CEH Science Programme

Since the formation of CEH, the Centre has been active in developing a Science Programme that underpins national and international requirements in the terrestrial and freshwater sciences. The Programme is divided into 10 component Programmes, all of which address issues of current environmental relevance and important scientific challenges. The Programme as a whole involves extensive collaboration with academic organisations throughout the world and with international research programmes.

Each CEH Programme is led by a senior scientist from within CEH, the Programme Leader. Programme Leaders are responsible for leading the development of their Programme and for ensuring a responsive approach as new environmental issues emerge.

All component parts of CEH are active participants in the Science Programme, each Institute and site contributing its own particular area of expertise.

	Bangor	Banchory	Edinburgh	Furzebrook	Merlewood	Monks Wood	Oxford	East Stoke	Wallingford	Windermere
Soil & Soil Vegetation Interactions	◆				◆		◆	◆	◆	◆
Land Use Science	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
The Urban Environment	◆		◆					◆	◆	◆
Freshwater Resources								◆	◆	◆
Biodiversity & Population Processes		◆	◆	◆		◆	◆	◆	◆	◆
Pest & Disease Control & Risk Assessment for GMOs				◆			◆	◆		◆
Pollution	◆		◆		◆	◆	◆	◆	◆	◆
Environmental Risks & Extreme Events				◆				◆	◆	
Global Change	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
Integrating Generic Science	◆			◆	◆	◆	◆	◆	◆	◆

The scientific quality and output of the Programmes is assessed annually by independent Programme Review Groups (PRGs) . The present composition of the PRGs is shown in Appendix 3.

The following section presents a report from each Programme Leader and a selection of scientific highlights for the year. The detailed structure for each Programme is given in Appendix 4.

Soil and Soil Vegetation Interactions

Programme 1

Soils have key roles in controlling global change, pollution impacts, maintenance of biodiversity and sustainable development. An understanding of soil physical, chemical and biological processes and functions is essential to the optimal and sustainable management of soils, land and water resources and the prediction and management of the impacts of pollution, environmental change and land use.

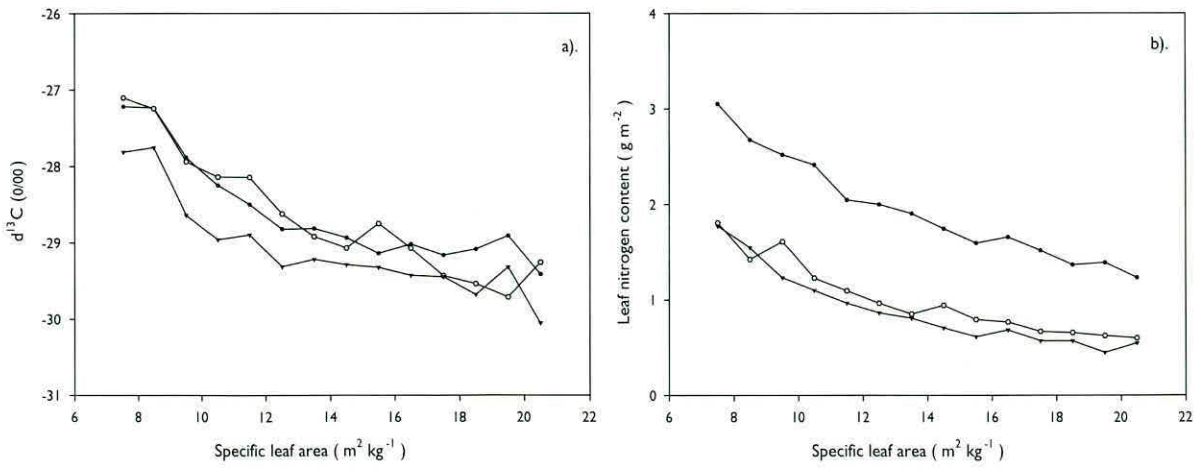
Programme 1 will improve understanding and the ability to model key soil processes which control the transformations of materials in soils and the flux of water through the soil–vegetation–atmosphere continuum.

Achievements Include:

- **Quantification of multi-element release in weathering.** The release of base cations in weathering is the one of major process controlling the buffering of acidity in terrestrial systems. Most laboratory studies of base cation release during weathering have concentrated on the release of single elements but in the field there is simultaneous release of a number of elements. Recent studies in CEH have quantified multi-element release rates from weathering rocks and incorporated mathematical descriptions of the release into solid-solute models.

- **Identification of methane oxidisers.** The identification and separation of the bacteria involved in methane oxidation in soils is extremely difficult with traditional culturing techniques and this has hindered their characterisation and study. Recent work in CEH has developed a methodology allowing the rapid identification of obligate methane oxidisers and separation of their DNA from the soil, thus allowing their characterisation.

- **The use of leaf litter to provide canopy information.** It is important to know quantitatively the vertical distribution of foliage in the canopy to allow scaling up of leaf processes measured at the leaf scale to a forest canopy. Destructive sampling of canopies is very time-consuming but recent work has shown that forest litter can be used to describe the canopy. Thus, variation in specific leaf area, leaf carbon isotope ratio and leaf nitrogen in litter can be related to original canopy position.



Relationship between specific leaf area and (a) $\delta^{13}C$ and (b) leaf nitrogen content of living canopy leaves (●) and senescent canopy leaves (○) and litter leaves (▼) in 1996.

Programme Leader's Report

During the year, CEH staff secured three awards under the NERC 'Soil Biodiversity' Thematic Programme and are collaborators in a further four awards. The Thematic Programme is focused on a grassland site at the Sourhope Experimental Farm in the Cheviot Hills. The CEH research includes protozoan and decomposer fungal diversity and function in the grassland soil, the identification of total versus active diversity in microbial populations, and tracking carbon transfers through trophic chains.

CEH staff are at the forefront of the application of isotopic approaches in soil ecology. The trophic work mentioned above is built around the introduction of a ^{13}C signal into the grassland system, using a specially built mobile laboratory. Use of isotopes in studies on diet selection by soil invertebrates has shown an almost complete turnover of bulk C in the actively grazing *Collembola* in 2 weeks at 15°C. Techniques were developed allowing isotope analysis of both bulk and individual compounds using a few individual animals. In a study of methane oxidisers, the use of ^{13}C methane allowed obligate methane consumers to be identified. Heavy DNA was subsequently extracted from the bacteria using density centrifugation, in collaboration with Warwick University. In the work on rates of soil carbon turnover, ^{14}C from nuclear bomb tests that was incorporated into soil organic matter has been used to calculate mean residence times of carbon in forest soils along a climate and pollution gradient in Europe.

In a more applied area of research, it is widely accepted that soil biota should be considered in assessments of soil quality. However, there are no national baseline data on soil biota. A project, funded collaboratively by CEH, the EA and DETR, aims to provide such baseline information. It involves sampling of soils at 5 locations in 256 1km sample squares, distributed across GB, and surveyed under the Countryside Survey 2000. Soil invertebrates are being extracted from the samples and microbial function assessed. In a parallel study, temporal variations in invertebrates and bacterial functional groups are being investigated using intensive sampling at terrestrial sites within the Environmental Change Network.

Model development also continues to be an important strategic and applied component of Programme 1. The physico-chemical Windermere Humic Acid Model (WHAM) of surface-solution interactions, which was developed at IFE Windermere, has been improved to provide a better description of dissolved organic matter concentrations and fluxes. The model is widely used in investigations of pollution impacts on water quality. At a different scale, a seasonal growth scheme has been incorporated into a computationally efficient GCM analogue model for the generation of land surface climatologies, in collaboration with the Hadley Centre.

Professor Mike Hornung is a soil scientist, specialising in the impact of pollution and land use on soil and soil water chemistry. He has a visiting Professorship at the University of Lancaster and is Head of ITE's Merlewood Research Station.

Land Use Science

Programme 2

Major changes in land use, locally, regionally and globally, have occurred over the last century. These will continue into the future and have a major impact on society. To ameliorate such impacts, the processes driving land use change need to be understood.

This Programme promotes an integrated approach to land use science that is applicable to the wide range of user community needs. The research focuses on:

- monitoring and understanding the impacts of land use change on water and carbon balances and on habitats and wildlife.
- modelling the processes and effects of land use change.
- developing strategies for the optimisation of land use.

These research areas will be developed to provide the basis for large-scale, long-term analytical studies of land use change.

Achievements Include:

- Over 90% of the field work for Countryside Survey 2000 completed.
- Publication of the Countryside Vegetation System, the first national vegetation classification with estimates of areas of the classes and access to the classification via the World-Wide-Web.
- A unique study of soil water contents and potential under grassland and beech forest down to 9 m in the chalk will provide essential information to assess the impacts on water resources of forest expansion in lowland England.
- Completion of experiments into the roles of nutrient supply and herbivory on the competitive interactions, above and below ground, of *Calluna vulgaris* and grass species.
- Establishing a firm scientific basis for describing the impacts of upland plantation conifer harvesting that is directly influencing forestry management approaches.
- Development of a semi-spatially explicit hydrochemical model that allows prediction of changes in stream acidification under a growing forest until 2020.
- Models of bird abundance within an interactive GIS are being used to estimate the impacts of changing cropping and management of hedgerows and other features of individual farms, on Biodiversity Action Plan listed birds such as the skylark.
- New studies of the financial loss due to bark damage caused by herbivores, based on damaged logs being rejected for structural use at a sawmill, show the actual loss to be 70% less than that perceived by a valuer surveying the standing crops.
- The Agroforestry Modelling Project (AMP) has organised workshops in the UK and Kenya disseminating the HyPAR model to 25 scientists in International Centre for Research in Agroforestry (ICRAF) and associated National Agricultural Research Stations. Significant improvements have been made in HyPAR v 2.7 (nutrient competition, hydrology, water competition, carbon allocation and management options), and it is available to a growing user group from the AMP Website

Programme Leader's Report

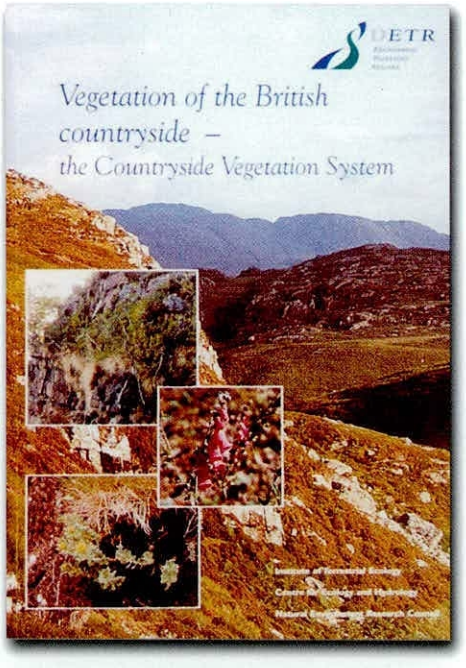
Land use change continues apace, in Britain and across the world. It is increasingly being recognised that in order to be truly sustainable land use practices must consider a broad range of issues, environmental as well as economic and social. UK Government policy is evolving rapidly with many new initiatives and a greater emphasis on the assessment of land use impacts. Fundamental to the contribution of environmental sciences to this process are three underlying themes. Namely, the ability to monitor the extent and type of land use change occurring, to understand the processes underlying the environmental impacts of different land covers and management, and the development of descriptive models based on this physical understanding to provide a predictive capability for land use managers and planners. To achieve this trilogy requires a truly interdisciplinary approach to problem solving and encompasses many skills.

Dr Mark Robinson is a hydrologist with interests in the impacts of forestry and agricultural land use changes. He is head of the Landscape Interactions Section at IH and is Programme Manager of a European-wide study into forestry impacts on extreme river flows.

Central to the monitoring of land use across Britain is the Countryside Survey 2000. The field survey work, supervised by ITE, was undertaken in 1998 and 1999. The results will be available towards the end of 2000. Information about CS2000 and also the Countryside Vegetation System, which can be used to classify vegetation samples in the wider British Countryside, is available on the World-Wide-Web from the CEH Homepage. An example of the application of such information is the development of an interactive GIS system to integrate ecological information into different land use change scenarios, thus predicting likely impacts on bird species composition and abundance.

Several new catchment-based research initiatives have been instigated during the year, particularly NERC's new lowland catchment programme, LOCAR. CEH scientists have been actively involved in the development of this new Thematic Programme. The Programme partially reflects the success of existing catchment studies in the upland, such as Plynlimon, in addressing environmental problems in those areas. It also reflects the increasing environmental pressures in the more densely populated and more intensively used and polluted lowland parts of the country.

On a global scale, some of the most pressing impacts of land use change are felt in the developing world, particularly in tropical regions. Much of the applied research in these areas is geared to poverty alleviation by providing farmers with better information regarding, for example, the inclusion of trees within a local agricultural system. Selecting suitable species that will not compete excessively with crops for water, sunlight and nutrients is of critical importance, as is ability of the trees to meet the farmers' requirements for tree products such as fruit or firewood. IH is contributing to this important work of DfID, which involves considerable 'stakeholder' participation and consultation.



The Urban Environment

Programme 3

Urban areas provide employment, housing and social contact but they consume resources, generate waste and pollution, alter habitats and are prone to environmental hazard and decay. The Earth Summit in 1992 highlighted the need to develop more socially and ecologically sustainable cities. In the UK, urban issues permeate the priority areas of science and technology identified in the Foresight Programme.

In response to the need for research dedicated to understanding urban environmental problems, Programme 3 has two main aims:

- developing and extending, through survey, monitoring and modelling, the interdisciplinary knowledge base required to plan and achieve more sustainable urban environments.
- understanding the key environmental patterns and ecological and hydrological processes in urban situations and their responses to change, especially those resulting from man's activities.

Measuring equipment for determining fluxes of air pollutants mounted on a mast 70 m above street level in Edinburgh.

Achievements Include:

- The first direct measurements of large-area emission and deposition fluxes for particles of different size ranges in polluted urban air have been made over the City of Edinburgh using instruments mounted on a tower 70 m above street level. The measurements show large emission fluxes that can be attributed to a source or sink 'footprint' of the city centre extending to several square kilometres. (Part of a collaborative project on aerosol flux measurements with the University of Manchester Institute of Science and Technology, funded by URGENT).
- CEH is contributing to an urban pollution management study for Yorkshire Water, investigating sediment dynamics and water quality in the sewer and river systems in Bradford. Progress has been made in quantifying the processes involved under normal and storm conditions and assessing variations over the seasons. (Part of an URGENT project, in collaboration with the universities of Sheffield and Exeter and is supported by Unilever, the Environment Agency and Yorkshire Water).
- The analysis of freshwater macroinvertebrates in three different types of urban towns has revealed that the type of town has very little influence on macroinvertebrate communities. The fauna of the river is much more strongly influenced by the upstream nature of the catchment. (This work was done with CEH Integrating Fund monies, using data made available by the Environment Agency).
- CEH will be involved in 3 new projects funded under NERC's URGENT Thematic Programme including:

  - impacts of vehicle emissions on vegetation
  - rehabilitation of urban rivers: modelling the ecological risks of urban river sediments
  - non-indigenous species and urban biodiversity: from generic models to practical management

Programme Leader's Report

This developing programme continues to focus on key environmental problems associated with urbanisation, and the development of scientific solutions to underpin technological advances. Many of these problems involve environmental pollution and the challenge is to understand how pollutants damage soils, waters and living organisms and to develop process-based remediation and restoration procedures.

Professor John Good is a plant eco-physiologist, with particular interests in woodland ecosystems in urban and rural areas. He is a visiting professor at University of Wales, Bangor and is Head of ITE's Bangor Research Station.

Much urban pollution finds its way into urban rivers and sewers. It is essential to know the origins of pollutants and understand the processes associated with pollutant mobilisation and movement within urban rivers and sewers. This will enable us to handle polluted water more efficiently and minimise damage to aquatic environments.

Urbanisation inevitably involves the fragmentation and/or destruction of semi-natural habitats. The challenge for ecologists is to determine the significance of habitat fragmentation on biodiversity and for the survival and spread of particular species. The aim is to develop a sound rule base for the development, design and management of urban infrastructure and greenspace.

These particularly urban problems also impact directly or indirectly on people, as well as on the many other living organisms that inhabit our towns and cities. Clean air and water and unpolluted soils, and also the space in which to live and grow, are as necessary for us as they are for other organisms. It is important, therefore, that in seeking to understand and deal with urban environmental problems we consider the benefits for people. Solutions to urban problems should encompass our aspirations for an optimal quality of life in our cities, while enhancing sustainable urban development.

Core scientific funding from the CEH Integrating Fund has provided underpinning finance for work within this programme. Scientists from different disciplines have combined to address problems that are fundamentally interdisciplinary in nature, such as the interactions between urban catchment characteristics, water yield and quality and impacts on aquatic flora and fauna. Most current funding comes, however, from NERC's major Thematic Programme on Urban Regeneration (URGENT). Successful bids into this programme have resulted in new collaborative projects with universities, government departments and industry across each of the problem areas noted above. Bids into the European Union's Fifth Framework programme, if successful, will further enhance our research role in this growing area of science.

Routine sample collection of polluted waters entering a sewage treatment works in Bradford, Yorkshire.

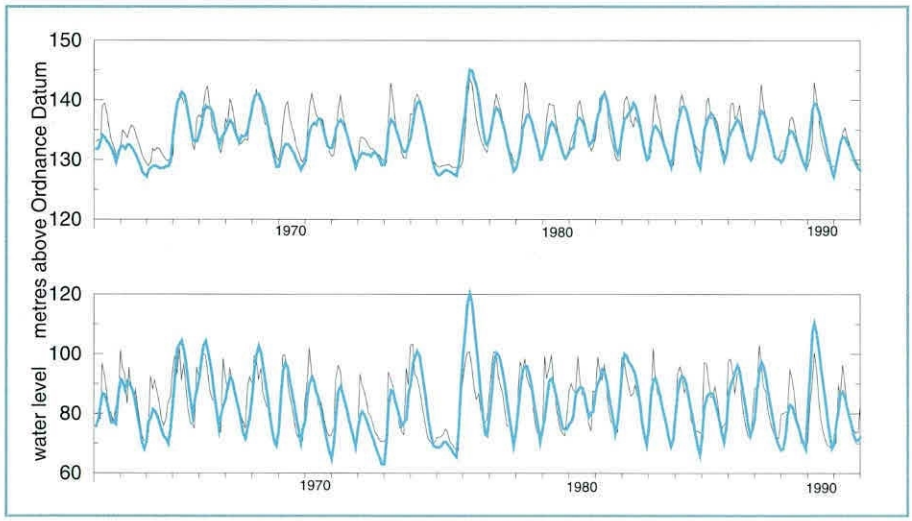
Freshwater Resources

Programme 4

The need for adequate and sustainable water resources forms the basis of much environmental policy worldwide, but the conflict between demands for freshwater and resource conservation are increasing, even in climatically wet countries like the UK. The driving objective behind this Programme is the need to improve the scientific basis for the effective strategic and sustainable management of freshwater resources required to overcome these conflicts.

This Programme brings together CEH's research in water quantity, water quality and the ecological components of freshwater systems into an integrated research programme, with major themes including:

- water quantity – improving understanding in surface–groundwater interactions and water resource modelling.
- water quality – measuring and modelling responses of aquatic biota to physical and chemical properties and improving water quality management.
- fisheries and aquaculture.



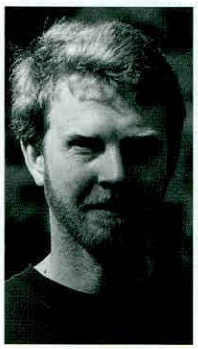
Measured (black) and modelled (blue) water levels at two sites on the chalk of southern England using a response function model of unsaturated zone flow.

Achievements Include:

- Water colour is a serious problem in Pennine water-gathering grounds. An earlier model has been successfully modified to represent the recent very high water-colours that have resulted from periods of summer drought.
- Detailed studies on phytoplankton in a shallow eutrophic lake, Loch Leven in Scotland, have shown, contrary to expectation, that algal biodiversity is high - over 150 taxa were recorded. This probably results from rapidly changing conditions driven by the variable oceanic climate.
- A key for the identification of eggs and juveniles of coarse fish has been completed.
- The modelled date of emergence of sea-trout fry in a Lake District stream, based on 30 years of observation, is strongly correlated with the North Atlantic Oscillation, probably as a result of the effect of winter water-temperature.

Programme Leader's Report

The dual funding of CEH, from both science budget and commissioned research, allows the knowledge, expertise and results of CEH scientists and science to be applied to solve practical problems in the management of freshwater resources. For example, a study has been commissioned by the Environment Agency to assess the feasibility of producing a national system to estimate groundwater recharge. Scientific methods and associated data requirements were assessed, together with appropriate software and the economic costs and benefits of such a system. Development of reliable recharge estimation is underpinned by research into estimation of recharge from surface waters to groundwater based on fieldwork and extensive development of models. The new NERC Thematic Programme on lowland catchments, LOCAR, should provide further impetus for this area of research.

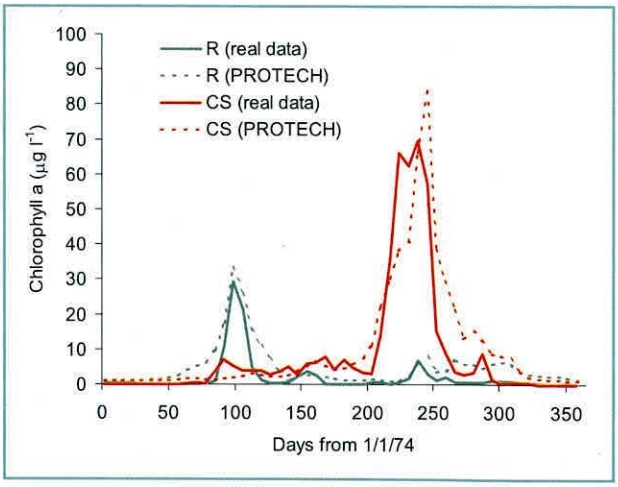


Dr Stephen Maberly is a plant ecophysiologist who has worked for IFE for 9 years. He is particularly interested in the photosynthetic physiology of phytoplankton and macrophytes and understanding the proceses that lead to long-term changes in lake performance.

Another example is the prediction of suspended solids, which can contribute significantly to water pollution, in rivers in Yorkshire. A statistical analysis of data provided by the Environment Agency showed the importance of land-cover in controlling suspended solids and this led to the construction of a time-series model that works well in four very different catchments. This work is currently being extended to produce maps of the risk of sediment pollution in individual river reaches.

CEH scientists have a long history of expertise in fish biology. A study for the Environment Agency on the effects of the River Tees barrage on fish populations in the river has shown that after barrage closure the proportion of dace fell to 38% and those of roach and chub increased. Overall, numbers of fish have increased since the barrage was closed. It is predicted that bream, perch and pike will increase in numbers and become a significant proportion of the community, that dace will continue their slow decline and that roach will continue to increase in numbers. However, it could be at least ten years before a relatively stable fish population is seen. Such studies provide valuable information for management plans.

Commercial need can drive a breakthrough in conceptualisation and intellectual understanding. There is a growing legislative demand for higher quality standards within the water industry . Both the water companies and their regulators require predictive models that assist in evaluating the cost-effectiveness of expenditure and its prioritisation. Over a number of years CEH scientists have been developing and refining mathematical models to simulate the dynamic performances of sample organisms, such as algae, in appropriately quantified model environments. The most recent model is PROTECH-C. The increasing sophistication of these models has been client driven and has also allowed remarkable intellectual advances. The reliability of the timing, magnitude and functional composition of simulated assemblies of organisms in the model, which have been validated against natural community assemblies, is probably unsurpassed in any other branch of ecology. The model is now being used to test ecological concepts.



Real and simulated chlorophyll a levels separated by CS and R functional categories in Blelham Tarn in 1974.

Biodiversity and Population Processes

Programme 5

Through the Convention of Biological Diversity and a diverse range of European and global protocols and legislation, the UK Government is committed to the conservation and sustainable use of biodiversity. Biodiversity is essential for the functioning of ecosystems, including wild places, rivers, lakes, forests, farmed land and urban environments. Understanding biodiversity is required to build sound national and international policies for the conservation of ecosystems and the sustainable use of natural resources from local to global scales.

This Programme will improve understanding of microbiological and biological resources at a range of scales. The research recognises biodiversity as the earth's biological capital, considers the underlying processes and resulting functions, and directs knowledge to the sustainable management of biodiversity.

Scottish Crossbill.

Achievements Include:

- **Niche separation in races of Crossbill.** In Northeast Scotland studies of the foraging and residency of sympatric crossbills have shown the ecological separation of populations with different bill sizes. In Northeast Scotland, Parrot crossbills (*Loxia pytyopsittacus*) have massive bills and prise the scales of the hard, woody cones of native Scots pine to feed on their seeds. Small-billed Common crossbills (*Loxia curvirostra*) prise the papery scales of the cones of non-native spruce and larch. Britain's only endemic bird species, the Scottish crossbill (*Loxia scotica*) has an intermediate-sized bill and prises the seeds from the cones of all these conifers. However, although there are striking differences in bill morphology and feeding niches, genetic analysis does not provide evidence to support separate species status.

- **Global ubiquity of microbial species.** The biosphere supports astronomical numbers of free-living micro-organisms. One current view is that the sheer abundance of microbes drives their large-scale dispersal and makes them ubiquitous. For example, examination of 0.1 cm^2 of sediment from Priest Pot, a small pond in the Lake District of England, revealed 78% of the global number of species of one genus of heterotrophic flagellates. One possible explanation is that species that are globally abundant will, through neutral migration, 'seed' the pond more frequently than rare species. These species are abundant because they are capable of population growth in a broad range of conditions, so these species will more frequently find opportunities for population growth.

- **Predicting effects of habitat change on geese populations.** Previous models of migratory bird populations have not dealt explicitly with their year-round movements. In conjunction with colleagues at the Institute of Zoology, CEH have developed and tested two spatially explicit models of the year-round dynamics of arctic-breeding geese. These have highlighted that using existing models to predict the effects of novel situations may generate density-dependent mortality and reproductive functions, and hence predictions of population size, that are seriously in error. This new modelling approach enables the complex relationship between local habitat change and global population dynamics to be more rigorously quantified then has previously been possible.

- **Habitat creation and restoration.** Multi-site experiments on the creation and restoration of herb-rich grasslands and heathlands in lowland England have shown substantive results in five years. All sown grass species and over 70% of herb species established and persisted. Several of the sown species were present in the seed bank at the end of the experiments. Heathland vegetation has been successfully established on ex-arable land, with the cover of heather Calluna vulgaris exceeding 25% after five years. The crucial factor is pH of the soil, with pH amendment required on soils that have previously been limed.

Programme Leader's Report

The Biodiversity and Population Processes programme continues to undertake research that improves our understanding of how natural populations and communities function and interact so that they can be managed sustainably. Increasingly CEH are in dialogue with the conservation agencies, government departments and EU bodies about gaps in knowledge and ensuring that we maximise the relevance to stakeholders.

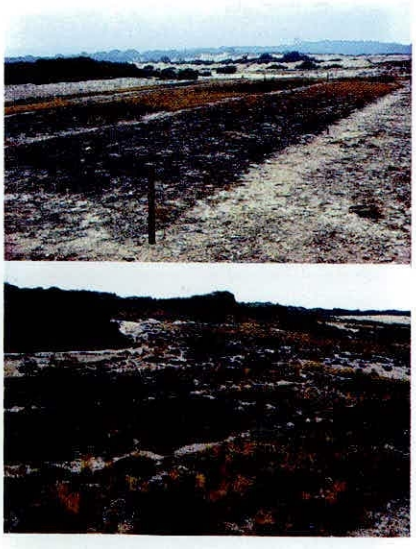
Professor Steve Albon is a population ecologist, with particular interest in mechanisms regulating abundance of animals. He is a Visiting Professor at the University of Aberdeen and is Head of ITE's Banchory Research Station.

Recent examples of work initiated to investigate how fundamental processes influence biodiversity are well illustrated by two projects, funded by the NERC Non-Thematic grant scheme, using two contrasting butterfly model systems. The first examines the ecological consequences of chemical and behavioural mimicry of ants. It specifically aims to test the hypothesis that some social parasites, for example large blue butterflies inhabiting ant nests, mimic the recognition signals not only of a single species of ant but also the signals of a local population of their host, or even closely-related colonies within an ant population. The second uses long-term datasets to link local population dynamics to changes in species distribution. In particular, the work will attempt to predict the outcome of scenarios of climate change and habitat fragmentation on future distributions.

In addition to work on factors influencing species diversity, CEH scientists have been examining factors contributing to genetic diversity within and between populations. Examples of this work have been undertaken by the joint NERC Aberdeen University Molecular Genetics Initiative, including investigations of the population structure and gene flow in red grouse (*Lagopus lagopus scoticus*) populations, as well as changing patterns of relatedness during their population cycles.

Recently CEH has organised a project for the Department of the Environment, Transport and Regions (DETR) aiming to identify the research needs arising from the proposed implementation of Biodiversity Action Plans. This will take the form of a series of themed workshops. So far these have included meetings on Biodiversity of Pastoral Systems and on Introductions, Translocations and Genetic Conservation. Others are planned for later this year. Similar initiatives dealing with research needs in biodiversity and land use research have led to bilateral discussions with both English Nature and Scottish Natural Heritage. These meetings are aimed at focusing research undertaken by both these conservation agencies and CEH.

On a broader scale CEH has contributed to the European Environment Agency (EAA) State & Outlook report on the EU's environment *Environment in the European Union at the turn of the century*. The report deals with an assessment of environmental quality and includes an examination of the threats to biodiversity and pressure from interconnected sources, principally land use change, pollution and the introduction of alien species.



Experimental plots used to assess different treatments, fertilizer additions and use of companion species in the restoration of heathland.
Top slide - start of experiment in 1991. Bottom slide - same plot summer 1999. Heathland has established in all plots; however cover and vegetation composition depends on the initial treatment.