

PEST & DISEASE CONTROL & RISK ASSESSMENT FOR GMOs

PROGRAMME 6

There is a worldwide need for more effective control agents for pests and diseases that are both sustainable and environmentally friendly.

The primary aims of Programme 6 are to assist in the provision of novel pest and disease control strategies whilst assessing any possible risk to the environment. The Programme falls into two main themes:

- ◆ pest control
- ◆ animal disease control

Molecular biology is essential to much of the work. This helps give the Programme a novel and progressive approach.



Virus infected pine beauty moth, Panolis flammea, larva. A single infected individual can contain several dozen genotypically distinct variants.



Virus infection in plants can have a variety of effects, including altering leaf colour. Experiments have been carried out to assess whether disease vectors such as aphids respond differently to different colour signals.

ACHIEVEMENTS INCLUDE:

- ◆ A model plant system has been developed which expresses chitinase derived from an insect baculovirus. This has been shown to protect the plant against infection by an economically important fungal disease (*Alternaria alternata*).
- ◆ Mixed infection studies on toxin-expressing recombinant baculovirus insecticides and unmodified wild types show possible blocking of closely related viruses and higher probability of infection by a recombinant virus.
- ◆ A method has been developed to identify oilseed rape crosses with wild relatives (turnip and cabbage) using species-specific microsatellites.
- ◆ Elucidation of the role of tick complement (a component of the immune system) in Lyme disease ecology.
- ◆ Successful development of fluorescent microscopy to enumerate viruses in aquatic environments.
- ◆ Development of molecular techniques which will not only identify live rabbits with rabbit haemorrhagic disease, but will also detect the virus in bone marrow up to 5 days after death.

PROGRAMME LEADER'S REPORT

Studies on pathogens form a major part of Programme 6. There are few long term studies which follow the dynamics and population structure of pathogens and we know little about their true diversity in the environment and their possible role in shaping communities. Pathogens, particularly viruses, are notoriously difficult to identify and to distinguish between closely related strains. However, molecular techniques now enable many of the fundamental questions concerning pathogen biology and ecology to be addressed.

Multidisciplinary and collaboration play a key role in these studies. In order to investigate disease epidemiology and host-vector-pathogen interaction, molecular techniques are combined with ecology, mathematical modelling and microbiology. Support for these initiatives has come from a variety of sources, including NERC, industry and the EU. The CEH Integrating Fund has supported several novel projects, such as the tri-trophic interaction between an insect, its host plants and a pathogen and an investigation into the prevalence of plant viruses in wild plant populations. CEH is very active in the NERC Thematic EDGE Programme. Projects include a detailed investigation of pathogen variation and its role in insect population dynamics and the investigation of the co-evolution between two plant viruses.

Programme 6 also covers the risk assessment of genetically modified organisms (GMOs), including plants, bacteria and viruses. The development of transgenic organisms is one route whereby crop losses can be reduced. However, the development of these organisms is a topical and highly contentious area. There is an urgent need to assess any potential environmental impacts that GMOs have and this risk assessment needs to be based on a sound knowledge of the biology of the organism and its interactions in the environment. CEH is ideally placed to provide such information and has been involved in the risk assessment of both genetically modified crop plants and bioinsecticides. CEH scientists have been developing the technology to identify crosses between crops and their closely related wild relatives using molecular techniques and investigating the prevalence of virus diseases in wild populations. Work of this nature is vital as it provides the background information on the environments into which novel GMOs will be released and thereby allows predictions to be tested about the potential interactions that may take place.

The determination of entire genomic sequences of bacteria and viruses that reproduce in the natural environment is now a reality. Large numbers of different micro-organisms can now be analysed simultaneously and the data will be used to understand the complex interactions between micro-organisms and their hosts. As an example, scientists at IVEM have described the population dynamics and evolution of a genus consisting of 70 tick- and mosquito- transmitted viruses. The analyses revealed significant differences in the rate and patterns of evolution of these viruses.

IVEM researches have recently used remotely sensed data to determine spread of disease. The data are beginning to reveal the mechanisms underlying the clinal evolution of tick-borne flaviviruses from east to west through the forests in northern Asia, and central and western Europe.



Dr Jenny Cory is an insect ecologist with particular interests in insect pathogen ecology, multispecies interactions, biological control and the risk assessment of genetically modified biopesticides. She is Head of the Ecology and Biocontrol Section at IVEM.

POLLUTION

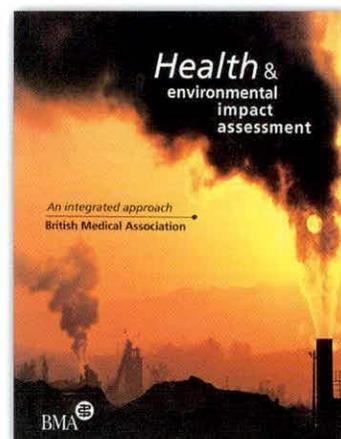
PROGRAMME 7

Pollution, and its possible impact on human health and organisms in the environment, is of concern worldwide. All countries impose regulation on chemical manufacture, use and disposal. This regulatory framework seeks to promote sustainable use of chemicals that allows the undoubted benefits without the potential harmful effects. For some chemicals the deleterious effects are well known, but the economic importance of the processes generating emissions require careful control to avoid damaging economic growth. For the many other chemicals in use, the major question is whether or not they produce adverse effects. For both known and potential chemical pollutants, regulation needs to be science-based to ensure that the priorities are correct and the recommendations for control will achieve the desired end. Increasingly, public perception of risk is a factor in how governments act on chemicals. The Programme seeks to inform government and the public on:

- ◆ ways of dealing with future accidents releasing radioactive material to the environment.
- ◆ the fate and effects of atmospheric pollutants and effective means to control release.
- ◆ risk assessment for heavy metals and other elements.
- ◆ methods of estimating exposure and effects of organic chemicals in the environment.

ACHIEVEMENTS INCLUDE:

- ◆ The transfer of radiocaesium across the sediment/water interface in Esthwaite Water has been measured and modelled. A dynamic model has been developed for radiocaesium transfer to grass from organic soils in Cumbria. Development of the first prototype dynamic model of radiocaesium behaviour which incorporates spatially variable parameter values, in collaboration with Nottingham University and other EU colleagues.
- ◆ New models of ammonia exchange with vegetation and its interaction with atmospheric aerosols have been developed. The models indicate the complexity of the exchange process showing both substantial recycling of ammonia within crop canopies and interactions with radiative forcing, through aerosol scattering. A European wide transect of ammonia exchange measurements with grasslands has been initiated under the GRAMINAE project. Some sites have already been established and these will provide data allowing surface exchange models to be developed relevant on European scales.
- ◆ Long-term experiments on the effects of ozone on beech have been completed. There were small effects on growth, but significant changes were noted in sap flow during the growing season, at exposures close to the Critical Level for ozone. A new experimental field site has been established at ITE Bangor for effects work with ozone. ICP-NWPC experiments are being conducted at 35 sites spread across 13 European countries plus the USA.
- ◆ Finalisation of work on industrial accidents and publication of a major report for DETR showing that accidents are the main source of unregulated chemical releases to the environment. CEH scientists have been investigating the environmental implications of the Doñana mine waste spill in Spain, and predicting and measuring the degree of contamination likely to impact on vegetation and birds.
- ◆ Research on the transport and fate of pesticides in the unsaturated and saturated zones of chalk has demonstrated clearly the rapid movement of pesticides from the surface to groundwater within days of application. This rapid movement is via by-pass flow routes. The conditions for macropore flow only occur where the water table is shallow.



CEH scientists have worked with the BMA looking at the potential health impacts of economic developments.

PROGRAMME LEADER'S REPORT



The Pollution Programme continues to research the fundamental science in the steps to risk assessment of chemicals and to support the main user community in regulatory agencies and departments worldwide.

Exposure to radioactive contamination needs to be considered at both an individual and a population level. The environmental behaviour of a wide range of radionuclides has been shown to be greatly influenced by ecosystem characteristics. CEH scientists have been developing dynamic models with spatially-varying input parameters to improve estimation of radiation doses. Close links have been established between predictions of contamination and variation in dietary habits. Experience from the Chernobyl accident has shown that indirect socio-economic impacts can be as important as the direct effects of radiation doses. Considerations of countermeasures therefore need to be fully integrated with socio-economic and psychological factors, particularly in the long term.

Emission of acidic oxides of sulphur and reduced and oxidised forms of nitrogen have been shown to have a profound impact on natural ecosystems. Demonstrable effects include acidification of soils and water with consequent forest die-back and loss of fish populations. Ongoing international negotiations are aimed at the continued reduction in emissions in an effort to prevent further damage and promote ecosystem recovery. CEH is contributing to the sound scientific understanding of the atmospheric transport, deposition and terrestrial and freshwater biogeochemistry of these compounds. This is necessary to underpin these negotiations.

Photochemical oxidants represent the most serious air pollution threat to vegetation health, and are also thought to be detrimental to human health. Ozone is also a radiatively active gas. Atmospheric measurements of oxidants and their precursors are necessary to validate and develop models of oxidant formation and distribution, from local to global scales. Such models can be used to advise emission control strategies, and evaluate exposure to oxidants. The Programme seeks to establish dose-response functions and measured or modelled exposures give a quantitative measure of risk.

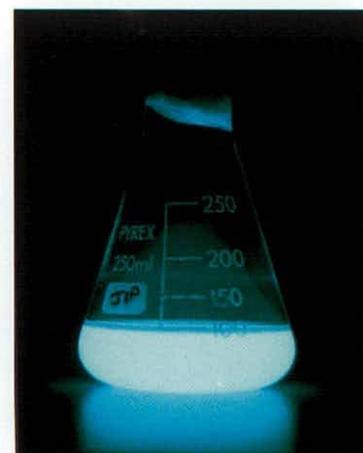
The Programme aims to bring together fundamental studies on metal speciation, fate and behaviour in the environment with measures of exposure and biological effect to inform further development of regulatory control. Physicochemical characteristics input to models provide output informing estimates of bioavailability. Effects studies are geared to extrapolation from individual to population and community effects via biomarkers of ecological significance.

Micro-organic contaminants can pose a threat to ecosystems, either through their direct action or through a variety of secondary effects. Government registration procedures involve numerous laboratory tests of degradation rates and measurements of physicochemical parameters that effect their transport in the environment, but it is only after their use that their fate, impact and effects can be assessed in detail. The information gained from our studies of organic contaminants also provides data on environmental pathways that must be considered prior to the release of new compounds.



Dr Stuart Dobson is an ecotoxicologist with particular interest in risk assessment of pesticides and industrial chemicals for terrestrial wildlife. He is based at the ITE Monks Wood Station.

The luminescence of bacteria marked with a lux gene is a rapid and simple biomarker of pollutant stress.



ENVIRONMENTAL RISKS & EXTREME EVENTS

PROGRAMME 8

The 1990s have been designated as the International Decade for Natural Disaster Reduction (IDNDR). CEH is contributing significantly to this through its programme of research into the prediction of extreme natural events such as floods and droughts. These are disasters affecting millions of people and causing billions of pounds worth of damage annually around the world. In addition, other unusual unpredictable events such as fire, strong winds and temperature extremes can often have dramatic effects on ecological communities.

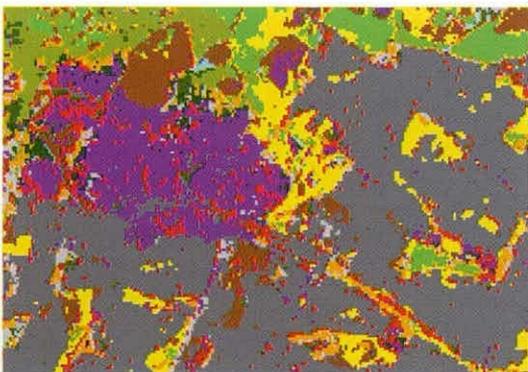
This research Programme is contributing to an understanding of how environmental extremes affect mankind and the natural environment and is developing quantitative predictive tools to describe these effects.

Easter 1998,
flooding at Evesham.



ACHIEVEMENTS INCLUDE:

- ◆ Flood frequency estimation is being explored through continuous rainfall-runoff modelling as part of a new strategic approach to the quantification of flood risk. A pilot spatial generalisation for Britain has been completed, allowing frequency estimation at ungauged locations. Extensions of the method to high recurrence interval floods has been undertaken using generated rainfall series; handling of climate change effects has also been demonstrated.
- ◆ A major review and intercomparison of rainfall-runoff models for flood forecasting is near completion. This compares eight models on nine catchments using up to ten years of data record. The results will be used to provide operational guidance on choice of the model for a wide range of catchment conditions.
- ◆ A topographic index map has been derived for the Dorset heaths, which uses the IH Digital Terrain Model to estimate potential soil moisture on a 50m grid. This has been linked to maps of the Dorset heath vegetation and will be used to predict vegetation types and the effects of drought. Satellite imagery has been used to create a map of wildfire incidence on the Dorset heaths at two points in time. This will be linked to the heath vegetation maps to allow analysis of the relation with wildfire occurrence.



A landsat image from May 1998 showing Canford Heath, in purple, and part of the Poole/Bournemouth conurbation in grey. The red areas are bare soil which may be tracks or fire breaks created as a fire prevention measure or are the result of heathland fires. By using Landsat images from previous years, the ITE's Dorset Heathland Survey and an index of soil wetness developed by IH, the type of heathland vegetation burnt and the extent of fires will be estimated.

PROGRAMME LEADER'S REPORT



Natural hazards resulting from meteorological extremes – storm, flood, drought, freeze, wind-throw and wildfire – continue to threaten our environment. Loss of human life and property and destruction of plant and animal habitats are risks we accept but can do something about. Research under this Programme aims to gain an improved understanding of extreme events and the environment's response to them. This understanding is used as a basis to develop improved modelling and risk assessment procedures as an aid to environmental hazard management.

Easter 1998 in the UK saw death and destruction from widespread flooding resulting in damage costs estimated at over £400m. This extreme event served to highlight vulnerability to flooding and the importance of better flood management in its widest sense. The Flood Estimation Handbook, produced by IH and launched in 1999, presents revised procedures for better estimating rainfall and flood extremes. This provides the authoritative "standard of practice" in the UK to be followed in design and planning of schemes affected by, or designed to mitigate, flooding. Important scientific advances include the use of new methods of pooling data from several sites to increase estimation accuracy, the use of digital terrain data to physically characterise catchments in support of flood estimation at ungauged sites, and new ways of establishing the uncertainty of storm and flood estimates.

Flood management is being treated as part of a much wider problem under a project concerned with Whole Catchment Modelling and Management. In the current year IH scientists have developed a generic design which will allow any network of models to be configured over a catchment to support a range of planning, design and operational problems. The system will allow hydrological catchment and groundwater models to be linked to hydrodynamic river models to represent water flows through a catchment in a flexible way. Beyond this, there is scope to incorporate models representing water quality, ecology and economic aspects. The model network for a catchment may be operated as a continuous simulation to derive design estimates at chosen points within a catchment. Changes in climate, land use or river cross-section can be invoked and used to investigate the impact on the frequency curve.

Progress on a CEH Integrating Fund project concerned with the impact of hydro-meteorological extremes on ecological systems has seen the publication of a new difference equation model representing how a brown trout population in different years of growth responds to drought conditions. The model provides important insights into population stability under the influence of different patterns of drought. Other work concerns topographic controls on soil moisture and the response of heathland plants and use of a one dimensional lake model to investigate wind-induced effects on the thermocline and the response of the white fish vendace.

A new partnership between the Meteorological Office and IH has led to the creation of the Joint Centre for Hydro-meteorological Research at Wallingford. It is hoped that in future years this will facilitate new research at the interface between meteorological and hydrological extremes and the feed-through to ecological responses.



Bob Moore is a hydrologist specialising in the development of mathematical modelling techniques for hydrological and water resource applications, especially flood forecasting. He is Head of the Hydrological Modelling and Forecasting Group at IH and Head of the IH/Met Office Joint Centre for Hydro-Meteorological Research.

GLOBAL CHANGE

PROGRAMME 9

Many changes are occurring globally as a result of man's activities. Some, such as losses of biodiversity, freshwater eutrophication and the emission of short-lived air pollutants, are occurring simultaneously in many places and their local or regional impacts are seen repeated around the world. Others, such as industrial activity, deforestation and desertification, occur locally but cause long-term significant changes directly or indirectly to the atmosphere or oceans, so that their effects persist and are seen globally – these global changes are the main focus of this Programme.

The Global Change Programme is increasing the accuracy of models to predict global change and its impacts. The research is focused on improving the accuracy of global change predictions by:

- ◆ improving our knowledge of greenhouse gas budgets and land–atmosphere interactions, and
- ◆ forecasting global change impacts on species, ecosystems and water resources.

The Meteorological Office Hercules aircraft, used to measure greenhouse gas fluxes over the whole UK.



ACHIEVEMENTS INCLUDE:

- ◆ Four round-Britain flights using the Hercules aircraft have enabled national scale emissions of methane and nitrous oxide to be measured in a range of conditions. In general, the aircraft estimates are in agreement with inventory estimates and confirm that the major sources of methane are areas of intensive livestock production and landfills.
- ◆ The first comprehensive budget of terrestrial carbon sources and sinks has been completed for the UK. The UK land surface is currently a net carbon source, but this will diminish over the next decade. The UK 'Kyoto forests' are predicted to offset 2.5% of the UK commitment to reduce annual emissions by 2008-2012 to 12.5% below 1990 levels.
- ◆ Estimates of the effect of land degradation/deforestation on rainfall in the Sahel have been made using two General Circulation Models. Similar spatial patterns of decrease in rainfall are predicted to those observed, with different land surface schemes.
- ◆ Seasonal weather forecasting for the Sahel, so vital for human well-being, has been improved by making the surface description more realistic so that models simulate long-lived travelling storms, lasting 4 days (the African Easterly Wave) as well as daily storms. This is a major improvement in Meteorological Office models.
- ◆ A framework has been devised for the phytogeographical analysis of the flora of the UK which provides a valuable tool to assess the impacts of climate change on natural vegetation

PROGRAMME LEADER'S REPORT



The 1990s decade has been the warmest in the 340-year record of monthly temperatures in central England. Also, 1997/98 and 1998/99 were the mildest two consecutive winters in central England, with only one day with a mean temperature below 0 °C.

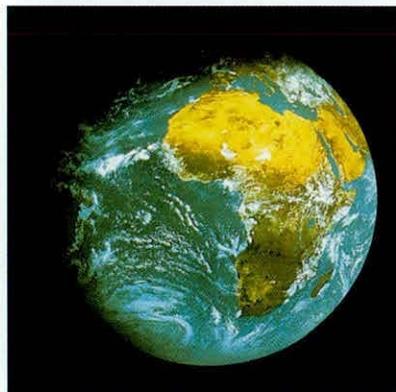
A report produced for DETR by CEH and the University of East Anglia of 34 possible indicators of future climate change revealed distinct recent trends. Winters in Scotland are getting wetter, with a stronger westerly airflow over Britain in winter, while summers in southeast England are getting drier. There are more outdoor fires and more cases of Lyme's disease, more water is used for irrigation, and there is earlier spring emergence of tree leaves and insects and earlier spring breeding behaviour of birds.

Internationally, the main activities of significance to CEH are two reports currently being prepared by the Intergovernmental Panel on Climate Change: the Third Assessment Report (TAR), which will update the predictions of climate change and their impacts, and the Special Report on Land Use, Land-use Change and Forestry (SR-LUCF). This second report will examine the scientific and technical implications of terrestrial carbon sequestration strategies. It will provide support to the Subsidiary Body for Scientific and Technological Advice on how to 'operationalize' Article 3.3 of the Kyoto Protocol, which allows parties to include restricted forest sinks. CEH staff are involved in the preparation of both reports. They will be significant in setting the scientific agenda in the new millennium.

One new development in CEH has been to take an Earth System approach, developing models of intermediate complexity to rapidly test the importance of new scalar quantities and internal feedbacks that are currently unrepresented in General Circulation Models. Significant gains have also been made in quantifying the sources and sinks of greenhouse gases in the UK. At the global level, we are developing hydrological models which incorporate realistic descriptions of the water balance, runoff, groundwater and soil moisture at a complexity and scale appropriate to numerical climate and forecast models.



Professor Melvin Cannell is a forest ecologist, with particular interests in global change and the carbon cycle. He is an honorary professor at the University of Edinburgh and is Head of ITE's Edinburgh Research Station.

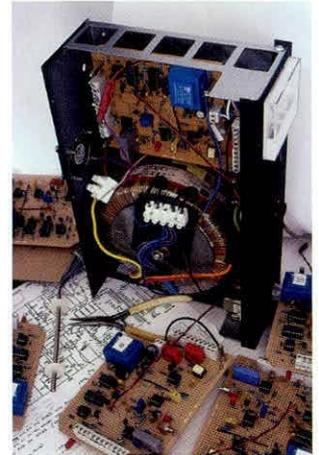


The earth from space.

INTEGRATING GENERIC SCIENCE

PROGRAMME 10

This Programme has been designed to provide a research framework for those areas of CEH science that underpin the nine other Programmes. These activities are cross-cutting, often dealing with new and innovative technology. The fundamental work undertaken on environmental monitoring and data management falls into this Programme, as well as development of new methods for interpreting and manipulating complex data. Development of new instruments and sensors, essential for progress in environmental sciences, is a well-established CEH activity and forms part of this Programme. Programme 10 undertakes research in its own right, as well as providing data and technological support to the other CEH Science Programmes.



Construction of electronic heat controllers. A novel use of thermocouple compensating cable as soil surface heating cable, allowed safe low-voltage operation and predictive control via five specially designed control modules.

ACHIEVEMENTS INCLUDE:

- ◆ The work of the Biological Records Centre (BRC) is being developed as a major part of NERC's contribution to the National Biodiversity Network, in particular to provide access to over 8 million records of plants and animals in the UK.
- ◆ Work under the NERC SEEDCORN Programme on the Stewardship and Exploitation of Environmental Data has catalogued over 600 data sets in ITE and IFE. Projects include the establishment of a linked database/ GIS system to investigate long-term changes in polychlorinated biphenyl residues (PCBs) in predatory birds and the creation of a central database to secure and improve access to four key freshwater data sets.
- ◆ A matrix of 24 grassland soil warming plots has been designed, constructed and installed as part of a contract for the University of York. These maintain grass roots at ambient or 3°C above ambient temperature regardless of shading regimes to enable the relation between root growth, temperature and light intensity to be investigated (ITE Merlewood).
- ◆ The first stage of development of an instrument to measure atmospheric flux of carbon dioxide and water vapour simultaneously, using an open path eddy correlation method, has been completed successfully by integration of a custom-built infra-red hygrometer with a commercial 3-D sonic anemometer (IH Wallingford).
- ◆ A system to enable phytoplankton and macrophyte growth studies has been developed under a Framework IV project. The apparatus consists of ten Perspex chambers which can be immersed in a natural lake. The chambers can be flushed with lake water, with the option of adding a specific treatment to each chamber and the temperature, pH and dissolved oxygen concentration in each chamber can be monitored automatically (IFE Windermere).
- ◆ Scientists at IVEM have detected altered conformations of prion protein dependent upon copper, which may be used for detection of prions in the environment.
- ◆ IVEM scientists are considering a new method of vaccine development, using cell surface expression of heterogeneous viral envelope proteins.
- ◆ The production of a book 'Statistics in Ecotoxicology', edited by Tim Sparks (ITE), with chapters contributed by staff on Biometrical Applications, Research and Development.

PROGRAMME LEADER'S REPORT



This large Programme consists of a number of discrete Themes. This short report describes some of the activities over the past year and some notable achievements within the separate Themes.

Biotechnology Development. CEH scientists are seeking to apply molecular methodologies to current issues of environmental concern and also to develop new technology for application in the future. Researchers at IVM have developed a recombinant baculovirus that produces foreign proteins on the surface of the infected cell where they can be identified by fluorescent antibodies. The technology is being developed for the simultaneous expression of thousands of proteins at once so that cells with novel functions can be identified.

Development of biosensors (BIOMATE): following the detailed study of the microbial diversity of polluted environments and biotreatment plants, component bacteria have been identified with predictable metabolic responsive ranges to known toxicants. A range of biosensors has been constructed, using selected isolates that have been genetically modified to carry a novel bioluminescent operon. IVM scientists are currently evaluating the ability of these biosensors to monitor effluent toxicity and bioreactor performance at a number of industrial locations.

Remote sensing. CEH has a strong reputation for the development of underpinning research concepts and for their application to practical problems in the environmental sciences. CEH has recently developed a strategy for remote sensing research, which is founded upon three linked objectives:

- ◆ Understanding and modelling radiation interactions
- ◆ Integration of remote sensing into hydrological and ecosystem models
- ◆ Dissemination of data and results

Biometrical applications, research and development. Currently there is much concern over the spread of genes from genetically modified commercial crops (e.g. oil seed rape and other *Brassic*as) to their wild plant relatives. CEH statisticians have devised a new way to analyse data in the study of gene flow between wild plant populations. Under particular assumptions of demography, genetics and dispersal, gene flow between wild populations can be estimated from the spatial variability in their genetic composition. This new approach provides more reliable confidence intervals for the fitted line and critical distance. The method has been applied to populations of wild cabbage and sea beet in Dorset.



Professor John Hilton is a freshwater chemist with particular interests in radioecology, eutrophication and environmental management. He is a visiting Professor at the University of Reading and is Head of IFE's East Stoke, River Laboratory.

Lay-out of soil-warming experiment at York University.



