor for use by ITES to measure the effects of climate change on vegetation, soils and invertebrates

ITE performance in 1992–93

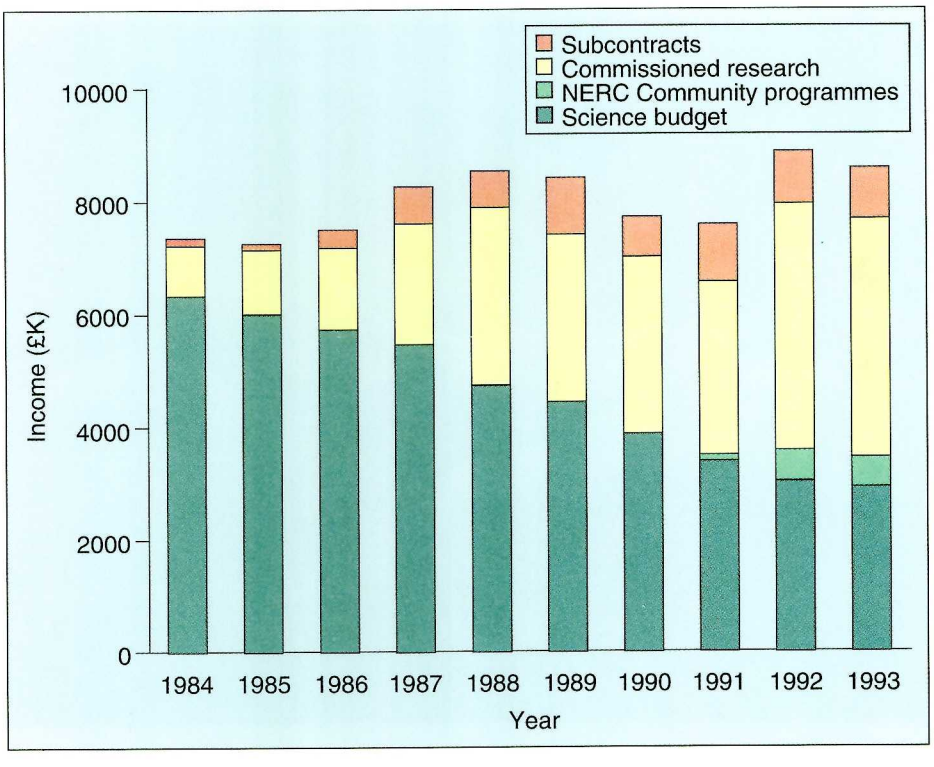
'Performance' is a word which is used widely in science and management today. The need to measure and improve performance pervades all levels in our organisation, from the junior staff making field observations or processing samples through to the Institute management as a whole. Indicators of performance include peer-review of new science projects, the ability to secure research support in open competition, 'value-for-money' in terms of published output, and quality assurance for commissioned research customers.

The two halves of ITE (North and South) have been managed as separate cost centres since 1989. The overriding factor affecting the Institute has been the decline in the Science Budget baseline over the period 1984–92. However, the annual budgets were in balance for 1992–93. Baseline funding for peer-reviewed projects comprised 30% of expenditure in 1992–93. A further 15% was secured from grant applications to specific science programmes (such as TIGER) and the remainder was derived from commissioned research. The financial position has stabilised and some modest improvements to capital resources and buildings were made in 1992–93. The most important development was the decision by NERC to rebuild the Banchory Research Station following the appalling fire in December 1991.



Long-term pattern of commissioned research income from major customers

The upward trend in income from commissioned research was sustained in 1992–93, although this trend is set to plateau in the near future. Since 1987–88, support from DoE has been increasing to just over 30% of total income, whereas support from the Nature Conservation Agencies, MAFF and ODA has declined in relative terms. Increased income has been secured from the CEC and the public/private industry sector.



Long-term trends in income

Key output indicators are scientific publications and contract reports. Nearly 200 contract reports were produced in 1992–93, along with over 300 scientific publications. The upward trend since 1989–90 has been sustained. In addition, Institute staff have produced 14 books. Most notable was the history of NERC produced by Professor John Sheail. Other important publications included national *Atlases* for mammals, bryophytes, craneflies and butterflies. Hazard assessment reviews published for DoE included cadmium, trichloroethane and diethylhexyl phthalate. ITE staff also edited books on biological recording, arctic ecology and estuarine barrages.

The scientific output by ITE continues to make a significant contribution to the overall output by NERC institutes and university units. Important output

indicators other than publications include:

- efficient management of national spatially referenced data bases;
- maintenance of long-term data sets on key indicators of environmental trends;
- development of large-scale experimental facilities;
- support for the university sector and national scientific infrastructure.

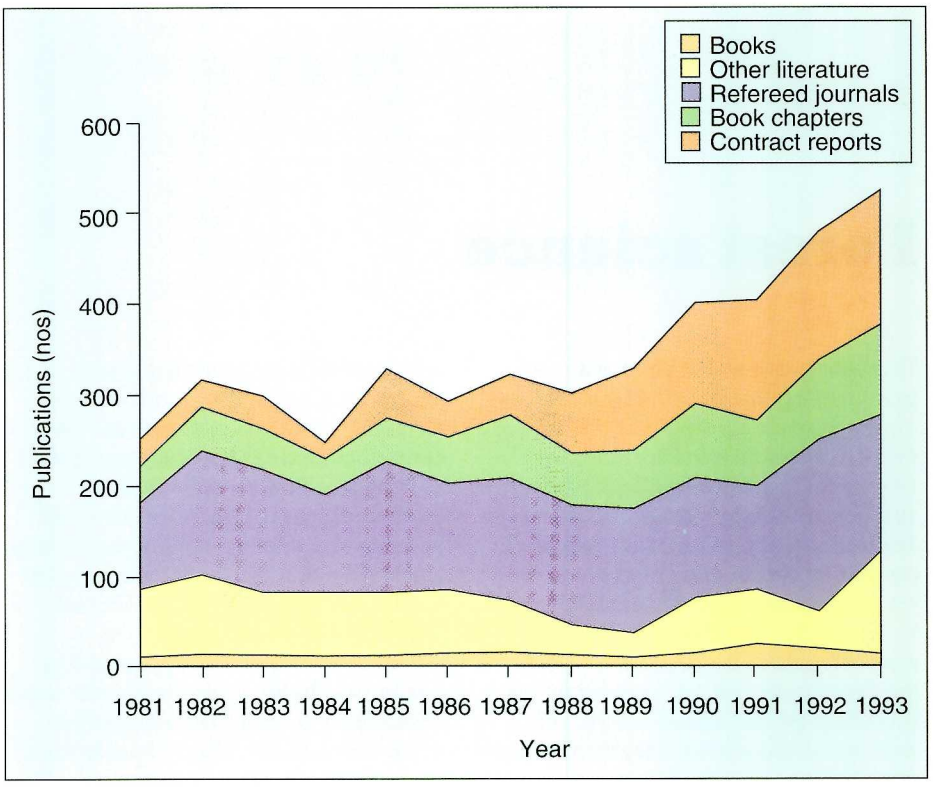
Forward Look strategy

The ITE strategy will clearly be influenced by the NERC response to the government's new strategy for science, engineering and technology. ITE will remain responsive to national priorities by:

- maintaining a breadth of disciplines and flexibility to form interdisciplinary teams;
- maintaining geographical distribution in order to provide a national capability, whilst exploiting regional research and commission opportunities;
- accelerated utilisation of new technologies (particularly in information technology, molecular ecology and mathematical modelling);
- increased collaboration through larger UK contracts, CEC programmes and links to global environmental research;
- improved service to the science infrastructure through improved access to national data bases and development of large-scale facilities;
- maintaining strong links between strategic research projects and scientific requirements in support of government policy;
- contributing to 'wealth creation' and 'quality of life' by collaborating with industry and commerce (including the rural as well as manufacturing industries).

Personal achievements

A most notable achievement during 1992–93 was the election of Dr Ian Newton as a Fellow of the Royal Society, on the basis of his distinguished contribution to evolutionary biology through long-term studies of sparrowhawks and finches. Dr Newton was also elected as President of the British Ecological Society. Professor Sheail was awarded the BUSK Medal by the Royal Geographical Society for his studies of the natural history of the British landscape. Dr Mike Harris received the British Trust for Ornithology's medal for Science, and Dr Bob Bunce was made a Fellow of the Royal Society for the Arts for his contribution to ecology and linkage between science and the arts. Dr Mike Morris was appointed Visiting Professor at the University of Southampton. Dr Graham Elmes was awarded a Doctorate of Science by the University of London.



Trends in output of publications

Each year Mrs Penny Ward combines vigour, attention to detail and tact in compiling and publishing the ITE Annual Report. Last year we agreed to test the market by asking our customers for their views. There was overwhelming support for continuing its present format, with suggestions to increase the Programme context and to include more graphic material. Despite suggestions for fewer individual reports, the authorship of contributions and the use of key references were welcomed. The Directors of ITE have responded to the feedback, and readers will note the increased attention to presentation in the papers which follow this Introduction.

O W Heal and T M Roberts

Directors, ITE

Scientific services

Plate 45. An inductively coupled plasma optical emission spectrometer in use at the Analytical Chemistry Group laboratory, ITE Merlewood

The business of an active and innovative research institute has seen a rapid increase in the range and number of research projects, the initiation of many new collaborative ventures with other research partners, new customers for its science, and the export of 'know how' to other practitioners in other parts of the world. These changes, so evident in the main science programmes of ITE, run throughout the organisation, and present new challenges and extra demands for the small teams providing specialist scientific, technological and professional services.

The work of these personnel provides:

- new experimental facilities;
- analytical chemistry laboratories
- development of instrumentation, statistical and biometric support;
- computer applications and data centres;
- libraries; and
- photography.

Each group must keep pace with technological development in its own field, initiate research into new applications and techniques, and develop and focus these to the special needs of the ecological research teams. Competing for resources to keep pace with technological advances in specialist areas, delivering services simultaneously to many different projects – often with contractual deadlines – and, in some cases, seeking commissions directly for their own expertise, present new management challenges for these personnnel. Scientific services is an area where quality assurance issues emerge strongly in analytical procedures, the production of software and instrumentation. There is increasing pressure for standardisation of methodology and for comparability both between studies and with research partners and customer departments.

Increasing overseas work sees the introduction of exotic materials and modifications to experimental facilities to accommodate new climatic conditions. It is also an area of great importance in external communications. Training for new researchers in specialist skills, technology transfer to developing countries, and the demonstration of expertise and capability as part of Institute marketing activities are areas of ever-growing importance.

Examples of the work of the specialist groups highlighted in this year's Annual Report demonstrate many of the facets of change and innovation in a modern institute. In-house technological advances, outreach through student training, technology transfer overseas, and the co-ordination of analytical chemistry requirements between research partners feature in the current work of the ITE Analytical Chemistry Group. Adaptation of the controlled environment chambers to study arid zone ecophysiology, and a new facility to study exposure of vegetation to ultraviolet-B radiation illustrate advances in experimental facilities. The role of statistical analysis and the significance of developing new techniques within many of the major ITE projects are explained. Here, the importance of training for visiting scientists from abroad in both statistical techniques and the competent use of computer software is emphasised.

Developments are also reported in two very different areas of specialist activity, illustrating the range of activities covered by scientific services. A strategy for exploitation of geographical information systems (GIS) in ecology and land use research at ITE is explained. Here, the emphasis is on the integration of thematic mapped data sets and of satellite images. Training in the use of GIS workstations and access to data sets via computer network are making access available throughout all the ITE locations. Work at Furzebrook in assessing types of molecular markers to study gene flow in plant populations is explained as a special example of external collaboration. Joint funding in partnership with a university and another research council illustrates the importance being placed by ITE on the sharing of skills and 'know how' to exploit new technologies for the advancement of ecological research within the Rothschild customer/contractor principle.

The provision of in-house scientific services in dedicated support of the specialised disciplinary missions has long been a feature of research at NERC institutes. They comprise a valuable and often unique asset to their departments, helping to advance the leading edge of science in an increasingly competitive environment where timeliness and value for money are being sought at all levels. The expansion of their function to many aspects of external communications between their area of science and the users of the research has been growing rapidly over the past two to three years. There is every indication that this trend will continue, and that demands upon them will increase as the government's new strategy for science, engineering and technology is emplaced.

A J P Debney

Co-ordinator of TFS scientific services (Institute of Hydrology)

Analytical chemistry

The Analytical Chemistry Group at ITE Merlewood provides :

- high-quality analytical support to the research of the Institute;
- direct input of chemical expertise into research projects;
- an analytical service for organisations outside ITE.

Analytical support

The Group supported 45 Institute projects during 1992–93. These projects were based in both the UK and overseas. Over 80% of the analytical service effort was in support of commissioned research and projects from NERC Community Programmes or Special Topics, such as the Terrestrial Initiative in Global Environmental Research (TIGER) and the Special Topic programme on Arctic Ecology. The proportions of soil, vegetation and water samples were similar to previous years, with water samples again dominating (Figure 64). Most of the samples originated from projects involved with the effects of environmental pollution or climatic change on natural ecosystems.

The main projects on which the Group has worked include:

- the Great Dun Fell TIGER experiment, studying the effects of temperature changes on soil processes and carbon turnover;
- the CORE project investigating mechanisms of nutrient cycling in forests and the effect of atmospheric pollution on these mechanisms;
- studies of the effects of atmospheric pollutants on trees;
- a Welsh experiment to predict critical loads for nitrogen in soils.

Overseas, ITE scientists are studying the effects of current management of *Acacia* fallows on soil amelioration and fertility decline in arid areas of Senegal, and soil samples have been brought to the laboratory for analysis. Work on the regeneration and management of tropical forests in Cameroon generated a large number of soil samples, which were analysed by the Group. Vegetation and water samples collected in Spitzbergen for studies under the Special Topic programme on Arctic Ecology have also been handled.

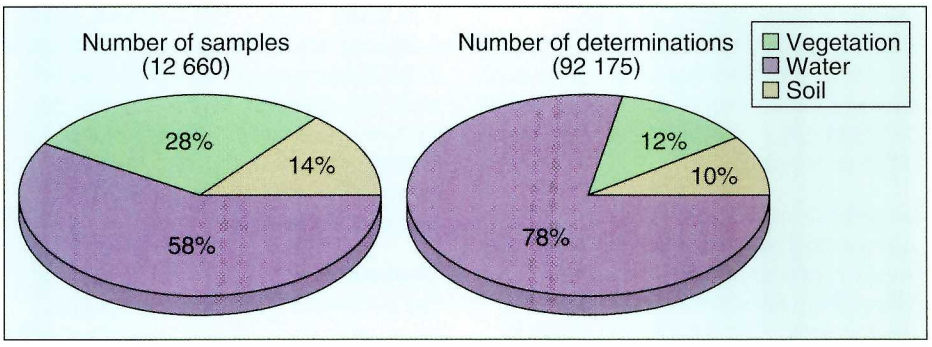


Figure 64. The numbers and proportions of samples processed by the Group and the number of determinations carried out during 1992–93

Analytical developments

All the main analytical instruments are now controlled by individual personal computers, which are in turn connected to the laboratory data processing package (BATCH) via a local area network (LAN). Further improvements have been made to this software package which runs on the station's mainframe computer. Weight data from electronic analytical balances can be input automatically to the package by transfer over the LAN. The data are then integrated within BATCH with data collected from analytical instruments, enabling automatic calculation of the final concentrations.

Some water samples are now being submitted with thymol added as a preservative. As a result, it has been necessary to modify sample preparation procedures for ion chromatography to remove this compound, as it interferes with the separation of anions on the chromatography column. Each sample is passed through a C18 chemically bonded solid phase extraction column prior to injection into the instrument.

Direct input to research projects

As well as operating an analytical service, the Group has been involved in activities where its expertise has been used directly within ecological research projects. This aspect of the Group's work has increased considerably over the last year. Four areas have been particularly notable:

- the Environmental Change Network (ECN);
- emission of 'greenhouse' gases from soil;
- atmospheric inputs of heavy metals to forest soils;
- the setting up of an analytical chemistry facility in Cameroon.

Environmental Change Network – terrestrial network

Within the ECN, the Group is responsible for co-ordinating the analytical chemistry requirements of the project. Seven organisations have joined the terrestrial network, with possibilities of other organisations becoming members soon. The Analytical Chemistry Group has considerable experience in monitoring variables and controlling procedures in order to detect changes with respect to treatments or time. This expertise has been applied to formulating protocols within which participating laboratories will operate.

To date, the main focus has been on water chemistry, where the analysis from each site will be performed in different analytical laboratories. Liaison between the chemists from each participating laboratory has identified a number of areas important to ensure comparability of data:

- reference techniques – designated as the most suitable for environmental measurement and against which future technique development can be standardised;
- approved methods – those methods providing potential to produce useful data;
- summary methodology – providing a record of methodology for the data base and evidence of error, calibration range and detection limits, etc;
- validation – documentation on measurements of accuracy and quality control, with specifications of control measures to be applied.

Each laboratory participated in an interlaboratory exchange exercise for analysis of cations, anions, DOC, alkalinity, pH and total N. This exercise

offered the opportunity for each analytical facility to obtain a measure of accuracy, gain experience in analyses of ecological solutions, and compare results obtained using alternative techniques in different locations.

In general, as concentration levels approached method detection limits, the level of agreement became poorer. Many of the laboratories were less familiar with DOC, total N and alkalinity methodology.

Mobile laboratory

The Analytical Chemistry Group has been involved in the commissioning and operation of a mobile laboratory, which is being used to quantify trace gas emissions from soils; a member of staff has been seconded to this project for a period of three years from 1992. The laboratory contains a gas chromatograph, with its associated gas supplies and data processing system, housed in a twin-axled box trailer with an external 4 kVA diesel generator to supply the electricity.

The laboratory is being used to analyse N_2O emissions from natural upland soils as part of the TIGER II group of projects. In order to collect the data, the mobile laboratory is required to operate unattended in remote locations for periods of up to four weeks at a time. In the first year of the three-year programme, the laboratory has been commissioned and operated successfully at six sites.

Heavy metal inputs to forests

During the Gisburn forest studies reported in previous ITE Annual Reports, high levels of heavy metals were discovered in the surface horizons of forest soil. The hypothesis was that the source was atmospheric. During 1992, a sandwich studentship was awarded to investigate this aspect further, and to set the foundation for a larger study. The project was supervised jointly by the Analytical Chemistry Group and the Soils and Nutrient Cycling Group.

Four forest sites on a north-east transect away from Preston, Lancashire, were used, with Grizedale Forest in the Lake District as the unpolluted control. Canopy throughfall and rainwater were collected at each site over a three-month winter period. Procedures were developed and applied for analysing the samples for Pb, Cd, Cu and Zn, and the results showed increased inputs to the soils under trees, compared with rainfall, indicating dry deposition of the pollutants to the forest canopy. Site differences were not apparent, confirming that the sources were more distant than the Preston area. It is hoped to take this study further and apply critical load concepts to the data.

Cameroon

The Analytical Chemistry Group has been involved in analysing samples from Cameroon (see above). However, in response to a request from the Office National de Dévéloppement des Forêts (ONADEF) in that country, a member of the Group went to Africa to advise and help set up a laboratory so that urgent analyses could be done locally. His remit was to assemble and commission a continuous flow colorimetric analyser and to train laboratory personnel in its use. Despite some problems because the laboratory itself was not fully ready, and because the time available was limited, the local technicians were taught how to use and maintain the instrument and to diagnose and rectify simple faults. Contingency plans were made to keep the facility in use whilst the rest of the laboratory was organised, and a further visit is envisaged to develop the capability further.

Analytical service for outside organisations

Direct contract analysis for customers outside ITE has been a significant proportion of the work of the Group. Traditional links with English Nature have continued, and terrestrial and freshwater scientists from the British Antarctic Survey have once again taken advantage of the service offered. A number of universities have submitted samples, notably the University College of North Wales, Bangor, who required water analyses as part of their tropical forestry studies in Jamaica.

J A Parkinson, A P Rowland, J D Roberts and P A Coward

Facilities for ultraviolet-B research at ITE Monks Wood

Depletion of the stratospheric ozone layer results in the transmission of more ultraviolet-B (UV-B) radiation (280–315 nm) through the atmosphere to the earth's surface. In addition to the ozone hole over Antarctica, satellite measurements have also shown a general reduction in stratospheric ozone in polar and mid-latitude regions of both the northern and southern hemispheres (Gleason *et al.* 1993). Direct measurements of UV-B at 3576 m in the Swiss Alps have shown an annual upward trend of 1% since 1981 (Blumthaler & Ambach 1990). Concern that terrestrial ecosystems may be exposed to increased levels of UV-B has been raised further by reports of the presence of reactive forms of chlorine, capable of ozone reduction, in both northern and southern winter polar vortices (Waters *et al.* 1993).

Changes in the level of UV-B are known to have a range of effects on vegetation, including reductions in leaf area and growth, changes in phenology, reduced photosynthetic activity, and changes in competitive interactions between species (United Nations Environment Programme 1991; Scientific Committee on Problems of the Environment 1992). Most research has been performed on crop species, and there is little information on species of natural vegetation.

A new facility for outdoor UV-B exposure of vegetation has recently been constructed at ITE Monks Wood. Banks of UV-B fluorescent tubes are suspended above experimental plots (Plate 46), and permit a supplementation of ambient UV-B levels. Experimental studies with UV-B

Plate 46. Outdoor ultraviolet-B exposure facility at ITE Monks Wood

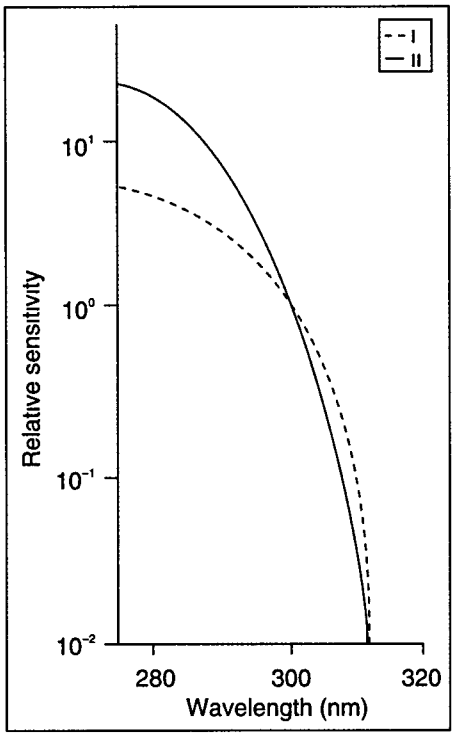


Figure 65 Action spectra used as weighting functions to calculate biological effectiveness of UV-B radiation (i) a generalised action spectrum for the response of plants to UV-B (from Caldwell 1971), and (ii) a generalised spectrum describing damage to nucleic acids (from Setlow 1974) Curves are arbitrarily set equal to 1 at 300 nm

are technically complex and require regular attention and calibration The spectral composition of light from artificial UV-B lamps does not match that of the solar spectrum Biological response to UV-B is dependent on wavelength and, in order to correct for the UV-B spectrum of the artificial lamps, a weighting function must be used, based upon an action spectrum (Figure 65) appropriate to the species and response under study The spectral composition of the UV-B treatment must be monitored regularly using a double grating monochromator spectroradiometer to ensure accurate exposures

The experimental lamps must be filtered to avoid exposing the vegetation to unwanted UV-C wavelengths (<280 nm), and it desirable to expose control plants to lamps from which the treatment UV-B has been removed This exposure is achieved using additional filters which only allow the transmission of the visible and UV-A wavelengths produced by the lamps

Experiments with UV-B have frequently been undertaken by simply switching the UV lamps on for fixed exposure periods centred around noon, when natural UV-B irradiance is greatest However, a more realistic treatment that maintains the ratio of UV to photosynthetically active wavelengths (400–700 nm) requires the modulation of lamp output to permit a fixed supplement to ambient UV-B levels A computer-based control system has been installed that permits fully automatic tracking of ambient UV-B levels and provides a proportional UV-B treatment and data logging capability

The control of lamp output for UV-B supplementation studies ideally requires modulation providing a 200 1 turndown ratio Special electrical circuits have been investigated to provide such a range of control for European and American fluorescent UV-B lamps at both standard (50 Hz) and high (30 kHz) electrical frequency The automatic feedback control also requires the use of UV-B sensors with a response to wavelengths that closely matches an appropriate action spectrum, and which is not influenced by ambient UV-A and visible wavelengths

The operation of the UV-B exposure facility has been evaluated throughout 1993 in order to commence studies during the winter of 1993–94 A research award will investigate UV-B impacts on natural vegetation as part of the NERC Terrestrial Initiative in Global Environmental Research (TIGER) and the Agricultural and Food Research Council's Global Change Programme

A R McLeod and E A Leeson

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Controlled environment chambers for arid zone ecophysiology

Nowadays the term 'dryland degradation' rather than desertification is used to describe the degeneration of ecosystems in semi-arid or arid regions, measured as a loss of primary productivity, species diversity and soil quality Dryland degradation research at ITE Bangor focuses on the water, carbon and energy balances of plants in fragile habitats, with the following specific objectives

i to investigate the water, carbon and energy relations of plants under conditions of drought stress, and to study the strategies adopted by selected xerophytic and halophytic species in balancing the need to minimise plant water loss against the need to assimilate sufficient carbon for growth, and hence survival,

ii to investigate how the structure and dynamics of plant communities in fragile habitats are determined by the water, carbon and energy balances of constituent species in competition for limiting resources,

iii to develop early indicators of degradation in fragile habitats, based on changes in plant community structure,

iv to examine the productivity of intercropped *Sorghum* in relation to water and nutrient stresses in semi-arid agroforestry,

v. to generate models which predict the outcome of competition between species in plant communities when resource supply and population density are altered.

In facing a given set of environmental constraints, the reproductive rate and survivorship that a plant achieves will be determined by its morphology, physiology, life history and behaviour. Because these traits depend on the pattern of carbon allocation within the plant, they are subject to unavoidable trade-offs; for example, photosynthate allocated to root growth in nutrient-poor soil cannot then be allocated to leaf growth or the production of seed. Plant community structure will be determined primarily by the interdependence between environmental limitations and species traits, in terms of the trade-offs that plants face in surviving and reproducing when limitations occur (Plate 47).

In environments where water is the principal limiting resource, the strategies taken by plants in dealing with water stress are solutions to a complex optimisation problem:

- in maximising carbon fixation and maintaining growth whilst minimising water loss through transpiration and preventing damage by drought;
- in partitioning fixed carbon to develop a more extensive root system in order to reduce water deficit at the expense of photosynthetic tissue and increased carbon fixation capability;
- in root placement, where water is differentially available to roots placed at different levels in the soil.

Experimental studies will be carried out in the field and under controlled environmental conditions to examine changes in the carbon, water and energy balances of selected plant species which exhibit stress adaptations, in response to alterations in environmental conditions. The environmental factors of particular interest are temperature, water and nutrient availability, and the interactions between these factors. The conversion of carbon assimilation into productivity is primarily determined by carbon allocation processes, including carbohydrate storage, which are poorly understood in plants from arid zones.

Plate 47. Sowing *Atriplex* for the improvement of degraded rangeland in Morocco: a better understanding of the interdependence between environmental limitations and species traits can assist in sustainable ameliorative measures

Information will be obtained about the strategies plants use to optimise production in relation to plant water availability, and about different methods adapted for specific environments.

The measurement of plant responses to imposed environmental conditions will be carried out in an experimental facility, consisting of eight growth chambers with high-intensity lighting and conditioned air supply. Arid lands are characterised by cold nights (0–5°C) when the humidity is high (70–85% RH), and hot days (38–46°C) with dry air (8–15% RH). The relationship between temperature and relative humidity will be utilised in the system design, obviating the need for strict humidification control. Cooling ambient air to 4°C will increase its relative humidity so that, in a British climate, it will be at or near saturation. Reheating this cold, saturated air will cause a concomitant decrease in relative humidity, imitating the environmental conditions found in dryland regions.

Thus, ambient air is chilled by the conditioning unit to 4°C and saturation, and blown through the chambers after reheating, using thyristor control, to temperatures up to 45°C and a resultant relative humidity of 15–20%. Environmental parameters within the chambers are continuously monitored: specifically, photosynthetically active radiation levels using quantum sensors; soil and air temperature using thermistor probes; and ambient relative humidity using solid-state hygrometric sensors.

Experiments will involve growing dryland species in the chambers at different levels of temperature, water and nutrients, to determine the effects of limiting resources on the growth of each species alone and in combination. Mixture studies will cover both substitutive designs, with combinations of two species sown in varying proportions whilst maintaining overall density constant, and designs where the density of the mixture is varied. The ability of individual plants to overcome certain trade-offs through phenotypic plasticity and altered allocation patterns when environmental constraints are changed will also be examined, and studies of competition between trees and crops of agroforestry systems for limited water and nutrients will be undertaken.

L S Anderson

Measuring genetic variation and gene flow in natural populations of plants

(This work was partly funded by the Department of the Environment, and involved collaboration with the University of Birmingham and the Agricultural and Food Research Council's Institute for Plant Science Research)

Gene flow, by means of pollen or seed, helps determine the way in which genetic variation is distributed in plant populations. These patterns are

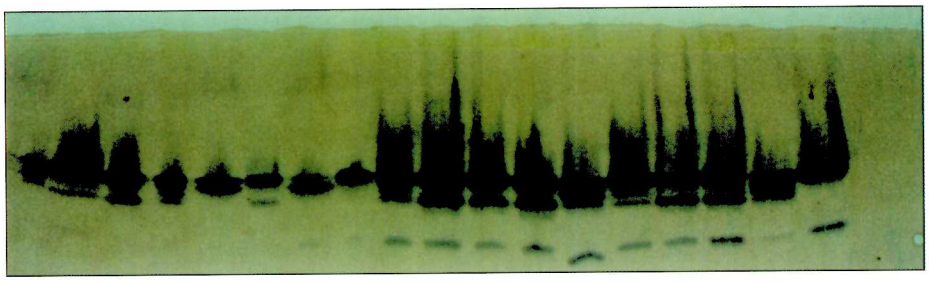

Plate 48. Polymorphism in glutamate oxaloacetate transaminase isozymes in sea beet

important to evolutionary biologists attempting to explain the fundamental questions of how and why genetic diversity is maintained in natural populations. At a more practical level, the conservation of biodiversity, the utilisation of wild germplasm in plant breeding, and the genetic isolation of crops from wild relatives can be much more efficient if patterns of genetic variation and rates of gene flow can be estimated. Of particular concern at present is the possibility that novel genes carried by genetically modified crops may be transferred to and spread among populations of wild crop relatives (eg Raybould & Gray 1993). Measurements of gene flow in these species are, therefore, crucial for accurate risk assessment before the release of modified crops.

To measure gene flow, one must have suitable polymorphic genetic markers. Genetic variation (ie variation in DNA sequence) can be detected at the morphological, physiological, protein or DNA level. Morphological and physiological variants can be used to estimate gene flow, but have the disadvantages that they are often determined by several genes, they can be relatively difficult to measure, and they affect plant fitness. Molecular markers (variation detected in single proteins and DNA sequences directly), on the other hand, are much more widespread, can be determined by single genes, and are often selectively neutral. These features make them ideal for gene flow studies.

The Department of the Environment is funding a study at ITE Furzebrook that involves assessing which types of molecular marker are most suitable for work on natural plant populations. We are examining three types of marker: isozymes, restriction fragment length polymorphisms (RFLPs), and randomly amplified polymorphic DNA (RAPDs) in two crop relatives, sea beet (*Beta vulgaris* ssp. *maritima*) and wild cabbage (*Brassica oleracea*). These species were chosen as they are conspecific to crops that have been genetically modified, and they have different pollination mechanisms, beet being wind-pollinated and cabbage insect-pollinated. Comparison of the distribution of genetic variation in these species may allow some generalisations to be made about the effects of breeding systems on rates of gene flow.

Isozymes are different forms of enzymes that have the same metabolic function but different amino-acid sequences, caused by variations in the DNA of the genes' coding for them. The differences can cause the enzymes to migrate at different rates through an inert gel when an electric field is applied (electrophoresis). The enzymes are detected by linking the reaction catalysed by the enzyme to the precipitation of a dye. The variants then appear as bands on the gel. Plate 48 illustrates a typical isozyme gel of sea beet.

We have found that isozymes are very reliable markers in both sea beet and wild cabbage. In wild cabbage, however, the isozymes must be extracted from young leaf tissue, otherwise resolution is poor. Our initial studies show that wild cabbage populations are more highly structured genetically than sea beet populations. This difference may be due to the long-range dispersal of pollen by wind and seeds by the tide in beet, in contrast with insect pollination and dispersal of seeds by shattering of the seed pod in wild cabbage.

In some respects, isozymes are ideal for population studies of wild plants (see Hamrick 1989 for a review) because, large numbers of plants can be assayed relatively cheaply and quickly, the development time for each new species is comparatively short, and the amount of equipment and technical expertise required is less than with some other markers. However, the amount of variation detectable is restricted by limitations on the number of enzymes for which detection methods have been devised, and because changes in the enzyme coding genes do not necessarily lead to differences in electrophoretic mobility.

RFLPs depend upon the ability of enzymes isolated from certain bacteria to cut DNA into fragments at points where specific base-pair sequences occur. This process is known as restriction. Variation in DNA sequences between plants leads to different fragment sizes being produced when the DNA is treated with one of these enzymes. As with isozymes,

Plate 49. Preparation of DNA from sea beet populations being undertaken in the molecular laboratory at Furzebrook

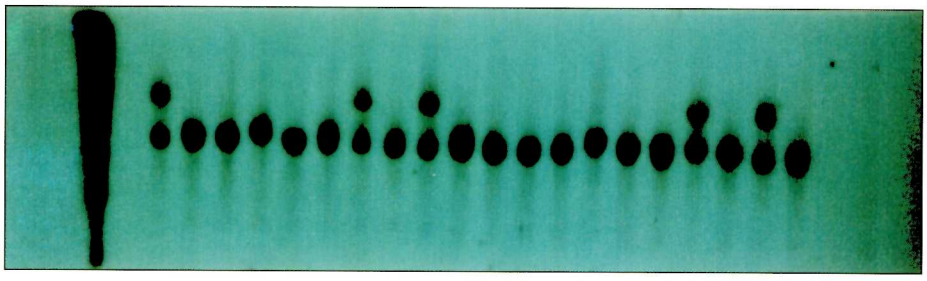

Plate 50. Restriction fragment length polymorphism in sea beet populations revealed by a radioisotope-labelled cDNA probe

the fragments can be separated in a gel by electrophoresis. The DNA is transferred to a nylon membrane and the polymorphisms are revealed by adding radioisotope-labelled DNA sequences ('probes') that can pair with fragments of interest, followed by exposure of the membrane to X-ray film.

Unlike isozymes, RFLPs detect DNA variation directly and are, therefore, more sensitive to changes in sequence. Also, they are not limited to genes that code for enzymes. Any piece of DNA that has homology with the plant DNA can be used. These factors make RFLPs potentially very powerful markers in population studies (Clegg 1990). However, there are several drawbacks. First, the quality of the tissue is vital. We have been unable to isolate DNA from wild cabbage that is suitable for cutting with enzymes, even though the methods used isolate good-quality DNA from cultivated brassicas. Thus, some species, or populations, growing under particular conditions may be unsuitable for RFLP analysis. Second, the development times are very long; three years were required to devise a successful protocol for producing sea beet RFLPs. Third, the methods are expensive, lengthy and technically more demanding than isozymes (Plate 49). Finally, suitable probes must be available. We obtained our probes through collaboration with groups at the University of Birmingham and the Institute for Plant Science Research in Norwich, and these are now revealing useful polymorphisms in sea beet populations (Plate 50). In short, before an RFLP study of natural populations can be envisaged, it must be ensured that DNA can be isolated from the species and that sufficient time and other resources and appropriate probes are available.

Another method of detecting DNA sequence variation directly is known as RAPDs (Hadrys, Balick & Schierwater 1992). This method employs the powerful polymerase chain reaction (PCR) method of DNA amplification. In a RAPDs reaction, a mixture of plant DNA, the four nucleotide bases that comprise DNA, an oligonucleotide of ten random bases (the primer), and Taq DNA polymerase is heated to over 90°C, causing the DNA to become single-stranded. The mixture is cooled to about 35–50°C, allowing the primer molecules to bind to homologous sequences in the plant DNA. The temperature is then raised to 72°C, and the Taq polymerase catalyses the synthesis of complementary DNA beginning from the primer. Taq polymerase is isolated from a bacterium that grows in hot springs, and hence is stable to heat, which permits the cycle of melting and resynthesis of DNA to be carried out many times. The result is that any stretch of DNA bounded by two sufficiently contiguous primer binding sites will be geometrically amplified. These fragments can be separated by electrophoresis. Plants differing in the presence or absence or relative positions of primer binding sites will show different banding patterns. A typical result obtained with sea beet DNA is illustrated in Plate 51.

RAPDs can, in theory, reveal enormous amounts of polymorphism over and above isozymes, as any ten-base oligonucleotide sequence can serve as a primer. They can be obtained in about the same time as isozyme phenotypes, but they are considerably more expensive to produce because of the high cost of Taq polymerase. They require less technical expertise than RFLPs and do not need specific DNA probes. Unlike isozymes and RFLPs, however, heterozygotes cannot be detected as the polymorphisms are the presence or absence of a band, rather than a difference in band position. In other words, the markers show complete dominance rather than co-dominance, which makes them unsuitable for some population genetics work.

RAPDs are also notoriously prone to unrepeatability. Several laboratories, including our own, have found that the same primer with the same DNA can give different banding patterns between laboratories or in the same laboratory at different times, or even between different scientists performing the reaction at the same time with the same reagents. We have obtained RAPD phenotypes with several primers from both sea beet and wild cabbage DNA, but useful polymorphisms have not been found and repeatability is very low. It is unlikely that RAPDs will be used in our future work on genetic variation.

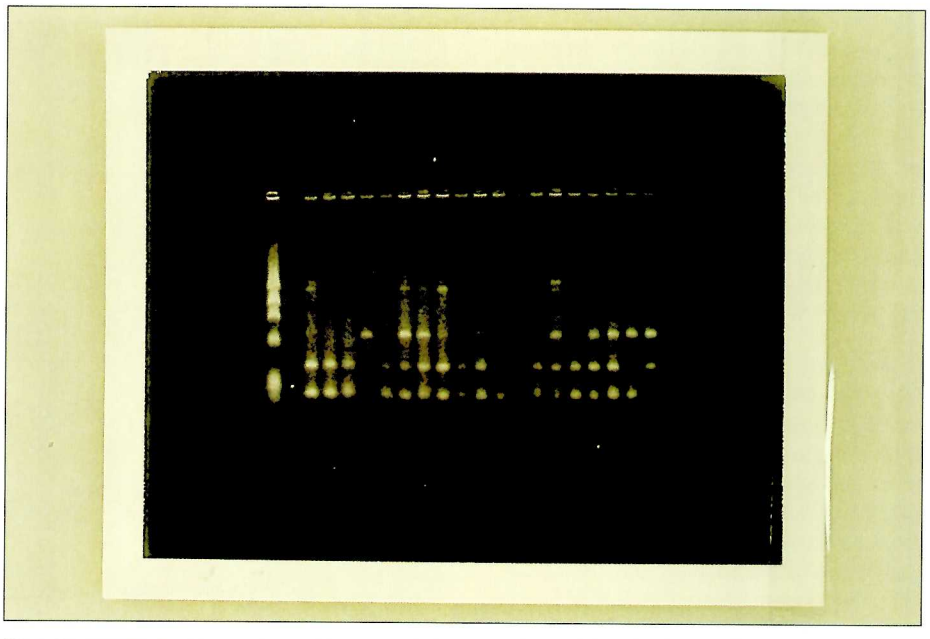

Plate 51. RAPD phenotypes in sea beet populations obtained with a ten-base primer

To summarise, several choices of marker are available. If large numbers of plants need to be screened quickly and cheaply and only a short development time is available, then isozymes may be preferred, despite their limited variability. If highly polymorphic markers are required and sufficient time and resources are available, then RFLPs could be considered. RAPDs may be suitable for some studies but, again, they are expensive and could prove unreliable.

A F Raybould, R J Mogg and A J Gray

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Plate 52. Predicted sulphur plume from a proposed incinerator, superimposed on the ITE land cover map using a geographical information system

A strategy for the exploitation of geographical information systems for research in ecology and land use

Geographical information systems (GIS) are of increasing importance in facilitating research across many of the Institute's programmes. Recent applications were reviewed by Wyatt, Bull and Brown (1992). GIS have had their most immediate impact in Programme 2 (Land Use, Agriculture and the Environment), but are playing an expanding role in Programmes 1 (Forest Science), 3 (Global Environmental Change), 7 (Environmental Pollution) and 8 (Population and Community Ecology). A strategy is now being developed to encourage the wider dissemination across the Institute's sites and research projects of the facilities and expertise which permit the effective analysis of ecological data in a spatial context.

Reinhardt (1992) defined GIS as 'computer-aided procedures for the capture, analysis and display of earth surface spatial features and their attributes'. The essential features of a true GIS are that it should provide, within an integrated computing environment, the functionality which allows mapped features to be interrogated both in terms of their geographical properties (location, extent, shape, context) and by chosen attributes or characteristics, such as the presence of natural biota, soil properties, hydrology, levels of pollution, etc. These attributes are held by the GIS within a structured data base system.

A GIS has three essential elements:

- the hardware on which the system operates;
- the software which provides the required functionality;
- and the data which constitute a geographical representation of the entity (eg ecosystem or landscape) of which the GIS is a model.

The NERC strategy is to maximise the use of proprietary GIS, avoiding the considerable investment that would be needed to develop and maintain in-house systems. Within NERC, an important requirement for GIS is that the chosen systems should interface with the relational data base adopted as a corporate standard, and which is used to manage most of the substantive data holdings in the Institute.

Hitherto, ITE has developed its GIS facilities within a limited number of key units, the most active of which are the Environmental Information Centre (EIC) at Monks Wood and the Land Use Research Group (LURG) at Merlewood. LURG has focused on the use of GIS to manage complex records of field survey generated within the 1990 Countryside Survey project and, using spatial overlay techniques, has been examining the causes and consequences of land use change. EIC is using GIS in a diversity of applications, drawing on a wide range of data which record the physical and biological characteristics of landscapes. Particular emphasis in EIC has been on the integration of data on land cover from satellite remote sensing with other topographic and thematic mapped data sets, on the incorporation of information on species distributions from the Biological Records Centre, and on the use of GIS for estimating and mapping critical loads of various environmental pollutants. EIC is also collaborating with other groups at Monks Wood to apply GIS to the prediction of the ecological consequences of climate change at national scales and above, and as a powerful tool for environmental assessment.

As opportunities emerge for the use of GIS in the wider scientific programme of the Institute, so the necessary investment is being made in the acquisition of distributed systems GIS workstations have been, or are being, installed at each of the Institute's sites, and local staff are being trained in their effective use Data bases are accessible from any site, either remotely using the Joint Academic Network (JANET), or, in the case of cartographic data sets which cannot be handled efficiently in this way, by providing duplicate copies at the 'satellite' locations A good example of the latter approach is provided by the ITE land cover map which, at full resolution, occupies 1 5 gigabytes in raster form The authoritative national version of this data base is held and maintained centrally in EIC, and subsets are distributed to other ITE locations, to provide regionally based facilities in Scotland (through ITE Banchory) and in Wales (through ITE Bangor)

The role of the main GIS groups in EIC and in LURG is increasingly

- to establish common standards for the storage and handling of geographically referenced data sets,
- to maintain large reference data holdings (eg the land cover map, the national critical loads data base, data sets compiled for modelling the impact of climate change, and data from the various national land use surveys conducted by ITE),
- to provide specialist advice and support in the use of GIS, and
- to undertake strategic research in ecological applications of GIS

Priorities for GIS systems research are, first, to achieve better integration of dynamic modelling within GIS, so as to support the implementation of spatially distributed models of, for example, pollutant dispersal (Plate 52) or the movement of species, and, second, to improve the capacity of GIS to handle data from different sources and in different formats The integration of raster data from earth observation imagery with vector-based map representations is of primary concern These interests are being pursued through collaboration with industry and with leading university groups in the field Staff at the Environmental Information Centre are collaborating with LaserScan Ltd, of Cambridge, in developing environmental science applications for an advanced integrated GIS, and the Centre has recently been successful in securing funding for two awards under the NERC Industry Targetted Studentship scheme, which will be used to realise the requirement for dynamic modelling within GIS

B K Wyatt

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A flavour of statistical consultancy within ITE

Most studies in Terrestrial and Freshwater Sciences in NERC require statistical and biomathematical arguments This article illustrates the role of ITE statisticians in statistical research and development work within an ecological framework

Background

There are six statistical consultants within ITE R I Smith at Edinburgh, R T Clarke (half-post) at Furzebrook, D K Lindley and Mrs D M Howard (half-posts) at Merlewood, and K H Lakhani and T H Sparks at Monks Wood There are over 110 senior scientists within the Institute working on over 50 projects with a wide range of statistical requirements, and so the statistical provision has to be managed efficiently

The work can be split into three broad but overlapping areas

- statistical training – to provide training on statistical techniques to ecologists,
- statistical consultancy – to provide statistical advice and support to ecologists (including reviewing proposals for future work),
- statistical research – to develop new methods, or modify existing ones, for statistical ecology

The statisticians attend professional meetings and conferences, to give papers and also to keep abreast of statistical developments, a very necessary function if a good consultancy service is to be provided across the wide range of statistical disciplines required for the Institute's work These disciplines include bioassay (to investigate the hazards of insect spray drift or to quantify plant damage with acid mist), habitat modelling (to describe the effect of field boundaries on bird species or to investigate the effect of woodland shading on invertebrates), analysis of monitoring data (streamwater chemistry or pollutant gas concentrations), modelling (quantifying the amount of nitrogen deposition in the UK and its effect on soils), and prediction (species response to climate change), among many other examples Statisticians also have an important role in refereeing papers for statistical and ecological journals

To supplement the on-site statistical support, ITE has close links with university departments where there is either joint supervision of students or direct collaborative research with university staff ITE also uses external statistical consultancy services where these are applicable, most notably for ITE Banchory where statistical advice is provided by staff in the Environmental Modelling Unit of the Scottish Agricultural Statistical Service

Statistical training for ecologists

Because statistical arguments play a vital role in most scientific studies, the training of ecologists in statistical and quantitative methods is very important Such training leads to an awareness of scientific method on the part in the researcher and fosters a healthy working relationship between scientists and the statisticians,

Table 19 Analysis of deviance of an auxin experiment

	Degrees of freedom	Difference in deviance
Block	5	6 5
Auxin application	4	12 2
Node (linear effect)	1	6 1
Stem volume	1	5 9
Residual	288	379 2

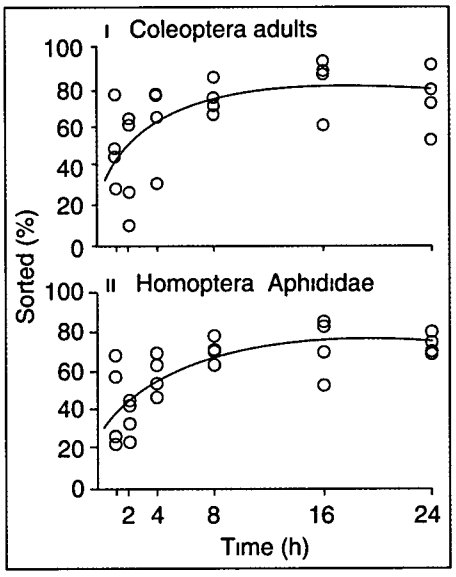

Figure 66 Insect sorting efficiencies at successive time intervals in the new sorting device

which is important for the quality of the science ITE also has many visiting scientists from less-developed countries where there may be no easy access to specialist statistical advice Training, therefore, must cover both the relevant statistical techniques and the competent use of appropriate computer software

A number of formal training courses have been developed at Monks Wood for staff at both Monks Wood and Bangor, and notes from these courses are available to staff elsewhere External courses are used occasionally and are sometimes tailored specifically for ITE requirements However, there is also a large amount of informal training undertaken, to small groups or on a one-to-one basis, as part of the statistical consultancy work in the Institute

Identifying relevant training

To be successful, training has to be focused accurately on the working situation of the scientist

Scientists at ITE Edinburgh are concerned about the design and analysis of propagation experiments in the tropics These experiments are part of programmes to develop clonal propagation of tropical hardwoods in local nurseries, and most are run without any local statistical support

To determine optimum rooting conditions, cuttings from stockplants, often the product of a small number of seed sources, are positioned in one or more rooting boxes for experimental work The rooting potential of the cutting will depend on its initial state, which is difficult to assess The variables often used are the shoot and node position of the cutting on the stockplant, the length and diameter of the cutting, and the leaf area remaining on the cutting The treatments may include modification of the cutting's initial state, application of a hormone, or shading and misting treatments to the whole or part of the box

There are design problems which are typical of any controlled environment experiment Any treatments which are applied to the whole box, eg misting frequency, are likely to have a low replication This problem can be overcome by a meta-analysis over a series of similar experiments, if the whole programme has been carefully planned

The usual analysis of a single experiment would be to use a generalised linear model (McCullagh & Nelder 1983) which allows the incorporation of all the explanatory variables and an appropriate error structure to model the binary response the cutting has rooted or it has failed to root A typical analysis of rooting at week 10 in an experiment to investigate five levels of auxin applied to the base of the cutting is shown in Table 19

In this case, the effects of node and stem volume are significant as well as the effect of the auxin application, based on the chi-squared tests of the differences in deviance Because the data are ungrouped, each cutting having a different node and stem volume combination, there is no test of the goodness-of-fit of the model and there is no simple estimate of under- or over-dispersion of the data If the data had been grouped, the interpretation of Table 19 and the subsequent calculation of estimates with standard errors would be different, but the computer output would often appear the same

This type of analysis has not been part of many basic statistics courses for biologists, and requires careful teaching and understanding of the techniques A larger experiment could have given the same results with a simpler statistical analysis but at a higher experimental cost In some situations, it may be prudent to increase the experimental costs in terms of plant material and labour and accept a less powerful statistical technique, until improved training and computer facilities are available At other times, it is important to insist on the more complex statistical analysis, which will require an increased element of training for the scientist and possibly different computer software .

Statistical consultancy and project development

The work of the Institute requires the application of a vast range of statistical techniques, from the more traditional design and analysis of experiments and surveys to the more recent developments in spatial processes, non-linear optimisation, capture/recapture methodology, and many others The statistician provides advice to ecologists in two different ways The most obvious is the provision of 'instant' advice and recommendations, either in planned short consultations or often in conversations in the corridor or canteen This day-to-day interaction is an important part of the statistical support

However, in the predominant mode of operation, the statistician is involved with in-depth studies of the work of a small number of projects for periods ranging from a few months to several years This

Table 20 Survival rates for shags

Year	No of ringed adults caught	Estimated no of ringed adults alive	Estimated probability capture	Estimated survival rate	95% confidence interval
1980	90	449	0 20	0 88	(0 80,0 95)
1981	213	519	0 41	0 99	(0 94,1 00)
1982	700	792	0 88	0 50	(0 43,0 62)
1983	79	558	0 14	0 76	(0 62,0 86)
1984	232	534	0 43	0 93	(0 87,0 97)
1985	341	755	0 45	0 63	(0 58,0 71)
1986	183	530	0 35	0 84	(0 76,0 91)
1987	174	512	0 34	0 88	(0 82,0 92)
1988	209	497	0 42	0 90	(0 83,0 94)

involvement allows the development of expertise in the statistical/ecological field at an international level to the benefit of both the statistician and the other project staff

The statistical input can be an obvious requirement for a project For example, the 1990 Countryside Survey required statistical advice in validating the modified land classification scheme, in selecting appropriate sample squares, and in both estimating the current UK land cover of a large number of features and the changes in those features since previous surveys Statistical consultancy is also required for major projects outside ITE core activities, for example, a statistician forms part of the ITE staff in the Environmental Change Network

Statistical input can appear in less obvious areas A new field-based device was developed at Furzebrook to reduce the time required to sort a sample of invertebrates (Moore, Clarke & Creer 1993) Various suction devices are used in the field to sample invertebrates living on all layers of plants down to and including the soil surface These devices are mainly used to sample from crops, grasses and herbs, but are sometimes used on trees and shrubs Separating the sampled insects from soil and plant debris can be extremely laborious and time-consuming However, in many natural habitats, the spatial distribution of invertebrates is patchy and the large numbers of samples needed to obtain sufficiently precise, and therefore useful, estimates of species abundance and diversity are often impossible to collect because of cost or time constraints The new apparatus will reduce the time required for sorting by a factor of four

The statistical problem arises because sorting efficiency is dependent on the taxa, the time in the sorter, and the amount of debris collected by the sampler To calibrate the sorter and to provide a method of estimating from the actual mean numbers of a taxon sampled, an experimental collection was made on an acidic grassland site in Dorset Modified exponential asymptotic curves of the type

$$p = a - b r^t - c \sqrt{W} \qquad (0<r<1, b>0)$$

were fitted to the data for each taxon, where p is the proportion sorted after t hours, and w is the total dry weight of debris (in grams) (two examples are given in Figure 66) The curves were fitted by a non-linear maximum likelihood procedure, with the proportion p treated as a binomial variable The parameter a is an upper asymptote for the curve, the parameter b allows for the high proportions sorted in the first hour, and the assumption of a binomial distribution tends to down-weight the influence of samples with only a few individuals for which p is likely to be poorly estimated The extra-binomial variation about the curve, a common possibility with this type of data, was allowed for in estimating the standard errors of the coefficients, and hence the final proportions sorted These best predictive curves for the proportion sorted enable the experimenter to derive estimates, with standard errors, for the total number actually captured in a sample with much less effort than previously possible

Statistical research and development

For some of the Institute's work, there are no readily available statistical answers to the problems posed In the studies on ozone described elsewhere in this Report (page 53–56), the properties of the distribution of cumulative dose experienced by a plant (a concept commonly used in the literature) are a subject of current statistical research Other examples include the methodological developments in the analysis of ring recovery data for estimating age-specific survival, and the detection of density dependence from annual censuses

A new statistical technique, the 'bootstrap' method (Stine 1990), has been used at Banchory to estimate the survival rates of shags (*Phalacrocorax aristotelis*) In long-term population studies of shags breeding on the Isle of May, over 13 000 chicks and 1800 adults have been individually ringed between 1963 and 1987 Subsequent sightings of these ringed birds have provided valuable information about their survival rates, which may vary by age, sex and year Although large numbers of birds are ringed, most are never seen again Furthermore, assessment of the errors in the parameter estimates is complicated by the fact that each bird ringed and recovered provides information about survival rates in all intervening years and at all intervening ages Bootstrapping, however, enables these errors to be assessed correctly

The capture history of each ringed bird is listed, and a bootstrap sample is generated by selecting with replacement capture histories from the complete list until the bootstrap sample size is equal to the number of birds ringed Thus, some birds are omitted from a given bootstrap sample, while others are included more than once

The results of this analysis indicate that survival rates are comparable for the two sexes Birds in their first four years of life survive less well than mature adults, and there is evidence that survival rates fall at older ages The annual survival rate for adults is relatively stable (Table 20), even in years when juvenile survival is very poor The two low estimated survival rates shown in Table 20 for 1982 and 1985 may arise from bias, in both years, a special effort had been made to detect all ringed adults on the Isle of May The effects of variable sighting effort on the estimates require further investigation

The future

The application and development of recent statistical research to ecological problems continue to be a vital and integral part of ITE's research effort Experienced and able statisticians capable of applying sound quantitative methods to biological problems will continue to remain a scarce resource For most ITE locations, an efficient practical management of this resource will probably be to limit the in-depth involvement of statisticians to a few selected projects per year, with broad supervision and routine input by them into other projects

The continuing strong trend towards faster and cheaper computers and automatic data recorders, combined with an increasing numeracy of the scientific staff, will encourage ITE to tackle even more complex and large-scale problems requiring increased statistical and biomathematical input

There will also be substantial advances in statistical and biomathematical methodology over the next decade, as current research work is translated into practical techniques The likely areas are in the expansion of spatial data, notably in geographical information systems, technologically driven areas such as remote sensing and genetic

fingerprinting, and new areas of simulation modelling and chaos theory These developments will have significant training implications for those working in statistics, which may not be satisfied by standard university courses in the biological sciences

Collaborative work with universities and other research institutes is likely to increase considerably, and will reflect both ITE's requirement for extra services and the universities' need to earn more contract income However, external consultancy services do *not* provide the direct integration of statistics with the ecological project, which has proved a major benefit in the past The multidisciplinary approach of the Institute, with its strong internal statistical presence and effective collaboration with other statistics groups, will provide a strong base for future statistical developments

R I Smith, K H Lakhani, S T Buckland and R T Clarke

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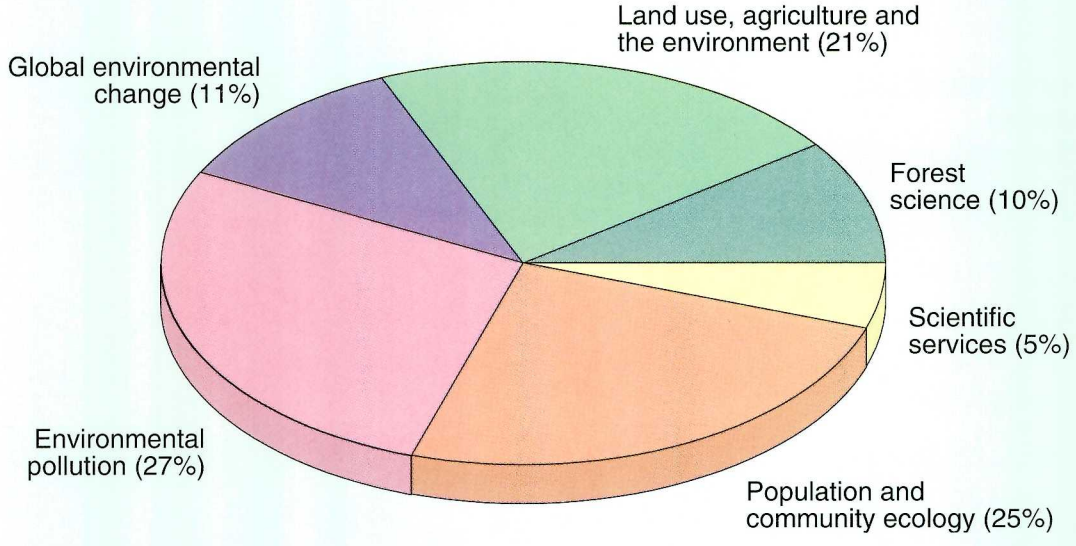
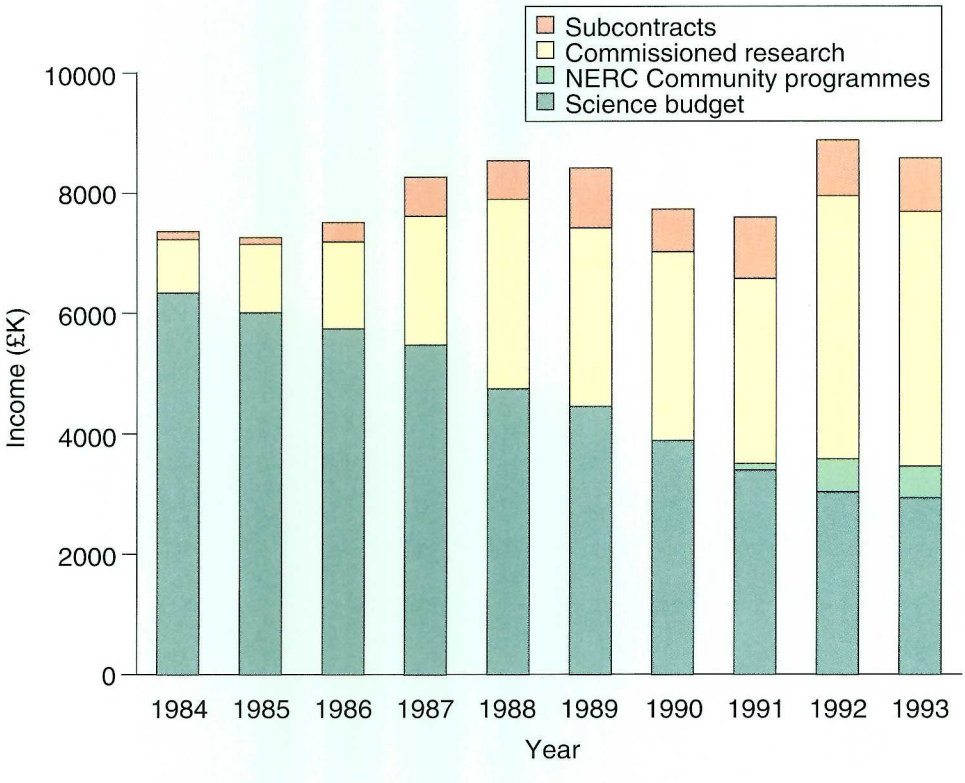
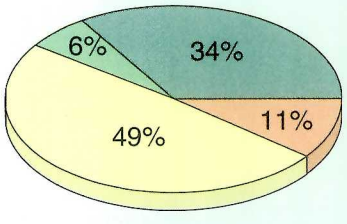
Appendix 2. **Finance and administration**

The following diagrams indicate levels of funding for the Institute, and provide details of expenditure.

The pie chart shows Institute expenditure (as full economic cost) for the year 1992–93 by scientific programme of work

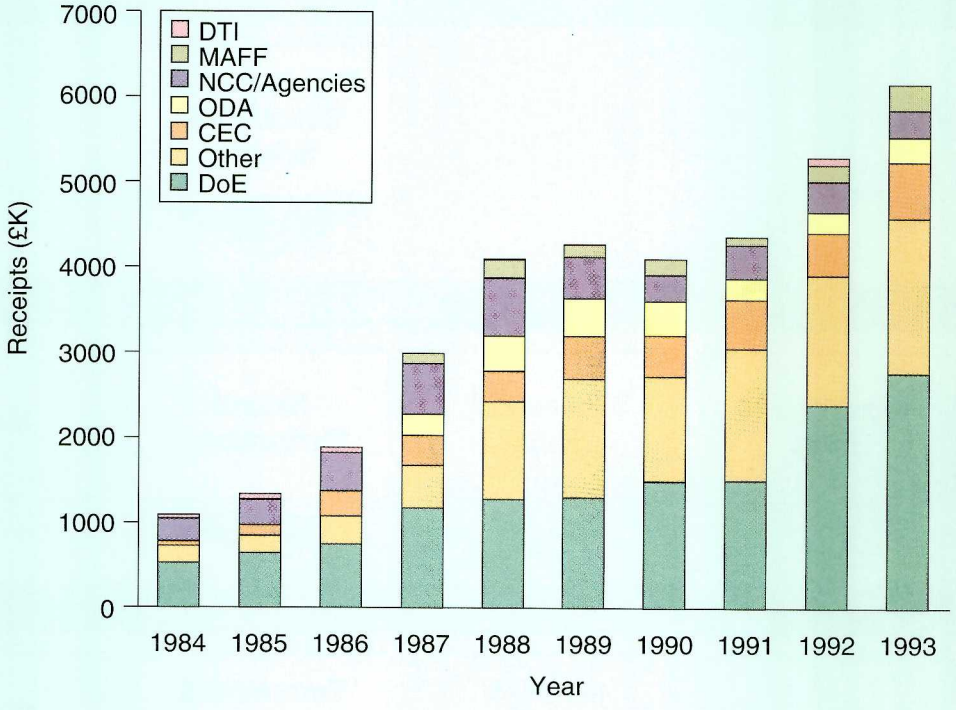


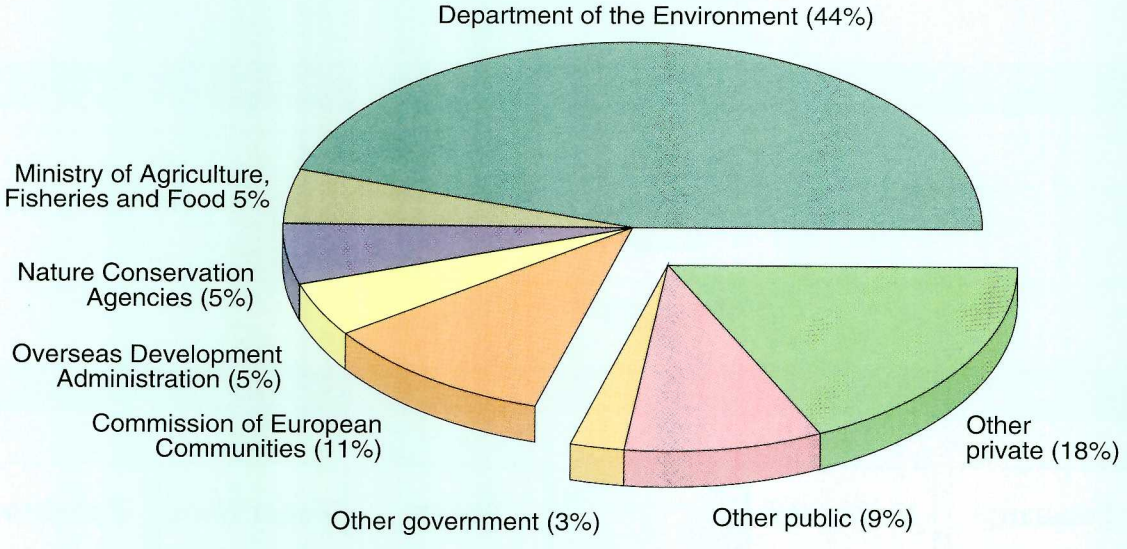




This graph illustrates trends in income (at constant prices – 1984–92 revalued to 1993 using Gross Domestic Product indices). The pie chart shows the percentage breakdown for 1993

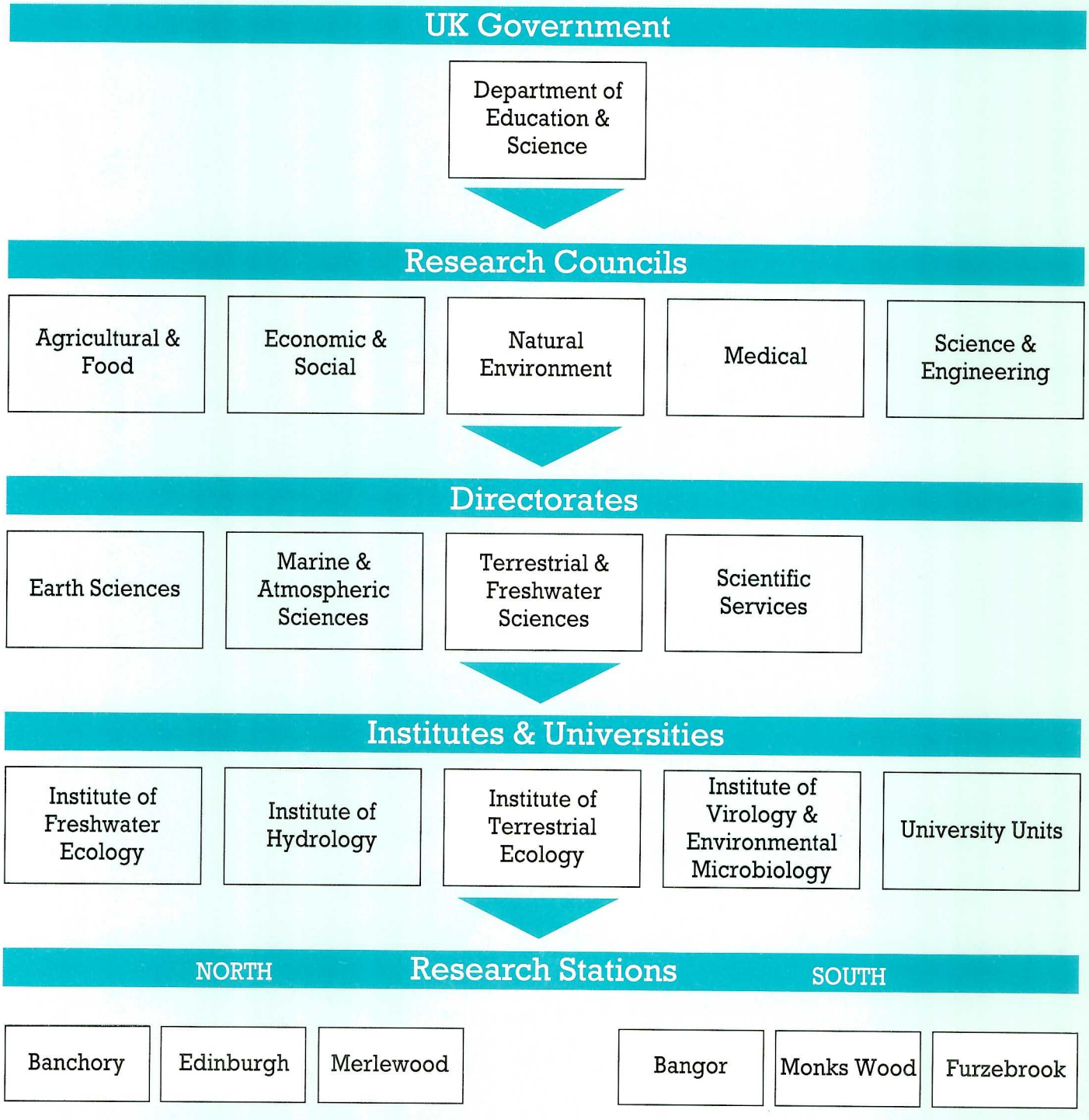
This graph illustrates the long-term pattern of receipts from major customers (at constant prices – 1984–92 revalued to 1993 using Gross Domestic Product indices)





The pie chart shows the division of 1992–93 commissioned receipts by major customers

The Institute's position within the UK Research Council system is shown below. ITE is an integral part of the Natural Environment Research Council, which supports a wide range of basic and applied research in universities and institutes. It is able to draw on the expertise of about 400 colleagues in terrestrial and freshwater research, and on 1300 scientists within NERC.



Appendix 3. **Research projects at 31 March 1993**

ITE NORTH — EDINBURGH RESEARCH STATION

Programme 1 Forest science

T01057-5	**Forest modelling**	**M G R Cannell/ A D Watt**
T01057v5	Frost hardiness of oak provenances	J D Deans
T01057w2	Mechanistic models of tree and forest growth	R C Dewar
T01057x2	Modelling the population dynamics of the pine beauty moth	A D Watt
T01057y1	Carbon sequestration by vegetation	A D Watt/ M G R Cannell
T01059-5	**Mycorrhizas and tree production**	**J Wilson**
T01059a2	Mycorrhizas and tree growth	P A Mason
T01059l1	Evaluating factors leading to optimum mycorrhizal development and growth of *Eucalyptus globulus*	P A Mason
T01059n1	*Eucalyptus* mycorrhizas in Chile	P A Mason
T01060-5	**Tropical forestry and tree improvement**	**R R B Leakey**
T01060a2	Domestication of tropical hardwoods	R R B Leakey
T01060i1	UNESCO MAB contracts	O W Heal
T01060j1	ITE/CATIE link	A C Newton
T01060k1	Cameroon forestry – Phase 2	R R B Leakey
T01060l2	Relationship between growth, shade tolerance and the physiology of rooting in tropical trees	A C Newton
T01060p5	Domestication of Cameroon fruit trees	R R B Leakey
T01060s1	Tropical tree improvement training	J Dick
T01060x1	Cameroon forest management and regeneration	G J Lawson
T01060y1	Tropical trees potential for domestication, rebuilding forest resources	R R B Leakey
T01061a3	The effects of farm woodland size, shape, structure and species composition on insect diversity	A D Watt
T01065-5	**Tropical forestry and tree improvement (cont'd)**	**R R B Leakey**

Programme 2 Land use, agriculture and the environment

T02051u5	Land use in Scotland	B G Bell

Programme 3 Global environmental change

T03054a6	Modelling carbon dioxide exchange at regional scales	R C Dewar
T03055i6	Process-based modelling of grasslands and forests CO_2 and climate effects	M G R Cannell/ J H M Thornley
T03057a6	Carbon balance of tropical forests	J Grace/J B Moncrieff/ P G Jarvis
T03057c6	Carbon flux in tropical forests below-ground biomass	J D Deans
T03064b6	Methane emissions from UK wetlands	D Fowler
T03064h6	N_2O flux measurement using chamber and micrometeorological techniques	D Fowler
T03065a6	Measurement of methane emission fluxes at the field/landscale scale	D Fowler
T03066d6	Tropospheric photochemistry in coastal and upland regions	J N Cape
T03091d6	Flask sampling atmospheric trace gases	B G Bell
T03091e6	Cameroon co-ordination	B G Bell
T03091k6	Impact of CO_2 on population dynamics of conifer-feeding insects	A D Watt

Programme 7 Environmental pollution

T07055l3	Exchange of NO_x and other gases before and after exposure to wind, ozone and polluted cloudwater	D Fowler/ J Grace
T07056-5	**Ecological effects of climatic change**	**M G R Cannell**
T07056d5	Response of trees to elevated CO_2	A Friend
T07057-5	**Atmospheric pollutants and trace gases**	**D Fowler**
T07057d5	Land/atmosphere exchange of methane	D Fowler
T07057h2	Deposition of lead 210	R Mourne
T07057m1	Ammonia deposition	D Fowler
T07057n1	SO_2 dry deposition	D Fowler
T07057o1	Seeder/feeder deposition	D Fowler
T07057p1	Occult deposition	D Fowler
T07057q5	Methane oxidation	D Fowler
T07058-5	**Atmospheric pollution modelling and chemistry**	**J N Cape**
T07058a2	The chemical composition of rainfall	J N Cape
T07058c1	Nitrogen chemistry on Great Dun Fell	J N Cape
T07058f1	DOE Programme Zero	D Fowler
T07058g1	Chemistry of particles in cloud	J N Cape
T07058h1	Nitrogen oxide measurement	J N Cape
T07059-5	**Effects of atmospheric pollutants on trees**	**D Fowler/ J N Cape**
T07059b5	Open-top chamber studies on spruce and beech	D Fowler
T07059e5	Effects of acid mist on mature trees	A Crossley
T07059h5	Ammonia fumigation of forests	J N Cape
T07059i1	St Fergus air quality report	D Fowler
T07059j1	St Fergus Project II	D Fowler

Programme 13 Scientific services

T13054b2	Utilisation of LIBERTAS in ITE libraries cataloguing	L M Scoular
T13054d2	Utilisation of LIBERTAS in ITE libraries serials management	S M Adair
T13054f2	Use of Email over JANET for interlibrary loans	L Dickson
T13059-5	**Edinburgh scientific support services**	**M G R Cannell**
T13059a2	Glasshouses and nursery support and development	F J Harvey
T13059e2	Controlled environmental facilities at ITE Edinburgh	R Milne
T13059f2	Operation of the Rivox field site	R Milne
T13059g2	Biometrics research and consultancy at ITE Edinburgh	R I Smith
T13059m1	ITE Edinburgh – local consultancies	M G R Cannell

ITE NORTH — MERLEWOOD RESEARCH STATION

Programme 1 Forest science

T01051-5	**Mycological and faunal processes in carbon and nutrient flux in soil and soil/root interactions**	**J Dighton**
T01051a2	Role of fungi in nutrient cycling with special reference to *Mycena galopus* in forest soil	J Dighton
T01051g2	A mechanistic approach to the study of the role of extramatrical hyphae of mycorrhizal associations in nutrient uptake	J Dighton
T01062-5	**Organic matter and nutrient dynamics in forest and upland soils**	**A F Harrison**
T01062d1	Application of nutrient bioassays to *Eucalyptus* forest management	J Dighton
T01062f1	Fast-growing tree project, Karnataka, India	A F Harrison
T01062g5	Rehabilitation of *Acacia* fallow systems and nutrient dynamics in the Blue Nile region, eastern Sudan	D K Lindley
T01062h5	The scientific management of renewable natural resources in China	D K Lindley
T01062i5	Nutrient cycling in European forests	P Ineson
T01062k1	*Acacia* tree fallows in Senegal	D K Lindley
T01062l2	Interactions between mineral nutrition of plants and air pollution, particularly CO_2	A F Harrison
T01062m5	Application of the nutrient deficiency root bioassays to forests	A F Harrison
T01062n5	Phosphorus dynamics in Thailand soils (in relation to organic matter management)	A F Harrison
T01062o1	Phosphorus dynamics in alley cropping systems in the humid tropics	A F Harrison

Programme 2 Land use, agriculture and the environment

T02051-5	**Land use change and ecological impacts**	**R G H Bunce**
T02051m5	Countryside survey 1990	C J Barr
T02051n2	Extending the use of the Merlewood land classification system liaison and collaboration	C J Barr
T02051o2	Land use data management and integration at ITE Merlewood	C J Barr
T02051p2	The application of Geographical Information Systems (GIS) to the Merlewood land use data base	D C Howard
T02051v3	Collaboration with NERC/ESRC land use programme (NELUP)	R G H Bunce
T02051w1	Northern Ireland countryside survey	R G H Bunce
T02051y1	Countryside survey information system	R G H Bunce
T02051z1	Changes in key habitats	C J Barr
T02064-5	**Environmental impact assessment**	**J M Sykes**
T02064e5	National survey of natural ecosystems in South Korea	D K Lindley
T02064f1	Disposal of oiled beach material	A F Harrison
T02065d3	Population dynamics associated with cereal straw microbial and earthworm dynamics in relation to straw as a resource unit (JAEP)	J Dighton
T02071-5	**Land use change and ecological impacts (cont'd)**	**R G H Bunce**
T02071c1	Potential wind turbine siting in Northern Ireland	D C Howard
T02071d1	Minor consultancy contracts	R G H Bunce
T02071f1	Countryside information system (Northern Ireland)	R G H Bunce

Programme 3 Global environmental change

T03055c6	CO_2 fertilization effects on decomposition processes	P Ineson
T03055e6	Field experiment study of the effects of global warming on carbon turnover in upland soils	P Ineson
T03056d6	The use of DNA amplification to identify patterns of fungal colonisation of litter affected by enhanced CO_2	J Dighton
T03064g6	Measurement of trace gas fluxes in forest and upland soils	P Ineson
T03087m6	Interactions between organisms at community boundaries in the uplands responses to simulated changes in climate and the environment	T V Callaghan
T03090-3	**Arctic terrestrial ecology (special topic programme)**	**T V Callaghan**
T03090c3	Arctic ecosystems and environmental change	T V Callaghan/M C Press/ J H Tallis

T03095-5	**Detection of environmental change**	**J M Sykes**
T03095a6	Environmental change network (ECN) (co-ordination)	J M Sykes
T03095c6	ECN and TIGER site management at Wytham	M D Morecroft
T03095d2	Effects of clearfelling on soil water chemistry	S M C Robertson
T03095e2	Long-term dynamics of forest ecosystems	J M Sykes
T03095f2	Rehabilitation of riparian zones in coniferous forest	J K Adamson

Programme 7 Environmental pollution

T07050-5	**Radionuclides in vegetation and soil**	**A D Horrill**
T07050c5	Post-Chernobyl radiation levels in soils and vegetation	R Moss/ A D Horrill
T07050h5	The role of the litter layer in the recycling of caesium isotopes in upland Britain	A D Horrill
T07050i2	The absorption and recycling of plutonium in plants	A D Horrill
T07050j2	Advisory committees on radionuclide research	A D Horrill
T07050k5	Radioactivity in natural ecosystems – EEC II	A D Horrill
T07050l2	Radioecology computer-based bibliography	V H Kennedy
T07050m2	Development and calibration of mechanistic models for radionuclide uptake from soils	B J Howard
T07050n2	Uptake of radionuclides by and distribution within basidiomycete fungi	J Dighton
T07050o1	Monitoring of radionuclides in tidally inundated pastures	A D Horrill
T07050p1	Radionuclides around nuclear sites	A D Horrill
T07051-5	**Radionuclide/animal transfers**	**B J Howard**
T07051d2	The dynamics of radionuclide uptake by sheep	B J Howard
T07051f1	Development of a method to rapidly predict the availability of radionuclides to animal products after an accidental discharge	B J Howard
T07051g5	Transfer of radionuclides in animal production systems	B J Howard
T07051i1	Transfer of COS to goat milk	B J Howard
T07051j1	Identification of hot spots in restricted areas	N A Beresford
T07051l1	Rapid prediction of radionuclide availability	N A Beresford
T07051m1	Review of the influence of stable iodine on radioiodine transfer to milk	B J Howard
T07051n5	Radioecological studies in the CIS	B J Howard
T07052-5	**Geochemistry of radionuclides**	**A D Horrill**
T07052d2	Radiochemical development	A D Horrill
T07052e2	Immobilisation of radioactive caesium in upland soils	A D Horrill
T07052g2	Association of the actinide elements with soil organic matter	A D Horrill
T07054-5	**Critical loads of acidity, S and N for soils**	**M Hornung**
T07054a5	Determination of critical loads of acidity, N and S for soils	M Hornung
T07054c1	Subcontract to Aberdeen University	M Hornung/ M Cresser
T07054d1	Subcontract to Lancaster University	M Hornung/ T A Mansfield
T07054e1	Subcontract to Nottingham University	M Hornung/ M H Unsworth
T07054g5	ENCORE	M Hornung
T07054h5	Modelling critical loads of N	M Hornung
T07054j2	Modelling the effects on water quality of liming in upland catchments	M Hornung
T07054n1	Dose/response relationships for use in models to determine externalities of energy generation by the coal fuel cycle	M Hornung
T07054o5	Biological indicators for setting of critical loads for soils	J Dighton
T07054p5	Liming and faunal inoculation of forest soils	J K Adamson
T07054q2	Effects of sulphur dioxide on fungal decomposition of tree leaf litter	P Ineson/ J C Frankland
T07054s5	Development of bioassay for N saturation	P Ineson
T07054t5	Quantification of N losses by denitrification	P Ineson
T07054u1	Subcontract with MLURI	M Hornung
T07054v5	Isotopic characterisation of nitrogen pollutant inputs to forests (NIPHYS)	A F Harrison
T07056s1	Effect of management and climate on carbon sequestration by UK soils	P J A Howard

Programme 8 Population and community ecology

T08052-5	**Plant strategies response to environmental stress**	**T V Callaghan**
T08052b2	Strategies of growth and population dynamics of tundra plants related to climatic change	T V Callaghan
T08052d2	Carbon isotope discrimination and water use efficiency in arctic clonal plants	J M Welker
T08052e2	Sources of water for polar semi-desert vegetation	J M Welker
T08052f2	Winter ecology in the high arctic of Svalbard plant/animal interactions in snow-free and snow-lying areas	J M Welker

Programme 13 Scientific services

T13054-2	**ITE library services**	**J Beckett**
T13054e2	Data base of ITE staff publications	J Beckett
T13055-5	**ITE chemical research and development**	**J A Parkinson/ M C French**
T13055a2	Chemical support studies	J A Parkinson
T13055i2	Merlewood Analytical Section accreditation scheme	A P Rowland
T13055j2	Data base for Merlewood Analytical Section records	A P Rowland
T13055l2	Analytical group methods book update and revision	J D Roberts

T13055n1	Direct contract analysis for non-TFS customers	J A Parkinson
T13056-4	**NERC mass spectrometer service**	**C Quarmby**
T13056a2	NERC mass spectrometer service	C Quarmby
T13057-5	**Merlewood scientific support services**	**D K Lindley**
T13057a2	Graphics and publications	C B Benefield
T13057b2	Biometrics and modelling support services at Merlewood	D K Lindley
T13057e1	Experimental design course for forestry staff, Nepal	D K Lindley

ITE NORTH — BANCHORY RESEARCH STATION

Programme 1 Forest science

T01061j3	Interactions between farm forestry and the population biology and dispersion of roe deer	B W Staines

Programme 2 Land use, agriculture and the environment

T02050-5	**Human impact, erosion rehabilitation**	**N G Bayfield**
T02050d1	Monitoring at Aonach Mor	N G Bayfield
T02050h1	Upland revegetation studies	N G Bayfield
T02050l1	Aonach Mor Intake 8 EIA	N G Bayfield
T02050q1	NIREX deep repositary study	N G Bayfield
T02050r1	Glas Maol monitoring	D Welch
T02050t2	North-western ethylene pipeline survey	N G Bayfield
T02050v1	Erosion control study	N G Bayfield
T02050w1	Monitoring Spey wellfield	N G Bayfield
T02050x1	Loch Lomond EIA	N G Bayfield
T02050y1	Inshriach track reinstatement	N G Bayfield
T02051x1	Land cover data base for Scotland	R P Cummins
T02070e2	Vegetation change in Scottish moorland and set-aside fields	D Welch
T02071a2	Hedgerow diversity	R P Cummins

Programme 7 Environmental pollution

T07050c5	Post-Chernobyl radiation levels in soils and vegetation	R Moss/ A D Hornill

Programme 8 Population and community ecology

T08050-5	**Vertebrate population dynamics and upland habitat geometry**	**R Moss**
T08050a2	Population regulation of cycling and non-cycling tetraonids	R Moss
T08050c5	Population ecology of capercaillie	R Moss
T08050g2	Population genetics of mute swans	P J Bacon
T08050i2	Epidemiology of *Trichostrongylus tenuis*	R Moss
T08050j2	Structure of moorland vegetation for red grouse	P J Bacon
T08050m1	Impact of afforestation on moorland birds	R A Parr
T08051-5	**Population ecology of predators**	**H Kruuk**
T08051c5	Interactions between populations of fish predators, and fish and their food species	H Kruuk
T08051d5	Piscivorous birds in Scottish salmon rivers	M Marquiss
T08051e2	Ecology of the pine marten	H Kruuk
T08051h5	Seabird studies	M P Harris
T08051i2	Comparison of high- and low-latitude shags	M P Harris
T08051m1	Hybridisation in British mammals	B W Staines
T08073-5	**Dynamics of upland and montane plant communities**	**J Miles**
T08073a1	Response of *Gentiana nivalis* population to withdrawal of sheep grazing	B W Staines
T08073c2	Vegetation dynamics and soils	J Miles
T08073f2	Deer in production forests	B W Staines/D Welch
T08073g2	Response of Sitka spruce to browsing and bark-stripping damage	D Welch/ B W Staines
T08073h2	Competition and niche segregation in red and roe deer	B W Staines
T08073i5	Selection of individual plants within species by herbivores (JAEP)	S Hartley
T08073j5	The influence of vegetation pattern on the distribution and foraging strategies of hill sheep and red deer (JAEP)	J Clarke
T08073k1	Blaeberry autecology	D Welch
T08073l2	Habitat use by wild boar in Tuscany	B W Staines
T08073m2	Habitat use by red and roe deer in Abruzzo	B W Staines
T08073n2	The effects of culling in roe deer populations	B W Staines
T08073p1	Red deer at Mar Lodge	D Welch/B W Staines
T08073q1	*Saxifraga hirculus* survey	D Welch
T08073r1	Vegetation dynamics in Scottish uplands	S Hartley

Programme 13 Scientific services

T13053-5	**Services at ITE Banchory**	**B W Staines**
T13053c1	Brathens consultancies	B W Staines
T13053d2	Biometrics	P J Bacon
T13053e1	Scottish Office consultancy	B W Staines
T13055f2	Scientific community services	B W Staines

ITE SOUTH — MONKS WOOD

Programme 2 Land use, agriculture and the environment

T02052-5	**EIC remote sensing**	**R M Fuller**
T02052a2	Information extraction from imagery	R M Fuller
T02052e2	Remote sensing in the Less Favoured Areas models for rural land use planning	A R Jones
T02052f5	Characterisation of grassland type and condition using remote sensing	A R Jones

T02052i2	Remote sensing in EIC	R M Fuller
T02052m5	Remote sensing the land cover of Great Britain	R M Fuller
T02052n5	Remote sensing in the countryside survey 1990	R M Fuller
T02053-5	**Ecological data management**	**K R Bull**
T02053a2	GIS research and applications development	N J Brown
T02053b1	EEC Corine biotopes project	D Moss
T02053e2	Data cataloguing and management	B K Wyatt
T02053j2	EIC co-ordination	B K Wyatt
T02053k3	GIS for monitoring and modelling land cover	G L Radford
T02053n1	Extension of Corine biotopes recording to central Europe	D Moss
T02054-5	**EIC Biological Records Centre**	**P T Harding**
T02054a5	EIC-BRC botanical recording schemes	C D Preston
T02054b5	EIC-BRC vertebrate recording schemes	H R Arnold
T02054c2	EIC-BRC non-marine Isopoda	P T Harding
T02054d5	EIC-BRC terrestrial and freshwater invertebrate recording schemes	B C Eversham
T02054e5	EIC-BRC Biological Records Centre co-ordination	P T Harding
T02054f2	EIC-BRC population fluctuations in annual legumes	C D Preston
T02054g5	EIC-BRC data management	C E Appleby
T02054h5	EIC-BRC butterfly monitoring scheme	P T Harding
T02054i5	EIC-BRC data base and atlas of aquatic plants	C D Preston
T02054j2	EIC-BRC data analysis and interpretation	P T Harding
T02054k2	EIC-BRC ecological and taxonomic studies of land slugs	B C Eversham
T02054n5	Co-ordinating Commission for Biological Recording (CCBR) programme	P T Harding
T02054o1	English Heritage biological data management	P T Harding
T02055-5	**Environmental impact assessment**	**R C Welch**
T02055b1	Channel Tunnel construction monitoring terrestrial (& freshwater) ecology	R C Welch
T02055i2	Interpretation of ecological information in environmental impact assessment	J R Treweek
T02055j2	Environmental assessment as a basis for decision-making in ecological assessment of afforestation schemes	J R Treweek
T02056-5	**Grassland ecology**	**T C E Wells**
T02056c2	Population studies on terrestrial orchids	T C E Wells
T02056e1	Autecology of rare species	T C E Wells
T02056f5	Monitoring ecological change and plant species – a critical loads approach	T C E Wells
T02056g1	Review of air pollution effects on vegetation (Liphook study)	A R McLeod
T02057-5	**Historical aspects of environmental management**	**J Sheail**
T02057a5	Historical aspects of environmental perception	J Sheail
T02057b2	Synthesis of the development of environmental sciences in NERC	J Sheail
T02059-5	**Wetland dynamics and management**	**T C E Wells**
T02059b5	Land use and ecology of Swavesey Fens the fauna and flora in relation to both established and changing management	K H Lakhani
T02059c5	Environmental impact of flood protection measures on the water regimes of wildlife habitats	J Sheail
T02059d1	The effects of nitrogen on species diversity and agricultural production on the Somerset Moors	T C E Wells
T02059f1	Wetland restoration – Phase 2	J Sheail
T02070-2	**Successional models for predicting ecological effects of changing agricultural practices**	**M O Hill**
T02070a2	Development of successional models	M O Hill
T02070b2	Plant dispersal within and between habitats	M O Hill
T02070c2	Neighbourhood relationships in establishing herb-rich grassland	P D Carey
T02070d2	Population and community dynamics of arable weeds	L G Firbank
T02070h1	Corridor dispersal review	M O Hill
T02071b1	Comparison of land cover definitions	B K Wyatt

Programme 3 Global environmental change

T03087b6	Ecological factors controlling species distribution and abundance	L G Firbank
T03088b6	Landscape dynamics and climate change dispersal models and GIS	B K Wyatt
T03088j6	Effects of climate change at regional and global scales remote sensing of disturbance in biomes as a measure of their sensitivity to change	B K Wyatt

Programme 5 Land/ocean interaction study (LOIS)

T05060a6	A coastal zone terrestrial GIS for the LOIS community	K R Bull
T05060d6	Flux studies at coastal sites	L A Boorman
T05060e6	Provision of land use data for the LOIS programme	R M Fuller

Programme 7 Environmental pollution

T07061-5	**Hazard assessment**	**S Dobson**
T07061a1	Hazard assessment of chemicals	S Dobson
T07061d1	Spray drift	B N K Davis
T07061e2	Insecticide spray drift and bioassay	B N K Davis
T07061g1	Analysis of biological and other environmental samples	M C French
T07061i1	Data base for HMIP	S Dobson
T07061j1	Media biomonitoring methodology	D Osborn
T07061k1	Task group for WHO	S Dobson

T07061m1	Landfill operations and the contamination of wildlife	D Osborn
T07061o1	Environmental follow-up to major industrial accidents	D Osborn
T07061p1	A comparative environment index	D Osborn
T07061q1	Arsenic in gold mines	C P Cummins
T07061r1	Blueprint to protect habitats (ERLs)	S Dobson
T07062-5	**Critical loads**	**S Dobson**
T07062a1	National critical loads mapping programme	K R Bull
T07062h1	Assessment of areas of critical loads exceedance and their implications for setting target loads	J R Hall
T07062i1	Critical loads maps for China	K R Bull
T07062j1	Assessment of critical loads exceedance in Wales	K R Bull
T07069-5	**Ecological consequences of climate change**	**K R Bull/ N R C Webb**
T07069a1	Application of GIS to climate change studies	K R Bull/ G L Radford
T07069b1	Department of the Environment climate change modelling programme	M O Hill/ J P Grime
T07069h5	Modelling effects of climate change on species distribution	M O Hill
T07069k2	Influence of climatic factors on amphibian breeding success	C P Cummins
T07069u5	Effects of rapid climatic change on plant biodiversity	M O Hill
T07070-5	**Ecotoxicology of terrestrial vertebrates**	**D Osborn/ S Dobson**
T07070a2	Avian ecotoxicology	S Dobson
T07070d2	Detecting subtle impacts of pollutants on individuals	D Osborn
T07070h2	Ecotoxicology chemical analysis	M C French
T07070i1	Ecotoxicological testing on bats	R F Shore
T07070j1	Review of pollutants and wild small mammals	R F Shore
T07073-5	**Interactive effects of pesticides**	**A S Dawson**
T07073a5	Pesticide interactions reproductive and field effects	A S Dawson
T07073b4	Pesticide interactions biochemical effects	A S Dawson

Programme 8 Population and community ecology

T08054-2	**Population dynamics of raptors**	**I Newton**
T08054a2	Population ecology of sparrowhawks (*Accipiter nisus*)	I Newton
T08054b2	Tawny owls in fragmented habitats	S M Redpath
T08054c5	Wildlife and pollution	I Newton
T08054d5	Raptor predation on red grouse populations	S M Redpath
T08054e1	Analysis of red kite data	I Newton
T08056-2	**Environmental control of avian breeding cycles**	**A S Dawson**
T08056d2	Avian photoperiodism	A S Dawson
T08056e2	Deferred breeding	A S Dawson
T08056f2	Puberty in starlings	A S Dawson
T08068-5	**Molecular ecology**	**A J Gray/I Newton**
T08068c2	Relatedness in sparrowhawks	I Newton
T08068d2	Relatedness in other birds of prey	I Newton
T08074-5	**Ecology and management of coastal systems**	**L A Boorman**
T08074a5	Effects of environmental change on British salt marshes	L A Boorman
T08074b2	Climate change, sea level rise and the English coast	L A Boorman
T08076-5	**Ecological processes in woodland**	**M O Hill**
T08076c2	Invertebrate fauna of native and introduced broadleaved trees in Britain	R C Welch
T08076e1	Bracken distribution and management	R J Pakeman
T08076f1	Integrated bracken control and vegetation restoration	R J Pakeman
T08076g1	Bracken control and vegetation restoration – literature review	R J Pakeman
T08080-3	**Wildlife diseases special topic**	**D Osborn**
T08082-5	**Metapopulation dynamics**	**I Newton**
T08082a5	Metapopulations and habitat fragmentation	I Newton

Programme 13 Scientific services

T13054c2	Development of current awareness services in ITE libraries	M Palmer
T13055o2	Chemistry research, development and maintenance	M C French
T13060-2	**Statistical research and development**	**K H Lakhani**
T13060a2	Estimation of population parameters	K H Lakhani
T13060b2	Statistical consultancy for Monks Wood/ITE/NERC	K H Lakhani
T13060c2	Biometrical research	T H Sparks
T13060d2	Statistical consultancy for Monks Wood and Bangor	T H Sparks
T13061-1	**ITE South consultancies**	**T M Roberts**
T13061a1	Small consultancies at ITE Monks Wood	S Dobson

ITE SOUTH — FURZEBROOK RESEARCH STATION

Programme 3 Global environmental change

T03086f6	Effects of elevated CO_2 and temperature on the growth rates and life cycle characteristics of herbivorous terrestrial invertebrates	N R C Webb
T03087d6	Ecological factors controlling species distribution and abundance	J A Thomas
T03087f6	Climate-related plant migrations and invasions ecological genetics and reproductive biology as determinants of plant response to climatic change	A J Gray/ R E Daniels

Programme 5 Land/ocean interaction study (LOIS)

T05060-6	**Land/ocean interaction**	**A J Gray**
T05060b6	Biogenic factors in sediment transport	J D Goss-Custard
T05060c6	Coastal vegetation and sediment dynamics	A J Gray

Programme 7 Environmental pollution

T07069-5	**Ecological consequences of climate change**	**K R Bull/ N R C Webb**
T07069o2	Butterfly monitoring scheme and climate change	J A Thomas
T07069s1	Climate change impacts on conservation (Phases 1 and 2)	G W Elmes

Programme 8 Population and community ecology

T08050k1	Scottish adder survey	C J Reading
T08057-5	**Migratory wader ecology**	**J D Goss-Custard**
T08057a2	Predator/prey interactions between the oystercatcher and mussel	J D Goss-Custard
T08057b2	Winter feeding ecology of juvenile oystercatchers	S E A Durell
T08057h5	Birds in estuaries	J D Goss-Custard
T08057j1	Cardiff Bay barrage bill	J D Goss-Custard
T08057k1	Duddon Estuary gas pipeline invertebrate survey	S McGrorty
T08057l1	Training in wetland bird research	J D Goss-Custard
T08058-5	**Resident vertebrate ecology**	**R E Kenward**
T08058a5	Squirrel demography and conservation	R E Kenward
T08058e2	Breeding success and survival in the common toad	C J Reading
T08058f2	Ecology and population dynamics of the grass-snake (*Natrix natrix helvetica*)	C J Reading
T08058g5	Developing software for radiotag studies	R E Kenward
T08058h5	Population dynamics and requirements of raptors	R E Kenward
T08058j5	Biomonitoring of sea-eagles	R E Kenward
T08058l1	Herpetological survey of Water of Ae, Scotland	C J Reading
T08059-5	**Plant genecology**	**A J Gray**
T08059c2	Genetic variation in wetland species	R E Daniels
T08059p1	Niche modelling of saltmarsh plants	A J Gray
T08059q1	Tidal regimes and saltmarshes - river Hamble	A J Gray
T08059r2	Genetic structure of plant populations	R E Daniels
T08059s1	Wytch Farm development	R E Daniels
T08060-5	**Evolutionary ecology of interacting populations ant/plant/butterfly parasitoid systems under different climates**	**J A Thomas**
T08060h2	Brunei rainforest biodiversity	G W Elmes
T08060i2	Social structure and ecological adaptations of *Myrmica* ants	G W Elmes
T08060j2	Comparative evolutionary ecology of *Maculinea* species	G W Elmes/ J A Thomas
T08060k5	Field tests of butterfly/ant population models	J A Thomas
T08068-5	**Molecular ecology**	**A J Gray/I Newton**
T08068a2	Gene flow in *Brassica*	A J Gray
T08068b2	Ant sociobiology	G W Elmes
T08068f1	Genetically modified crops	A F Raybould
T08068g1	Gene flow in natural populations of *Brassica* and *Beta*	A J Gray
T08068h1	Gene flow between forage crops and wild relatives	A J Gray
T08078-5	**Assessment, management and reconstruction of lowland communities**	**M G Morris/ N R C Webb**
T08078b1	Dorset oilfields biological monitoring	R E Daniels
T08078c1	West Wellow bypass ecological appraisal	L K Ward
T08078e1	M3 Bar End to Compton ecological studies	M G Morris/ N R C Webb
T08078f2	Diversity of grassland types invertebrates	M G Morris
T08078g2	Demography and conservation of scrub	L K Ward
T08078h5	Old Winchester Hill management and invertebrates	M G Morris
T08079-5	**Metapopulation dynamics, habitat templets and successional processes**	**N R C Webb**
T08079d1	New Forest cicada	L K Ward
T08079e2	Heathland habitat templets	N R C Webb
T08079f2	Habitat occupancy and dispersal by heathland species	N R C Webb
T08079g2	Invertebrate succession on heathland	N R C Webb
T08079h2	Dorset heaths GIS	N R C Webb
T08079i2	Invertebrate geographical ranges and climate	L K Ward
T08079j2	Biodiversity of hyperdiverse taxa	M G Morris
T08083-5	**Vertebrate geodemography**	**R E Kenward**
T08083a1	Demography of saker falcons in central Asia	R E Kenward

Programme 13 Scientific services

T13060e2	Statistical and computing services at Furzebrook	R T Clarke
T13060f2	Statistical and computing services for the IFE River Laboratory	R T Clarke
T13060g2	Biometrical research at ITE Furzebrook	R T Clarke
T13061-1	**ITE South consultancies**	**T M Roberts**
T13061b1	Small consultancies at ITE Furzebrook	M G Morris

ITE SOUTH — BANGOR RESEARCH UNIT

Programme 1 Forest science

T01064-5	**Land use research overseas**	**J E G Good**
T01064a2	Land use ecology in Morocco	L S Anderson
T01064b1	Forest hydrology and soil erosion in Jamaica	P A Stevens

T01064c2	Clonal selection for tolerance of drought and salinity in semi-arid zone trees and shrubs	J E G Good
T01064e5	Productivity of intercropped sorghum, in relation to water and nutrient stresses in semi-arid agroforesry	L S Anderson
T01064f5	Nutrient cycle of semi-arid agro-forestry in Nigeria	P A Stevens

Programme 3 Global environmental change

T03086d6	Ecophysiological responses to CO_2 enrichment and other climatic factors in a wide sample of functional types of British plants	T W Ashenden
T03087e6	Growth and developmental responses to CO_2 enrichment under different temperature and nutrient regimes in a wide sample of functional types of British plants	T W Ashenden
T03087u6	Effect of climate change on woodland ecosystems – experimental studies on CO_2 and temperature effects on oak/sycamore – herbivorous insect interaction	J E G Good
T03091c6	Methane and nitrous oxide fluxes from mire soils and plants responses to nitrogen supply and carbon dioxide enrichment	M C Press/ J A Lee/ T W Ashenden

Progamme 7 Environmental pollution

T07064-5	**Air pollution/climate change research**	**T W Ashenden**
T07064l5	Critical loads of N and S deposition to semi-natural vegetation	T W Ashenden
T07064m5	Effects of increasing concentrations of carbon dioxide on grassland communities	T W Ashenden
T07064o5	Critical loads of pollutants for semi-natural ecosystems in Wales	T W Ashenden
T07064p2	Effects of acid fog on upland vegetation	T W Ashenden
T07064q2	Environmental facility development	C R Rafarel
T07064r2	Effects of climate change on upland ecosystems	T W Ashenden
T07064s5	Effects of elevated CO_2 and temperature on rye-grass	T W Ashenden
T07064t2	Ecophysiology of the effects of elevated atmospheric carbon dioxide on growth of montane plant species	R Baxter
T07072-5	**Upland nitrogen dynamics**	**B Reynolds**
T07072a5	Nitrogen critical load experiment	B A Emmett
T07072b5	Forest nitrogen survey	P A Stevens
T07072d5	Estimation of atmospheric inputs to catchments	B Reynolds
T07072h5	Biochemical consequences of climate change upon riparian wetlands	C Freeman
T07072i5	Modelling upland nitrogen dynamics	B Reynolds
T07072j5	Solute pathways in upland catchments	B Reynolds
T07072k1	Water quality implications of conifer harvesting	P A Stevens
T07072l1	Review of acid deposition effects in Wales	B Reynolds
T07072m2	Climate change and microbial ecology a university support project	C Freeman
T07072n5	Nitrogen processes in upland forest soils	B A Emmett

Progamme 8 Population and community ecology

T08077-5	**Upland ecology**	**G L Radford**
T08077b2	Exploitation of montane habitats by free-ranging sheep	A G Thomson
T08077c1	Upland grass re-establishment	J E G Good
T08077e1	Effects of grazing on upland invertebrates in Snowdonia	A Buse
T08077f5	Modelling rhododendron invasion in Wales	A G Thomson
T08077g2	Climate and high-altitude invertebrates	A Buse
T08077h5	A GIS for conservation in Wales	G L Radford
T08077i1	Environmental assessment of four British Gas sites	G L Radford

Programme 13 Scientific services

T13061-1	**ITE South consultancies**	**T M Roberts**
T13061c1	Small consultancies at ITE Bangor	J E G Good

Appendix 4. **Publications by ITE staff, 1992–93**

1. Refereed papers in journals

Adamson,J.K., Hornung,M., Kennedy,V.H., Norris,D.A., Paterson,I.S. & Stevens,P.A. 1993 Soil solution chemistry and throughfall under adjacent stands of Japanese larch and Sitka spruce at three contrasting locations in Britain *Forestry*, **66**, 51-68

Ashenden,T.W., Baxter,R. & Rafarel,C.R. 1992 An inexpensive system for exposing plants in the field to elevated concentrations of CO_2 *Plant Cell and Environment*, **15**, 365-372

(Barker,M.G.) & Ashenden,T.W. 1992 Effects of acid fog on cuticular permeability and cation leaching in holly (*Ilex aquifolium*) *Agriculture, Ecosystems and Environment*, **42**, 291-306

(Barker,M.G.) & Ashenden,T.W. 1993 Foliar injury in young *Betula pendula* Roth , *Salix purpurea* L and *Ilex aquifolium* L trees and in propagated *Taxus baccata* L shoots exposed to intermittent fog at a range of acidities *Environmental Pollution*, **80**, 123-127

Bayfield,N.G., (Barker,D.H. & Yah,K.C.) 1992 Erosion of road cuttings and the use of bioengineering to improve slope stability in peninsular Malaysia *Singapore Journal of Tropical Geography*, **13**, 75-89

Beresford,N.A., (Mayes,R.W.), Howard,B.J., (Eayres,H.F., Lamb,C.S.), Barnett,C.L. & (Segal,M.G.) 1992 The bioavailability of different forms of radiocaesium for transfer across the gut of ruminants *Radiation Protection Dosimetry*, **41**, 87-91

(Boates,J.S.) & Goss-Custard,J.D. 1992 Foraging behaviour of oystercatchers *Haematopus ostralegus* specialising on different species of prey *Canadian Journal of Zoology*, **70**, 2398-2404

Boorman,L.A. 1991 The environmental consequences of climatic change on British salt marsh vegetation *Wetlands Ecology and Management*, **2**, 11-21

(Bourn,N.A.D.) & Thomas,J.A. 1993 The ecology and conservation of the brown argus butterfly *Aricia agestis* in Britain *Biological Conservation*, **63**, 67-74

(Brittas,R., Marcstrom,V.), Kenward,R.E. & (Karlbom,M.) 1992 Survival and breeding success of reared and wild ring-necked pheasants in Sweden *Journal of Wildlife Management*, **56**, 368-376

Bull,K.R. 1992 An introduction to critical loads *Environmental Pollution*, **77**, 173-176

Bull,K.R., Hall,J.R., (Steenson,D., Smith,C. & Cresser,M.) 1992 Critical loads of acid deposition for soils - the UK approach *Endeavour*, **16**, 132-138

Buse,A. 1992 Environmental effects of land use change, as identified by habitat recording a case study in the Llyn Peninsula, Wales *Journal of Environmental Management*, **35**, 131-151

Caldow,R.W.G. & (Furness,R.W.) 1993 A histochemical comparison of fibre types in the *m pectoralis* and *m supracoracoideus* of the great skua *Catharacta skua* and the herring gull *Larus argentatus* with reference to kleptoparasitic capabilities *Journal of Zoology*, **229**, 91-103

Callaghan,T.V., (Sonesson,M. & Somme,L.) 1992 Responses of terrestrial plants and invertebrates to environmental change at high latitudes *Philosophical Transactions of the Royal Society of London B*, **338**, 279-288

Cape,J.N., Hargreaves,K.J., Storeton-West,R., Fowler,D., (Colville,R.N., Choularton,T.W. & Gallagher,M.W.) 1992 Nitrite in orographic cloud as an indicator of nitrous acid in rural air *Atmospheric Environment*, **26A**, 2301-2307

Carey,P.D., (Fitter,A.H. & Watkinson,A.R.) 1992 A field study using the fungicide benomyl to investigate the effect of mycorrhizal fungi on plant fitness *Oecologia*, **90**, 550-555

(Carlsson,B.A.) & Callaghan,T.V. 1991 Positive plant interactions in tundra vegetation and the importance of shelter *Journal of Ecology*, **79**, 973-983

Carss,D.N. 1993 Grey heron, *Ardea cinerea* L , predation at cage fish farms in Argyll, western Scotland *Aquaculture and Fisheries Management*, **24**, 29-45

Carss,D.N. 1993 Cormorants *Phalacrocorax carbo* at cage fish farms in Argyll, western Scotland *Seabird*, **15**, 38-44

Clint,G.M. & Dighton,J. 1992 Uptake and accumulation of radiocaesium by mycorrhizal and non-mycorrhizal heather plants *New Phytologist*, **121**, 555-561

(Cole,D.N.) & Bayfield,N.G. 1993 Recreational trampling of vegetation standard experimental procedures *Biological Conservation*, **63**, 209-215

(Coulson,S., Hodkinson,I.D., Strathdee,A., Bale,J.S., Block,W., Worland,M.R.) & Webb,N.R. 1993 Simulated climate change the interaction between vegetation type and microhabitat temperatures at Ny Alesund, Svalbard *Polar Biology*, **13**, 67-70

Daniels,R.E. 1992 Variation in performance of *Phragmites australis* in experimental culture *Aquatic Botany*, **42**, 41-48

Davis,B.N.K., Lakhani,K.H., Yates,T.J., Frost,A.J. & Plant,R.A. 1993 Insecticide drift from ground-based, hydraulic spraying of peas and brussel sprouts bioassays for determining buffer zones *Agriculture, Ecosystems and Environment*, **43**, 93-108

Dawson,A. & McNaughton,F.J. 1992 Puberty in European starlings can nestlings perceive daylength? *Ornis Scandinavica*, **23**, 209-213

Deans,J.D., Billington,H.L. & Harvey,F.J. 1992 Winter frost hardiness of two Chilean provenances of *Nothofagus procera* in Scotland *Forestry*, **65**, 205-212

Deans,J.D., (Mason,W.L.) & Harvey,F.J. 1992 Clonal differences in planting stock quality of Sitka spruce

Forest Ecology and Management, **49**, 101-107

Dennis,P. & (Fry,G.L.A.) 1992 Field margins can they enhance natural enemy population densities and general arthropod diversity on farmland? *Agriculture, Ecosystems and Environment*, **40**, 95-115

Dewar,R.C. & Watt,A.D. 1992 Predicted changes in the synchrony of larval emergence and budburst under climatic warming *Oecologia*, **89**, 557-559

Dewar,R.C. & Cannell,M.G.R. 1992 Carbon sequestration in the trees, products and soils of forest plantations - an analysis using UK examples *Tree Physiology*, **11**, 49-72

Dewar,R.C. 1993 A mechanistic analysis of self-thinning in terms of the carbon balance of trees *Annals of Botany*, **71**, 147-159

Dick,J.McP. & Dewar,R.C. 1992 A mechanistic model of carbohydrate dynamics during adventitious root development in leafy cuttings *Annals of Botany*, **70**, 371-377

Dighton,J. & Jones,H.E. 1992 The use of roots to test N, P and K deficiencies in *Eucalyptus* nutrition *South African Forestry Journal*, no 160, 33-37

Dighton,J. & (Coleman,D.C.) 1992 Phosphorus relations of roots and mycorrhizas of *Rhododendron maximum* L in the Southern Appalachians, North Carolina *Mycorrhiza*, **1**, 175-184

Dighton,J., Poskitt,J.M. & Brown,T.K. 1993 Phosphate influx into ectomycorrhizal and saprotrophic fungal hyphae in relation to phosphate supply a potential method for selection of efficient mycorrhizal species *Mycological Research*, **97**, 355-358

(Dore,A.J., Choularton,T.W.) & Fowler,D. 1992 An improved wet deposition map of the United Kingdom incorporating the seeder-feeder effect over mountainous terrain *Atmospheric Environment*, **26A**, 1375-1381

Durell,S.E.A.Le V.dit, Goss-Custard,J.D. & Caldow,R.W.G. 1993 Sex-related differences in diet and feeding method in the oystercatcher *Haematopus ostralegus* *Journal of Animal Ecology*, **62**, 205-215

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Elmes,G.W. & Thomas,J.A. 1992 Complexity of species conservation in managed habitats interaction between *Maculinea* butterflies and their ant hosts *Biodiversity and Conservation*, **1**, 155-169

(Ferris,C., Callow,R.S.) & Gray,A.J. 1992 Mixed first and second division restitution in male meiosis of *Hierochloe odorata* (L) Beauv (holy grass) *Heredity*, **69**, 21-31

(France,J.), Thornley,J.H.M., (Baldwin,R.L. & Crist,K.A.) 1992 On solving stiff equations with reference to stimulating ruminant metabolism *Journal of Theoretical Biology*, **156**, 525-539

Freeman,C. & (Lock,M.A.) 1992 Recalcitrant high-molecular-weight material, an inhibitor of microbial metabolism in river biofilms *Applied and Environmental Microbiology*, **58**, 2030-2033

(Gammelgaard,A.), Freeman,C. & (Lock,M.A.) 1992 Measurement of electron transport system activity in sphagnum-derived peat *Soil Biology and Biochemistry*, **25**, 505-507

Good,J.E.G., Winder,J.D., Sellers,E. & Williams,T.G. 1992 Species and clonal variation in growth responses to waterlogging and submersion in the genus *Salix* *Proceedings of the Royal Society of Edinburgh*, **98B**, 21-48

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Greatorex-Davies,J.N., Hall,M.L. & Marrs,R.H. 1992 The conservation of the pearl-bordered fritillary butterfly (*Bolona euphrosyne* L) preliminary studies on the creation and management of glades in conifer plantations *Forest Ecology and Management*, **53**, 1-14

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Hinsley,S.A. 1992 Bioenergetics of a desert specialist, the double-banded sandgrouse, and the problem of stress induced by experimental conditions *Comparative Biochemistry and Physiology*, **102A**, 433-439

(Hochberg,M.E.), Thomas,J.A. & Elmes,G.W. 1992 A modelling study of the population dynamics of a large blue butterfly, *Maculinea rebeli*, a parasite of red ant nests *Journal of Animal Ecology*, **61**, 397-409

Howard,D.M. 1992 Canonical analysis of soil data *Journal of Applied Statistics*, **19**, 171-181

Howard,P.J.A. 1993 Soil protection and soil quality assessment in the EC *Science of the Total Environment*, **129**, 219-239

Howard,P.J.A. 1993 An analysis of the effects of atmospheric sulphate and ammonium on soil solution chemistry using median polishing *Journal of Applied Statistics*, **20**, 119-126

(Iason,G.R.), Hartley,S.E. & (Duncan,A.J.) 1993 Chemical composition of *Calluna vulgaris* (Ericaceae) do responses to fertilizer vary with phenological stage? *Biochemical Systematics and Ecology*, **21**, 315-321

(Jenkinson,D.S., Harkness,D.D., Vance,E.D., Adams,D.E.) & Harrison,A.F. 1992 Calculating net primary production and annual input of organic matter to soil from the amount and radiocarbon content of soil organic

matter *Soil Biology and Biochemistry*, **24**, 295-308

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Jones,H.E., Quarmby,C. & Harrison,A.F. 1992 Evaluation of the sensitivity of a ^{15}N test for nitrogen deficiency in plants *Communications in Soil Science and Plant Analysis*, **23**, 1333-1343

Kenward,R.E., (Marcstrom,V. & Karlbom,M.) 1991 The goshawk (*Accipiter gentilis*) as predator and renewable resource *Gibier Faune Sauvage*, **8**, 367-378

(Kershaw,C.D.) & Fuller,R.M. 1992 Statistical problems in the discrimination of land cover from satellite images a case study in lowland Britain *International Journal of Remote Sensing*, **13**, 3085-3104

Kruuk,H. 1992 Scent marking by otters (*Lutra lutra*) - signaling the use of resources *Behavioral Ecology*, **3**, 133-140

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McLeod,A.R., (Shaw,P.J.A. & Holland,M.R.) 1992 The Liphook Forest Fumigation Project studies of sulphur dioxide and ozone effects on coniferous trees *Forest Ecology and Management*, **51**, 121-127

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Mazzoleni,S., French,D.D. & Miles,J. 1991 A comparative study of classification and ordination methods on successional data *Coenoses*, **6**, 91-101

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Appendix 5. **ITE publications**

HMSO publishes for the Institute, and acts as an agent for a substantial backlist of ITE titles. Unless specified otherwise, all books are paperback with prices shown net (as per the Net Book Agreement), and are available from HMSO bookshops

Forest science

Cumbrian woodlands (ITE symposium no 25)
J K Adamson (ed)
94pp 0 11 701421 4 £7 10 1989

The ecology of even-aged forest plantations
E D Ford, D C Malcolm & J Atterson (eds)
582pp 0 904282 33 3 £9 00 (Hardback) 1979

Effect of birch on moorlands
J Miles
18pp 0 904282 47 3 £1 50 1981

Environmental aspects of plantation forestry in Wales
(ITE symposium no 22)
J E G Good (ed)
77pp 1 870393 02 3 £3 25 1987

A field key for classifying British woodland vegetation: Part I
R G H Bunce
103pp 0 904282 68 6 £3 00 1982

A field key for classifying British woodland vegetation: Part II
R G H Bunce
95pp 0 11 701417 6 £7 95 1989

Identification of ectomycorrhizas (ITE research publication no 5)
K Ingleby, P A Mason, F T Last & L V Flemung
112pp 0 11 701461 3 £30 00 1990

Pasture woodlands in lowland Britain
P T Harding & F Rose
94pp 0 904282 91 0 £5 00 1986

The temperate forest ecosystem (ITE symposium no 20)
Yang Hanxi, Wang Zhan, J N R Jeffers & P A Ward (eds)
189pp 1 870393 01 5 £7 50 1987

Trees and wildlife in the Scottish uplands (ITE symposium no 17)
D Jenkins (ed)
196pp 0 904282 97 X £3 50 1986

Land use, agriculture and the environment

Agriculture and conservation in the hills and uplands
(ITE symposium no 23)
M Bell & R G H Bunce (eds)
164pp 1 870393 03 1 £5 00 1987

Agriculture and the environment (ITE symposium no 13)
D Jenkins (ed)
195pp 0 904282 73 3 £3 50 1984

Angling and wildlife in fresh waters (ITE symposium no 19)
P S Maitland & A K Turner (eds)
84pp 0 904282 99 6 £4 00 1987

The biology and management of the River Dee
(ITE symposium no 14)
D Jenkins (ed)
160pp 0 904282 88 0 £6 00 1985

Britain's railway vegetation
C Sargent
34pp 0 904282 76 7 £3 50 1984

Distribution of freshwaters in Great Britain
I R Smith & A A Lyle
44pp 0 904282 25 2 £2 00 1979

Historical ecology: the documentary evidence
J Sheail
22pp 0 904282 34 1 £2 00 1980

Moorland management: a study of Exmoor
G R Miller, J Miles & O W Heal
130pp 0 904282 79 1 £4 50 1984

Rural information for forward planning
(ITE symposium no 21)
R G H Bunce & C J Barr (eds)
115 pp 1 870393 05 8 £5 50 1988

The use of land classification in resource assessment and rural planning
R S Smith
43pp 0 904282 62 7 £3 00 1982

Vegetation change in upland landscapes
D F Ball, J Dale, J Sheail & O W Heal
45pp 0 904282 64 3 £2 00 1982

Global environmental change

Climatic change, rising sea level and the British coast
(ITE research publication no 1)
L A Boorman, J D Goss-Custard & S McGrorty
24pp *0 11 701429 X* *£2 75* *1989*

The greenhouse effect and terrestrial ecosystems of the UK
(ITE research publication no 4)
M G R Cannell & M D Hooper (eds)
56pp *0 11 701488 5* *£2 45* *1990*

Climatological maps of Great Britain
E J White & R I Smith
37pp *0 904282 69 4* *£2 00* *1982*

Environmental pollution

Acidification and fish in Scottish lochs
P S Maitland, A A Lyle & R N B Campbell
71pp *1 870393 04 X* *£3 50* *1987*

Early diagnosis of forest decline
J N Cape, I S Paterson, A R Wellburn, J Wolfenden, M Mehlhorn, P Freer-Smith & S Fink
68pp *1 870393 07 4* *£5 00* *1988*

Effects of air pollutants on agricultural crops
F T Last, D Fowler & P H Freer-Smith
27pp *0 904282 90 2* *£2 00* *1985*

Methods for studying acid precipitation in forest ecosystems
I A Nicholson, I S Paterson & F T Last (eds)
36pp *0 904282 36 8* *£3 00* *1980*

Pollution in Cumbria (ITE symposium no 16)
P Ineson (ed)
92pp *0 904282 96 1* *£52 50* *1986*

Predatory birds, pesticides and pollution
A S Cooke, A A Bell & M B Haas
74pp *0 904282 55 4* *£4 00* *1982*

Radionuclides in terrestrial ecosystems
K L Bocock
27pp *0 904282 42 2* *£2 00* *1981*

Population and community ecology

Bedford Purlieus (ITE symposium no 7)
G F Peterken & R C Welch (eds)
209pp *0 904282 05 8* *£1 00* *1975*

Birds of St Kilda
M P Harris & S Murray
42pp *0 904282 27 9* *£6 50* *1989*

Butterfly research in ITE
M L Hall
28pp *0 904282 46 5* *£1 50* *1981*

Coast dune management guide
D S Ranwell & R Boar
105pp *0 904282 93 7* *£3 00* *1986*

Conserving otters
D Jenkins
14pp *0 904282 44 9* *£1 00* *1980*

Distribution and status of bats in Europe
R E Stebbings & F Griffith
142pp *0 904282 94 5* *£2 50* *1986*

Ecology of quarries (ITE symposium no 11)
B N K Davis (ed)
77pp *0 904282 59 7* *£2 00* *1982*

Handbook of European sphagna
R E Daniels & A Eddy
262pp *0 11 701431 1* *£10 50* *1990*

Heather in England and Wales (ITE research publication no 3)
R G H Bunce (ed)
40pp *0 11 701422 2* *£2 95* *1989*

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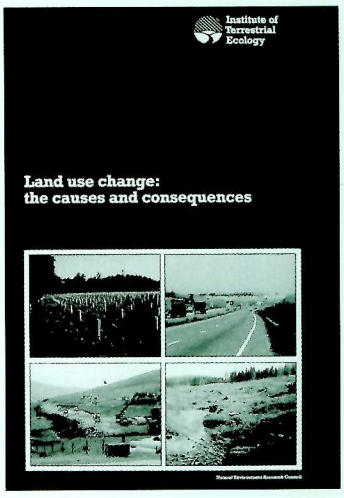

Land use change: the causes and consequences

M C Whitby (editor)

Increased population density, a rise in standards of living and improved, more widespread, personal mobility have meant increasing competition for rural land use. The long-standing primary position of agriculture and forestry as economic activities in land use is being slowly undermined. Growing competition between different interest groups has created a pressing need for a re-evaluation of current land use policy. These Conference proceedings focus on four areas which require research before policy changes can be developed to identify new opportunities and to solve specific problems. Analysis of the causes of change, assessment of the consequences of change, the detection of change and the assessment of land use options are essential areas of investigation requiring a multidisciplinary effort in deciding priorities for the future. This book provides a comprehensive overview of the main issues and takes a tentative look at the options for the future.

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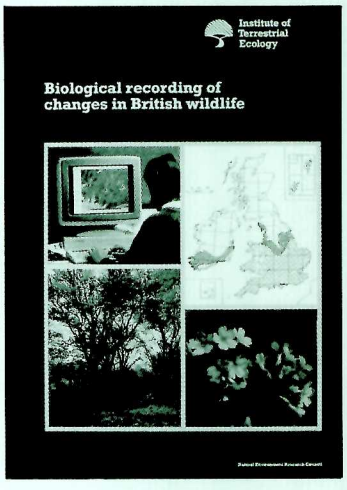
Biological recording of changes in British wildlife

P T Harding (Editor)



In 1990 the Biological Records Centre and the Natural Environment Research Council celebrated their 25th Anniversaries at a Conference, where a series of papers were presented. During the past 25 years the unprecedented and rapid changes in land use and environmental management that have occurred have ensured an increasing importance for both BRC and NERC. These papers trace the history of the BRC and review the effects of environmental changes on wildlife through several case studies. Time-series data bases are essential for assessing the effects of land use change and pollution; future applications and the effects of policies and legislation are also considered.

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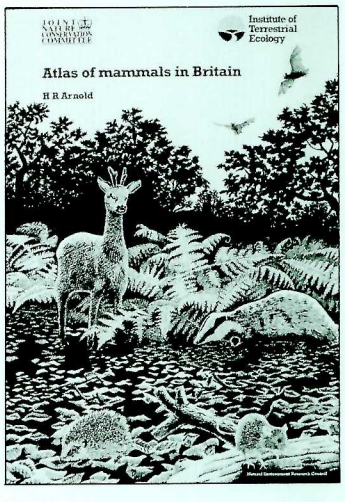

Atlas of mammals in Britain

H R Arnold

Over 115 000 sighting records of British mammals have been collected between 1959 and 1991. This new *Atlas* from the Institute of Terrestrial Ecology summarises all the data to form the most accurate picture available to date of the distribution of mammals in Britain.

Each mammal species is described individually, a table provides basic record details, and a clear map illustrates the mammal's distribution in Great Britain and the Channel Islands up to 1959 and from 1960. In all, 65 mammals are listed which range from the mole, the most commonly recorded species, to the greater white-toothed shrew for which only five records exist.

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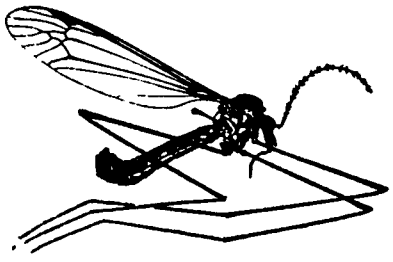
A E Stubbs



The *Atlas* summarises information on the occurrence in Britain and Ireland of long-palped craneflies in the genera *Ctenophora, Dictenidia, Dolichopeza, Nephrotoma, Nigrotipula, Pnonocera, Tanyptera* and *Tipula* It includes distribution maps and brief accounts of all 87 species

Also included are a history of cranefly recording, a description of the data and notes on the ecology and habitat associations of Tipulinae in Britain and Ireland The status of species in Britain is also examined The bibliography of over 300 titles is an essential guide to the literature on craneflies in Britain and Ireland

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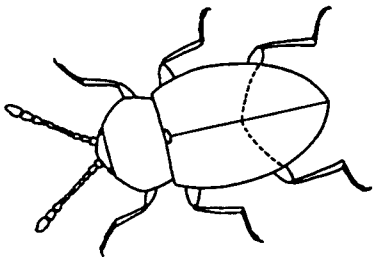
C Johnson

The *Atlas* summarises information on the occurrence in Britain and Ireland of Atomariinae beetles in the genera *Caenoscelis, Atomaria, Ootypus* and *Ephistemus* It includes distribution maps and brief accounts of all 48 species



Also included are lists of the occurrence of all species by vice-counties, with more detailed information for the less common species The *Atlas* includes a complete checklist of species and a bibliography of key works for the identification of Atomariinae

91pp 1 870393 17 1 1993 £5 50

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