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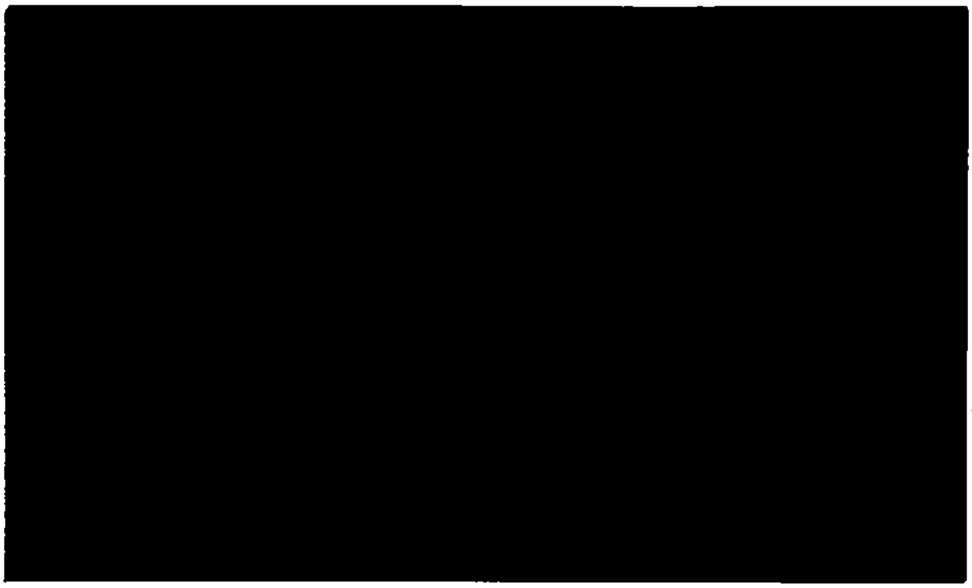

ITE undertakes specialist ecological research on subjects ranging from micro-organisms to trees and mammals, from coastal habitats to uplands, from derelict land to air pollution. An understanding of the ecology of different species and of natural and man-made communities plays an increasingly important role in areas such as:

- monitoring ecological aspects of agriculture
- improving productivity in forestry
- controlling pests
- managing and conserving wildlife
- assessing the causes and effects of pollution
- rehabilitating disturbed sites

The staff can offer objective, impartial, advice on a wide range of topics, and can assess the impact of different land use options. ITE's applied and basic research contributes to the efficient use of the natural environment and provides information on which to base predictions of future trends.

INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

DOE/NERC CONTRACT PECD7/12/67
ITE PROJECT T07069
3rd Interim report to the Department of the Environment

THE DEPARTMENT OF THE ENVIRONMENT CORE MODEL PROJECT: THE IMPACTS OF CLIMATE CHANGE ON NATURAL AND SEMI-NATURAL ECOSYSTEMS

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EXECUTIVE SUMMARY

1 This report summarises the third year's work of the DOE Core model project on the impacts of climate change on natural and semi-natural ecosystems. The DOE, Core Model programme also includes major projects with the Institute of Hydrology and Climatic Research Unit which are the subject of separate reports.

2 The aim of the core model programme is to provide a demonstration project describing the process of model building and providing illustrative core models for the prediction of climate change effects on:

(a) the distribution of vegetation, communities and individual species (equilibrium models);

(b) population changes to species (dynamic models);

(c) land-use interactions and economic considerations.

3 The emphasis of work done during 1993 has been to draw together the core-model components into a more integrated whole. The development of the GIS 'Core Model Demonstrator' at Monks Wood has provided a focus for this integration but there has also been some restructuring of the programme components and a more rigorous specification of outputs from the component sub-projects to ensure that models and databases can be cross-linked. The Core Model Demonstrator links together datasets and models developed in the Core Model programme within an Arc/Info GIS environment, to allow an interactive exploration of climate change impacts.

4 The first three sections of the report review the background and objectives of the Core Model programme and present a conceptual framework (Figure 1) linking together the main components of the work: species, habitats, land use and climate. This framework forms the basis for the subsequent development of the Core Model Demonstrator as a step towards the overall project objective of a "complete demonstration of the operational predictive capability in the form of integrated databases and models". To achieve this, the work has and will continue to address key issues relating to the compatibility of data sources, the integration of data with models, the development of spatial models within a GIS environment, and the use of models and data within a GIS as a decision support system and for further climate impacts research.

5 In section 4 progress towards this objective and remaining work to be done in the fourth and final year of the programme is reviewed by reference to contributions from the main sub-projects. These contributions are from: ITE(S) - GIS Section; ITE(S) - Monks Wood; ITE(S) - Biological Records Centre; ITE(N) - Merlewood;

Durham University - ERC; NERC - Unit of Comparative Plant Ecology(UCPE); Oxford - Environmental Change Unit (ECU); and soils data from Soil Survey and Land Research Centre (SSLRC).

6 Database development; has centred on the securement of data for species, habitats, land use and climate at GB and European levels to compatible standards and formats.

(i) Species distribution data - Durham University have provided 128 European species distributions. Data on a complementary suite of British species from BRC will be available in February.

(ii) Habitat distribution data are now available on the basis of soils (SSLRC) and land cover (ITE) and procedures to obtain additional information from Countryside Survey 1990 and BRC are in progress.

(iii) Land use data have been made available from the MAFF agricultural census data, using a technique developed by ITE GIS;

(iv) Climate data from a variety of sources have been used throughout the Core Model (including MORECS, IIASA and bioclimatic data) but the impacts community should soon be able to standardise on GB and European data from CRU. Baseline data for GB and Europe are already available and climate change scenarios will be available in March.

7 The development of models has focused on:

(i) Climate envelopes, - using species distribution data to compare different methods of relating species distribution to climate (ITE, Biometrics) with the aim of providing methods that can be used interactively within the Core Model Demonstrator;

(ii) Models of species dispersal developed at ITE, Monks Wood for a few species will be generalised in the final year and incorporated into the Demonstrator to allow an assessment of the sensitivity of species migration following climate change in relation to variations in factors such as dispersal rates and habitat availability.

(iii) Habitat/vegetation modelling - work at UCPE based on plant species strategy is now complete and is now being linked directly to the Core Model where it will be applied to species and habitat data available from 6(i) and 6(ii) to predict changes in vegetation structure across GB.

(iv) Land use change modelling at ECU has examined the effects of climate on crop potential on GB and European scales and these models will now be interlinked with the other work through the Core Model Demonstrator.

7 Development of the Core Model Demonstrator is currently being undertaken within the GIS Section at Monks Wood. The basis for the development of the Demonstrator

has been the formulation of the conceptual framework linking the key data and model requirements for climate change impacts on semi-natural species and communities. The Demonstrator will contain a hierarchy of interlinked datasets and models to predict the impacts of climate changes on natural resources, particularly water and semi-natural flora and fauna. The system has been designed primarily to meet DOE's requirements for regional scale predictions in Great Britain and Europe. The Demonstrator is based on Arc/Info GIS making it compatible with the system being used at the Institute of Hydrology. The menu structure for the demonstrator has now been developed and work is beginning on installing data-sets and models into the system. When complete, the Demonstrator will be used to illustrate applications to applied problems, and for climate change sensitivity analyses of the kind that may be useful for detecting 'critical loads' for climate change.

8 Dissemination of results. The report also introduces plans for the dissemination of results from the Core Model programme in the form of a publication of key results at a final seminar to be held in December 1994. The broad aim of the seminar will be to present some basic tools for climate change research and to provide a stimulus for further research in this field. The seminar is being designed primarily for members of the climate change impacts and modelling community within the UK and, in addition to research scientists, a range of users in policy fields will be invited.

1. BACKGROUND

The DOE Core Model Project is now starting the last year of a four year programme of research. In this report, the last of three interim reports, we will briefly review progress towards the project objectives relating to the ITE component of the Core Model programme. It will put particular emphasis on work done during 1993, and identify the remaining tasks which need to be completed in 1994 to bring the project to a successful conclusion. Other parts of the Core Model programme, being undertaken by the Institute of Hydrology and the Climatic Research Unit at the University of East Anglia, are reported separately. Links with these groups, however, have been maintained and these are referred to in this report.

1.1 Aim of the Core Model Programme

The aim of the ITE contribution to DOE's Core Model programme is to provide a demonstration project describing the process of model building and providing illustrative core models for the prediction of climate change effects on:

(a) the distribution of vegetation, communities and individual species (equilibrium models);
(b) population changes to species (dynamic models);
(c) land-use interactions and economic considerations.

The investigation of climate change effects on semi-natural species and communities is a complex multi-disciplinary activity. The Core Model programme is designed to bring together these disciplines within a structured framework. The main contributors within this framework are:

(a) ITE(S): GIS Section - land use data, data mangement and GIS development;
(b) ITE(S), Monks Wood - climate envelopes, population models;
(c) ITE(S): Biological Records Centre - GB species and biotope distribution data;
(d) ITE (N),Merlewood - land use, species/habitat distributions;
(e) Durham University ERC - European plant species distribution;
(f) NERC, Unit of Comparative Plant Ecology (UCPE) - vegetation change

models;

(g) Environmental Change Unit (ECU), Oxford - land use/agricultural change;

(h) Soil Survey and Land Research Centre (SSLRC) - soils data;

Inputs from other parts of the DOE, Core Model Programme are:

(i) Institute of Hydrology - hydrological data and models;

(j) Climatic Research Unit - climate baseline data and change scenarios.

Over the past year, we have moved towards closer integration between these components by means of:

i) the development of a conceptual framework which encompasses the Core Model components;

ii) the development of a Core Model GIS/Demonstrator to provide a direct link between the models and datasets developed within the programme;

iii) meetings to ensure that all parties can work comfortably within the framework and produce outputs (data and models) which can be used directly within the Core Model Demonstrator.

1.2 Development of a GIS demonstrator

A major practical aim of the Core Model project is to achieve a "complete demonstration of the operational predictive capability in the form of integrated databases and models". To do this we aim to link all the Core Model components into a single, integrated, GIS demonstrator. In so doing we will address issues relating to the compatibility of data sources, the integration of data with models, the development of spatial models within a GIS environment, and the use of models and data within a GIS as a decision support system and for further climate impacts research. The demonstrator will provide the means by which interactions can be explored, complex questions addressed and spatial, mapped outputs produced.

A decision has been made to base this demonstrator on Arc/Info GIS. Steps were taken during 1993 to ensure that outputs from sub-projects could be used within this demonstrator.

1.3 Aims of this report

The aims of this report are:

- to describe a conceptual framework for the Core Model activities;
- to use this framework as the basis of a Core Model /GIS demonstrator and to illustrate how individual sub-projects will be linked within this;
- to summarise progress towards specific objectives relating to this framework;
- to summarise work to be completed in 1994, the final year of the project;
- to make proposals for the dissemination of results at a seminar to be held in December 1994.

In contrast to the first two interim reports, this one is not a sequential compilation of sub-project reports. This report is structured around the conceptual framework presented in section 2, and sub-project contributions have been split accordingly. This has helped to highlight overlaps and develop links between sub-projects. The report is limited to 50 pages and is not intended to give a detailed description of the work done or results. These can be found in previous annual reports, sub-contract reports and published papers - a list of which is given in the bibliography.

2. CORE MODEL: CONCEPTUAL FRAMEWORK

In this report we present a revised framework which covers the ITE contribution to the Core model programme. This framework will serve as both the conceptual structure linking together the various activities within the Core Model programme and as a structural framework for the Core Model GIS demonstrator.

Figure 1 shows a framework for the ITE component of the DOE/NERC core model programme on climate change impacts. The framework represents a system in which the three main elements are species, habitats and land use. Data on the current spatial distribution of these elements (at GB and European scales) are combined with current baseline climate data to provide models describing the current distribution of these elements. These models can then be used with data from climate change scenarios to predict potential distributions in the future. These potential distributions will be constrained by factors other than climate such as habitat availability, species biology and socio-economic constraints on land use. There are many possible constraints and the interactions between them are likely to be complex, but within this framework the most relevant links are through the effects of changes in land use on habitat distributions (not vice versa), and through the effects of changes in habitat distribution on species distribution (but not vice versa). The main abiotic factors driving the system are climatic, but soils and hydrological inputs are also important.

The key aim of the work encompassed by the framework is to provide a methodological framework which links data and models to predict effects of climate change on natural and semi-natural communities.

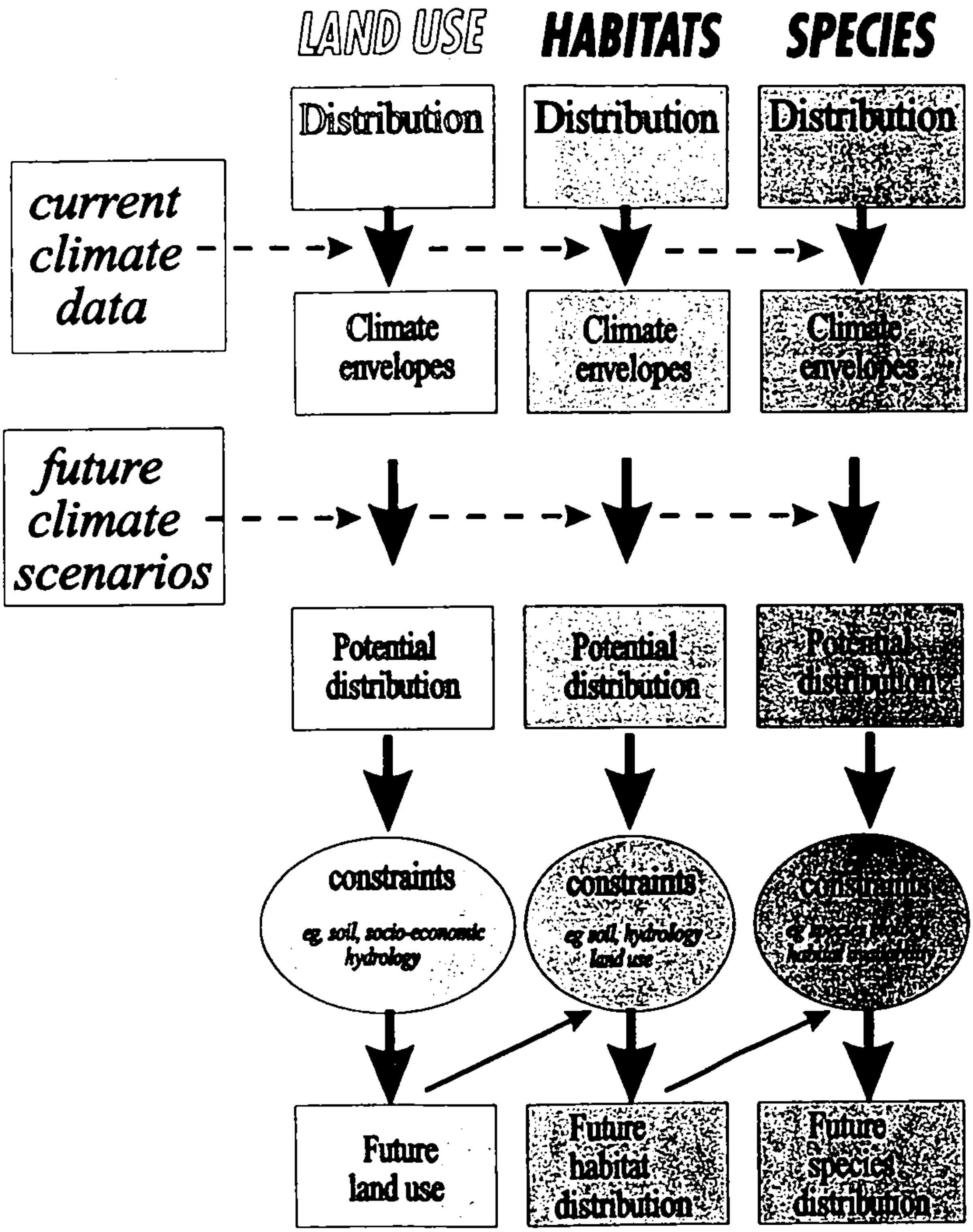
The inputs to the process are spatial data sets describing the current, baseline distribution of species, habitats, land use and climate. These are discussed in more depth in sections 3.1 and 4.1.

Within the framework, the main elements are linked by relationships and models from which current and future distributions of species, habitats and land use can be predicted in relation to climate and other constraints (sections 3.2, 4.2). These constraints will include hydrological factors, with information being provided by projects within the Institute of Hydrology's contribution to the Core Model programme.

These components will be brought together in a GIS demonstrator (sections 3.3, 4.3).

The outputs from the models and demonstrator will be spatial data sets describing the distribution of species, habitats and land use. The function of the system is to provide a method which can be used to predict climate change impacts on natural and semi-natural species and habitats. The demonstrator will not be capable of addressing all questions of interest relating to climate change impacts, but it should provide a framework which can be readily adapted to meet a wide range of user requirements. A few examples of some specific issues which the demonstrator might be used to address are given in section 4.5.

Figure 1. Conceptual framework for the ITE component of the DOE Core Model Programme. Data and information are represented by the blocks and models by the arrows.



3. SUMMARY OBJECTIVES

The objectives of the Core Model project have been restructured (but not changed) to fit into this framework. They are summarised below:

3.1 Database Development

Objective 1: to construct an integrated geographic database covering a range of relevant environmental variables. This database will include data on biota and land use, and data obtained by remote sensing.

The database has four main components:

(i) species distribution data;
(ii) habitat distribution data;
(iii) land use distribution data;
(iv) climate data.

3.2 Model Development

Objective 2: To set up models which demonstrate the relationship of species to climate, physiography, soil and land use and to use the models, in conjunction with a range of climate change scenarios, to produce predictions of future vegetation cover.

Modelling activities have been divided into 4 parts:

(i) climate envelopes and correlative models;
(ii) species distribution modelling including dynamic models of species dispersal by linking invasion and habitat density models - the models will incorporate realistic assumptions about species biology including the processes of dispersal, establishment and loss of local populations;
(iii) habitat distribution modelling - to predict the future distribution of habitats as an input to the dispersal models developed in (ii);
(iv) land use modelling - to set up environmental models which predict land cover changes in response to varying commodity prices. To predict the indirect ecological impacts of agricultural change.

3.3 Integration of data and models - the Core Model/GIS Demonstrator

Objective 3: Spatially referenced data used in the project will be integrated within a geographic information system (GIS). This will be fully structured, showing direct links to the associated non-geographical data. The GIS demonstrator will be aimed at national models which are able to respond to different climatic scenarios. Models will be tested against available data, making use of equivalent climates where possible and GIS/model links will be developed to model GIS data and produce mapped model output. A complete demonstration project will be developed by the end of the research period The demonstrator should fulfill 4 functions:

(i) it should enable the display and analysis of the various biological and non-biological spatial data sets being used and establish a methodology for comparing and integrating these data at different spatial scales;

(ii) it should enable users to explore and relate the links between its various components and facilitate the answering of complex multi-disciplinary questions on climate change impacts;

(iii) it should provide links between the databases and models and include facilities for producing hard-copy maps from model outputs;

(iv) it should establish the methodology for linking and integrating models/databases with other parts of the core modelling programme (i.e. Institute of Hydrology, Hadley Centre).

3.4 Testing and Validation

Objective 4: The Core Model Demonstrator will be used to assess the sensitivity of the model outputs to variations in both climatic and also biological variables such as long distance dispersal.

3.5 Applications

Objective 5: Illustrate potential applications of the Core Model Demonstrator by reference to some real world questions. The final choice of examples will need to be agreed between DOE and Core Model contributors.

3.6 Projects outputs and dissemination

Objective 6: the following outputs will be provided for DOE:

(i) A computer demonstration system which brings together the data and models developed within the Core Model programme. GIS/display software will be used to show model results and to illustrate the current and future distributions of a selected number of species in Britain and Europe.

(ii) A complete demonstration package and supporting documentation will be prepared for a national conference (now planned for December 1994) aimed at presenting the results of the Core Model Project.

(iii) A PC based demonstrator package for use by the department which incorporates elements from all parts of the the projects.

(iv) In parallel with the computer based demonstrator, documentation of illustrative results from the Core Model programme will be prepared. The document will make use of material from the demonstrator and will be made publicly available. It will be aimed at the scientific community, government and the educated layman and will be disseminated widely by DOE.

4. PROGRESS TOWARDS OBJECTIVES

This section reviews progress towards the project objectives. *Text highlighted in italics indicates work which will be completed in 1994.*

4.1 DATABASE DEVELOPMENT

Data on the current distribution of species, habitats and land use are required for describing current distributions in climate space and modelling the impacts of climate change scenarios. A range of data sets have been collected together under the core model programme and procedures have been developed to ensure that the data are available in compatible forms.

4.1.1 Species Distribution Data

The Core Model Demonstrator will contain distribution data for a cross section of species with different types of distribution in Europe and Great Britain. Data will be available from three main sources:

i) European data for about 100 plant species, derived from the Atlas Flora Europaeae (AFE) (presence/absence on UTM grid). Data provided by Brian Huntley (Durham);

ii) GB data for a range of plant and animal species. Presence/absence data in 10*10 km squares provided by the ITE, Biological Records Centre;

iii) GB estimates of the abundance of common plant species within 1 km squares derived using information from ITE land cover map and the DOE/NERC Countryside 1990 field survey.

<u>European Species Distribution Data</u>

The Core Model sub-contract with Dr Huntley at Durham University is now complete. A full description of the work done to derive species distribution data for Europe, some uses of these in developing climate space models, and the relationship between this work and complementary work in the TIGER Programme is presented in a summary report (Huntley & Ascroft 1993).

In summary, the *Atlas Florae Europaeae* (AFE) grid basemap has been further refined and is now in version 14. This version has now been supplied to ITE(S) and to collaborators in Helsinki who are working to automate data capture from the originals of the AFE maps held there. 105 AFE distributions captured, using a scanning method, by our collaborators in Helsinki have been received and checked for errors (Annex A). The list is heavily biased towards tree species because of data availability. In addition, menu-driven software for the manual capture of AFE distributions has been used to capture 23 distributions. A parallel version for capturing data from distribution maps from other sources manually transcribed onto the AFE grid has been developed and used to capture over 30 further distributions.

A total of 128 European species distribution maps have been forwarded to ITE Monks Wood and have been incorporated in the Core Model demonstrator. Distribution data on four additional species (Lizard Orchid, Bee Orchid, Sweet Chestnut and Agrostis curtisii) have been supplied from other sources.

Great Britain - BRC Data

The Biological Records Centre's (BRC) original function was to record and map the distribution of plant and animal species in Britain. It now encompasses a wide range of species-related data, covering aspects of ecology and biotope (habitat) preferences of species, as well as their distribution in space and time. BRC's computer database contains over 6 million records of some 10,000 species, and currently forms a focus for a wide-ranging research programme on such themes as biodiversity hotspots, patterns of rarity, the effects of land-use and climate change. As the BRC species distribution data are one of the key building blocks for predicting climate changes impacts in GB, data for a range of species will be provided within the Core Model Demonstrator.

The Biological Records Centre will provide distribution maps, in digital form for incorporation in the Core Model demonstrator, including 150 species covering the following types:

- *plant species for which AFE data are already available (ie 68 of the Annex A species for which GB data are available);*
- *10 vascular plants characteristic of each of 4 major biotopes (heath and moorland, lowland dry heath, calcareous grassland, and a wetland category);*
- *representative plant species covering the following categories:*

- *abundance status (eg Red data book, scarce, common);*
- *changing status (expanding - static - declining);*
- *different types of biogeographic distribution eg montane, Atlantic, Mediterranean;*
- *other distribution patterns eg reflecting responses to pollution or land use;*

- *a selection of about 50 species from better-recorded animal groups e.g. mammals, butterflies, dragonflies and molluscs.*

In addition, BRC will provide some examples of derived variables eg of species richness data for some biotopes which will summarise data from a wide range of taxonomic groups, perhaps 2-300 species in some cases.

For each taxonomic group included in the list, a brief assessment of the pattern of recorder effort, and significant gaps in coverage, will be provided. For the whole species list, an explanation of its representativeness and of the selection criteria will be provided.

Distribution data for common plant species in Great Britain

ITE (Merlewood) will develop techniques for estimating the distribution and abundance of some common plant species within 1 km squares, by combining information from the ITE land cover map and Countryside 1990 field survey. The final choice of species has not yet been made but it will aim to overlap and complement those provided by BRC and to provide a representative selection of species from the major habitat types in GB. Distribution data will be provided separately for linear features (hedgerows, waterside and roadside verges) and open landscape habitats (eg fields, woodlands and moorland).

4.1.2 Habitat Distribution Data

Species distributions are controlled by climate requirements and the availability of suitable habitats. Data on the current and future (modelled) distributions of habitat are required within the core model demonstrator to investigate the effects of habitat availability on the potential distribution of species.

Data on the current distribution of habitats will be derived from 4 sources:

(i) Soils data from SSLRC;
(ii) Land Cover data from the ITE Land Cover Map;
(iii) Use of the Countryside Survey 1990 field data and the ITE Land Classification to predict habitat distributions within GB;
(v) BRC will present examples showing the use of the Biotopes Occupancy Database and BRC records to map biotope distribution at the 10 km scale.

Soils data 1 km square soils data from SSLRC showing dominant and sub-dominant soil types are available for use within the Core model project. Where species are confined to particular soil types this data set provide an indication of potential habitat distributions.

Land Cover Data

Land cover maps can be used to provide an indication of the distribution of many habitat types eg woodlands, heathlands. An example, showing the distribution of deciduous woodland in GB is shown in Figure 2.

Estimates of land cover in all 1 km squares of GB have been derived from the ITE Land Cover map of Britain. This is based upon Landsat remote sensed imagery at 25 metre pixel resolution, and provides information on the presence of 25 different land cover types. These data have been aggregated to provide summary data, for each 1 km square of GB. Both the full resolution and 1 km data have been used in the Core Model project, although only the 1 km data set will be used within the demonstrator.

Countryside Survey Field Data

ITE are developing methods of predicting the probability of finding a particular habitat or vegetation type within each 1 km square of GB as a method of generating habitat distribution maps for Great Britain at a 1 km scale. The approach will involve the integration of field results from Countryside Survey 1990 with the ITE Land Cover Map and is only likely to be appropriate for the more common habitat types.

Field survey data will also be used to estimate the species composition of these *habitats, making use of ITE Land Class, soils, and climate data to provide regional breakdowns wherever this is possible and appropriate. This information will be used in the vegetation/habitat change modelling being done at UCPE (Section 4.2.3).*

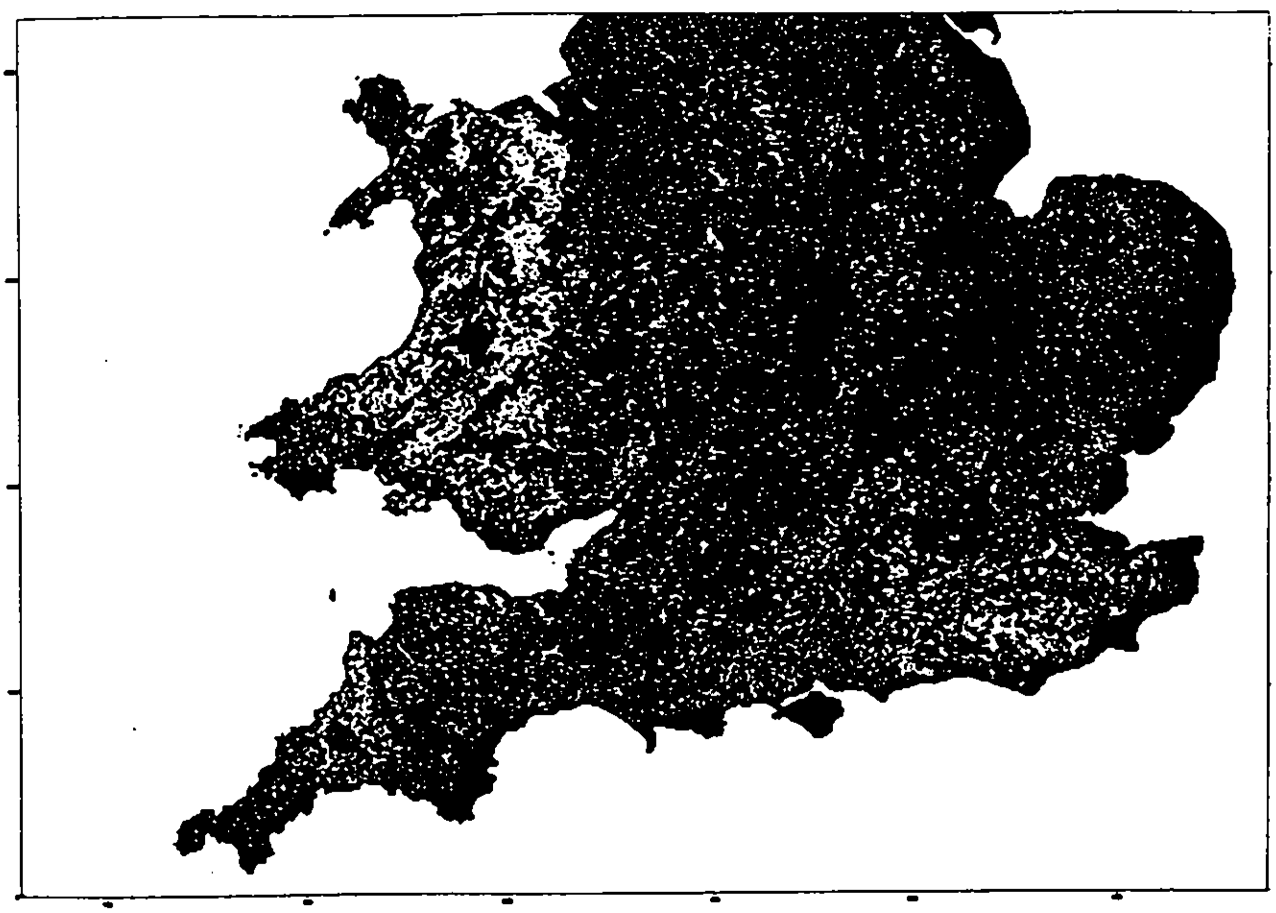


Figure 2. Distribution of deciduous woodland in southern Britain from the ITE Land Cover map (high density of woodlands shown as lighter greys). Data such as these can be refined in combination with Countryside Survey 1990 field data to show areas of existing habitat for specified species. They can also be combined with vegetation change models or soils data to show the distribution of available habitat for woodland species after climate change.

Biotopes data

The Biological Records Centre are developing techniques for mapping habitat distributions within Great Britain, using species distribution records in combination with the Biotopes Occupancy Database (BOD). In this method species, or combinations of species, which are known to be characteristic of particular biotopes (habitats) are used as indicators of biotope distribution.

The Biotope Occupancy Database has been built up from an extensive literature search, and after consultation with a wide range of specialists (Eversham et al. 1993),. All the major biotopes (habitats and land-management classes) within which each species has regularly been reported are coded, using the European standard system developed by ITE - the CORINE Biotopes Classification (Commission of the European Communities 1991). During 1993, data for vascular plants have been enhanced both from taxonomic literature and from the National Vegetation Classification.

The CORINE system of biotope coding is hierarchical, so it is possible to specify the biotopes of a species to varying degrees of precision. In general, the scarcer the species, the more precisely it has been possible to delimit its biotope occupancy.

One can depict the national distribution of a biotope by mapping the species-richness of an assemblage of species characteristic of that biotope. The pattern not only shows where a biotope occurs, but gives an indication of the biotope-specific biodiversity in each area. It is also possible to compare biodiversity for a range of different plant and animal groups (Prendergast et al. 1993). The maps in Figure 3 shows the distribution of fenland and water-margin plant species, using this technique. By comparing data before and since 1960, the change in biotope distribution over time may be shown. In this example, the change is due mainly to agricultural intensification and drainage; however, sensitivity to previous land use change is likely to reflect sensitivity to future climate-induced changes, both direct and mediated by land use.

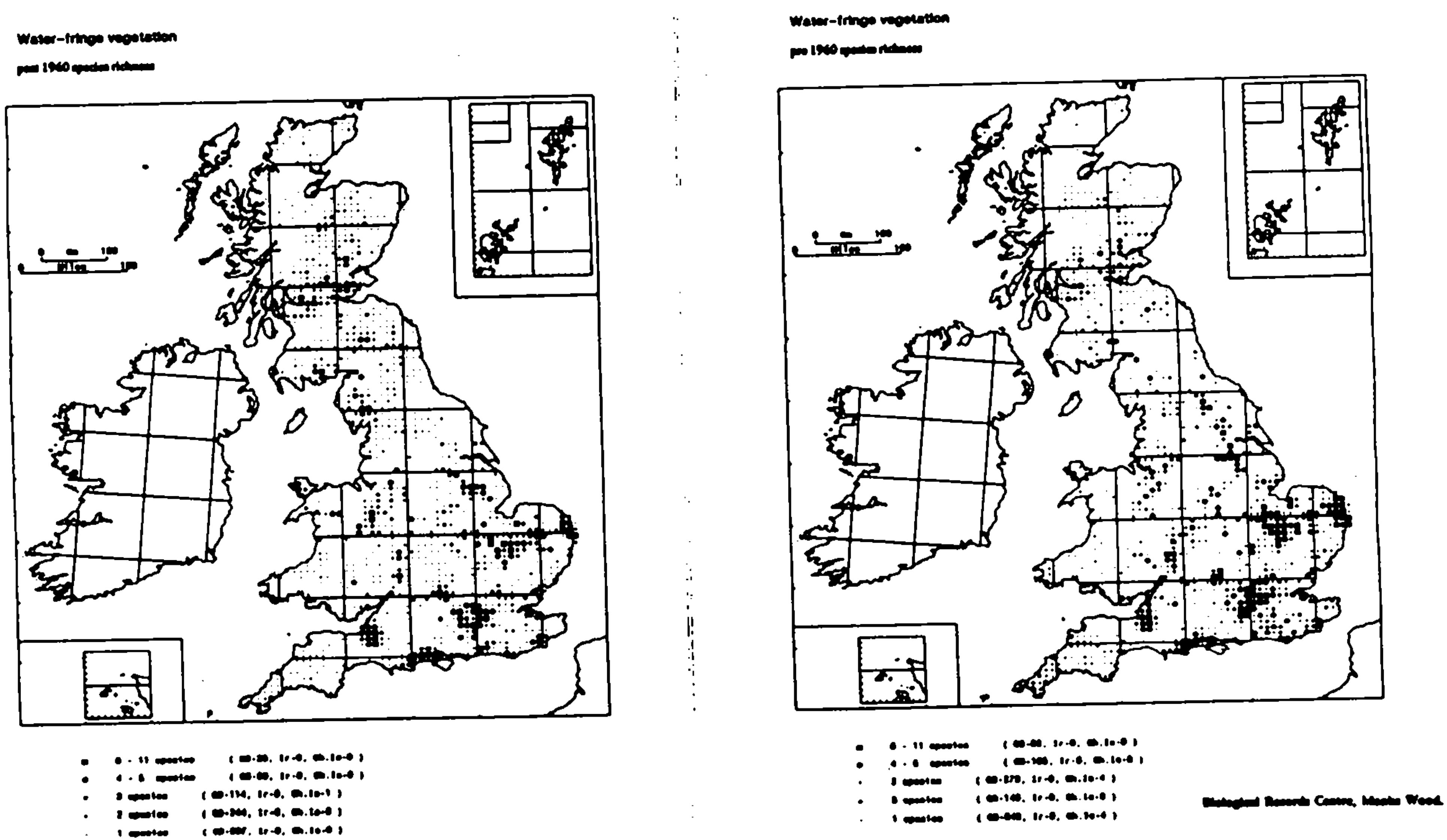
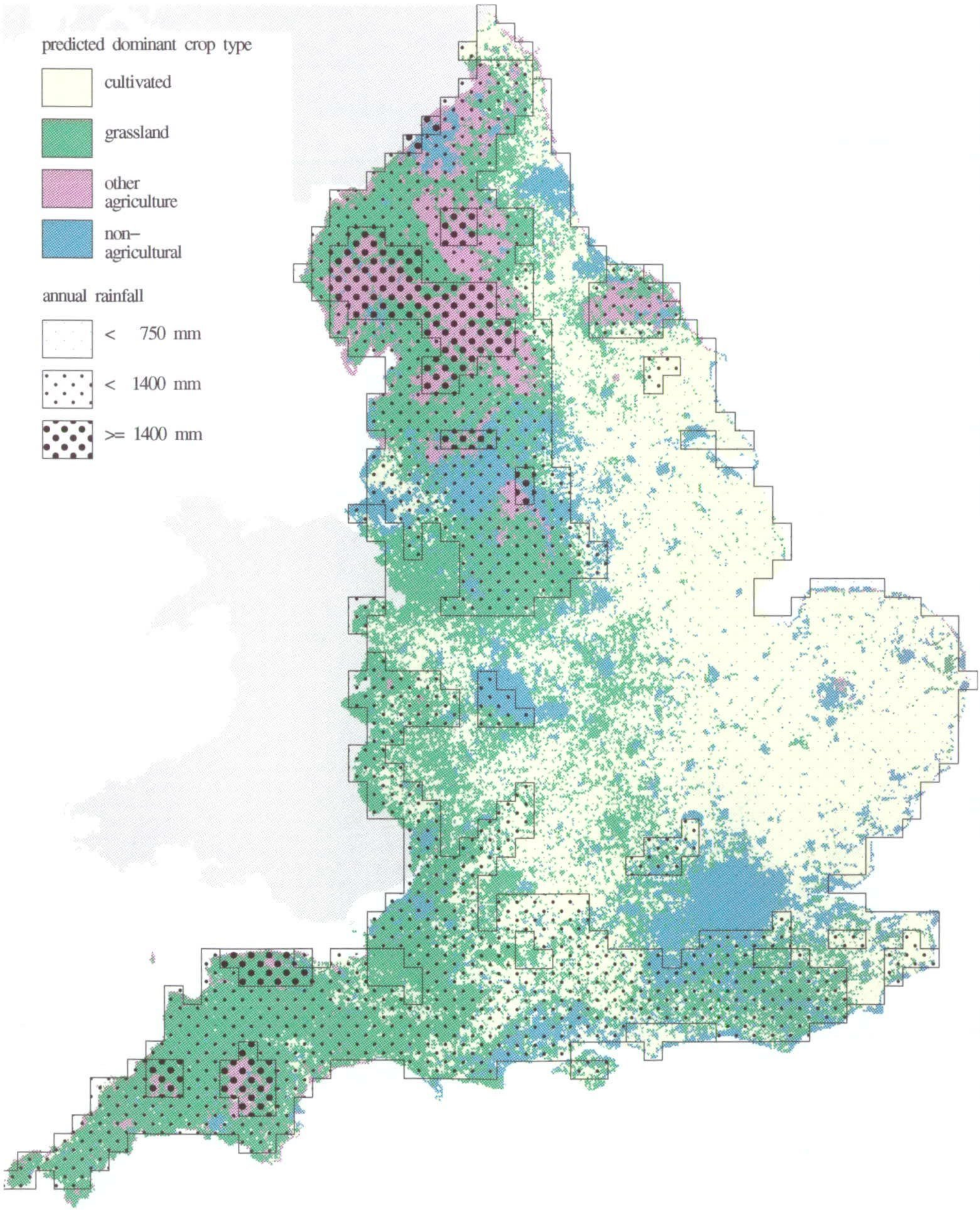


Figure 3. The distribution of fenland and water-margin vegetation in Britain, before and since 1960. Land drainage and agricultural intensification has reduced the range of most wetland species, so that 'hotspots' of wetland biodiversity are now confined to a few areas, such as the Somerset Levels, Fenland and Norfolk Broads. Wetlands are expected to be particularly sensitive to future climate change impacts, both directly and through the shift in agriculture which it will induce.

Figure 4. Example from the land use database showing the dominant crop type in 1 km squares, predicted from MAFF Agricultural Statistics for 1989, in relation to rainfall.



4.1.3 Land use data

The MAFF agricultural census statistics provide an indication of agricultural land use in England and Wales for aggregations of parishes. These data are updated annually and will provide a continuous monitoring system for agricultural change in England and Wales. Techniques are being developed for making use of these data within the Core Model Demonstrator.

A 1 km data-set of the predicted distribution of agricultural land use has been derived from the ITE land cover map and MAFF county agricultural statistics (MAFF 1991) using an areal interpolation method (Allanson 1993). Use has been categorised by crop type, ie cultivated land, pasture, other agriculture (which is 69% rough grazing) and non-agricultural. Figure 4 shows the distribution of the cultivated-land/pasture ratio obtained using this method, related to annual rainfall for comparison.

The same method can be applied to other crop or farm production statistics, using parish level data to provide more accurate 1 km predictions.

4.1.4 Climate: baseline and scenario data

The lack of good usable climate data has been mentioned in previous Core Model reports. Consequently climate data from a variety of sources have been used in the Core Model development work and these have generally been of low resolution and/or for a limited number of variables. These data have been described in previous annual reports, but the most important of these are summarised here:

The MORECS dataset is a GB dataset spanning a total of 30 years from 1961-1990. Records held (on the ORACLE database) are the mean (or total) monthly values for 190 40 km Ordnance Survey squares in GB. The variables include are total rainfall (with altitude effects removed), total sunshine, temperature, potential evaporation, actual evaporation, end of month soil moisture deficit, effective precipitation (hydrologically effective rainfall) , vapour pressure and windspeed.

The International Institute for Applied Systems Analysis (IIASA) global database currently being developed by Rik Leemans and Wolfgang Cramer.

This is a global database on a half-degree grid giving rainfall, cloudiness and temperature thirty year means (1931-1960) for each month. The differences between this database and MORECS database in GB were discussed in the 1992 Interim report (Bull et al 1992). There were some distinct differences between the datasets and the conclusion was that better fine-resolution data were an essential requirement for future Core Model work.

Other climate datasets used in the Core Model work include a 1 km dataset for GB derived by ITE Merlewood, bioclimatic data generated by Wolfgang Cramer for Brian Huntley for the 50 km (approximately) resolution AFE mapping system and European agro-climatic data on a 0.5° latitude by 1.0° longitude grid used by the Environmental Change Unit for land use and crop modelling.

There is now a need to standardise as far as possible on the climate data provided by the Climate Research Unit (CRU) through the DOE LINK project. However climate data used previously will be retained within the Core Model Demonstrator. These data will provide the opportunity to test results against different climate baselines and provide a test of the robustness of the results and conclusions to variations in the baseline data. Work at the Environmental Change Unit has been comparing 1951-80 and 1961-90 climate baselines and to compare the scenarios of several GCMs in terms of their implications for impact studies. This will be presented as a separate component within the Core Model Demonstrator.

Standard Climate Data from the Climate Research Unit

The Climate Research Unit are sub-contracted by DOE to provide higher resolution baseline data and climate change scenarios for both the UK and Europe. The baseline conforms to the 1960-91 standard, which is used in GCM control runs and using Meteorological Office data for the UK. Data are available at a 10 km resolution for the UK, and at 0.5° longitude and latitude resolution for Europe. Monthly data for minimum, mean (GB) or modal (Europe), and maximum altitude for the following variables for the two grids are available:

- minimum temperature (°C)
- mean temperature (°C)
- maximum temperature (°C)
- precipitation (mm)

- sunshine hours
- wind speed (m/s)
- relative humidity (%)
- frost days
- rain days.

Climate change scenarios will be based upon the results from three GCM experiments:

- UK Meteorological Office equilibrium high resolution (2.5° lat by 3.75° long);
- Canadian Climate Centre equilibrium high resolution experiment;
- Transient run from the Meteorological Office (2.5° lat by 3.75° long) with two time slices - 2020 to 2030, and 2050 to 2060.

CRU have outlined some of the inherent problems of using the output from GCMs. These include the crude boundaries between the ocean and land within the model, the interpolation of model output to a 10 km grid, and the coarse topography of each square. The highest available resolution of output from a GCM only has 4 grid squares over the UK!

<u>CRU: climate data availability with the Core Model Programme</u>

Subject to final arrangements with CRU, 10 km baseline data for GB will be available for use in the Core Model. European baseline data are only currently available in a provisional form. The final European baseline and GCM Scenario data should be available in March 1994.

4.2 MODEL DEVELOPMENT

The databases developed above will be used within the Core Model Demonstrator to illustrate and develop techniques for describing the distribution of species in relation to climate using a range of correlative and dynamic models. The aims are first, to describe the current distribution of species, habitats and land use in terms of climate parameters; second, to use these models to predict the potential future distributions under different climate change scenarios; and third to model the constraints on these potential distributions imposed by habitat, land use and species biology to predict actual distribution patterns through time.

Modelling activities have been divided into 4 parts:

(i) construction of climate spaces and climate envelopes for species, habitats and land use variables;

(ii) dynamic models of species spread including example models of invasion, dispersal, establishment and local extinction, based on realistic assumptions about species biology; to simulate migration through Britain over time;

(iii) habitat change models which predict vegetation change in relation to climate;

(iv) models of land use potential - environmental models to predict land cover changes in response to varying commodity prices and to predict the indirect ecological impacts of agricultural change.

4.2.1 Climate Envelopes

Climate envelopes define the current range of a species or habitat in terms of climate variables (Figure 5) and can be used to illustrate how the potential range of a species may respond to changes in climate. Core Model work at Monks Wood has compared a range of techniques for calculating climate envelopes with the general aim of developing a method that can be used efficiently within the Core Model Demonstrator.

Climatic variables and climate envelopes derived from them are insufficient in their own right to describe the actual distribution of plant or other species. Instead, a climate envelope is used to suggest the potential habitat of a species given that other non-climatic environmental conditions are satisfied. This caveat will protect against, say, misleading predictions of calcareous species appearing in acid sites.

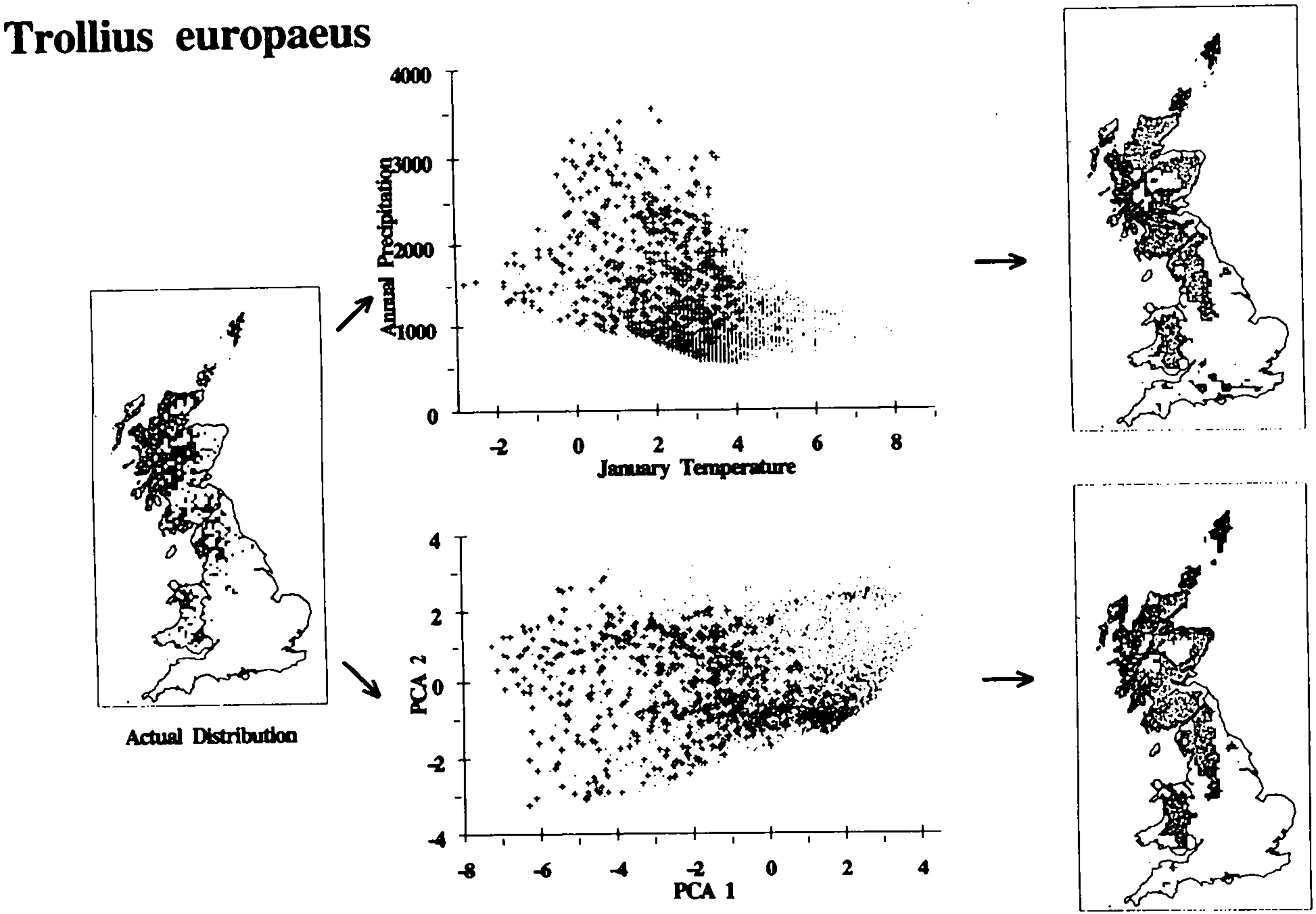


Figure 5. The distribution of T. europaeus in geographic, climate and PCA space, and Nix-type envelopes formed from the latter two.

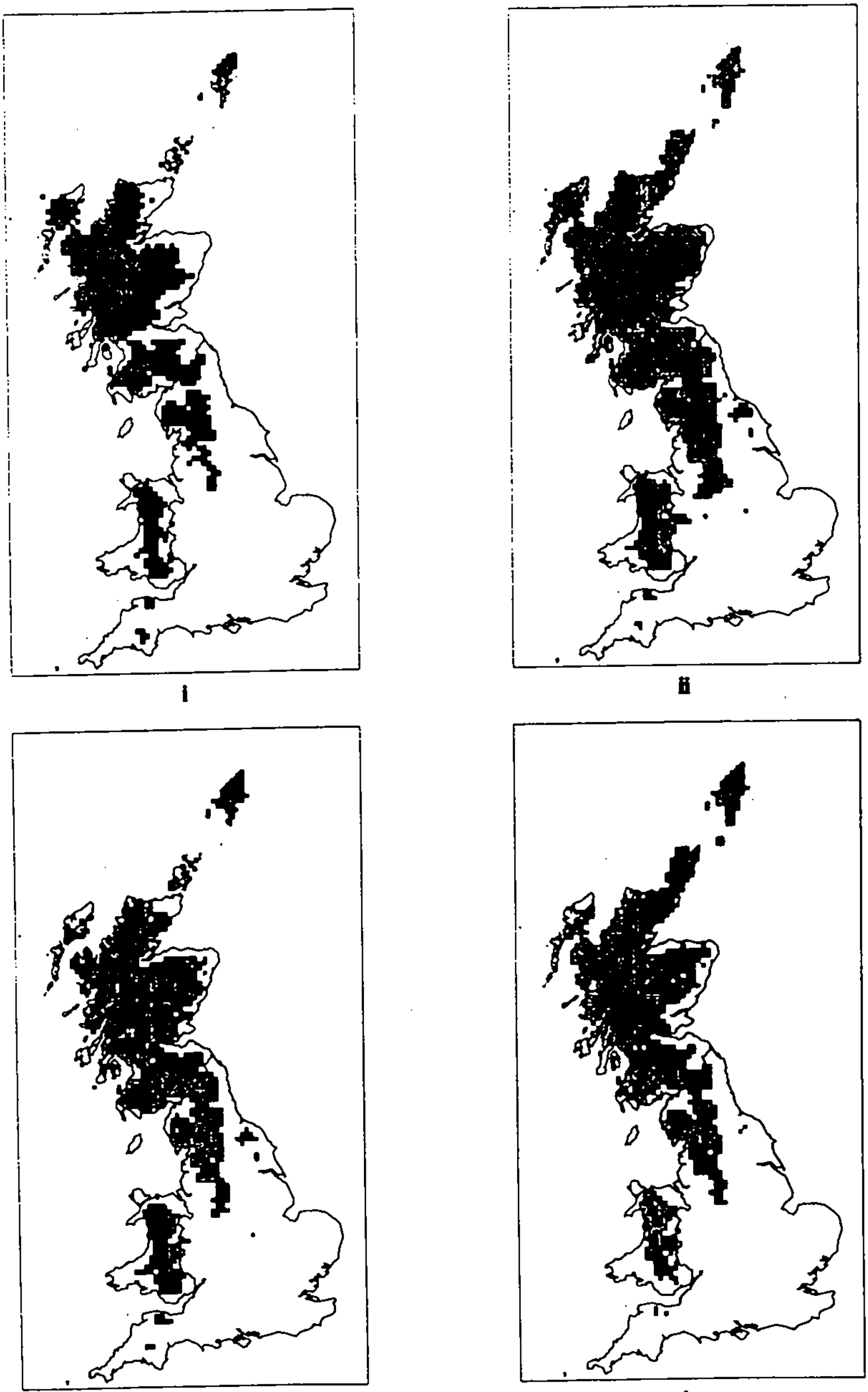


Figure 6. Envelopes created by (i) linear discriminant analysis; (ii) logistic regression; (iii) grid based approach on two variables; (iv) grid based approach on two PCA variables.

Further consideration will be given in the Core Model Demonstrator to ways of modifying predicted distributions to take into account unsuitable habitat categories and other environmental features.

In the initial, 1991, project report eight suggestions were made for improving the definition of climate envelopes of species distributions. At the time of writing that report climate data were only available on an unsatisfactory 40 km grid. Climatic data at a 10 km resolution only became available in December 1993 and the opportunity is now being taken to investigate some of the additional suggestions made in the initial report.

The choice of variables for constructing climate envelopes

The availability of 10 km resolution climate data provides a large pool of potential climatic variables. In the 1992 report it was shown that using a fixed number of climatic variables was both cumbersome and unnecessary and that acceptable envelopes could be obtained using a reduced set of variables. It is, however, necessary to find those climatic variables that maximally discriminate between occupied and unoccupied squares, i.e. which climatic variables are different between occupied and unoccupied squares.

Several ways of doing this have now been examined including: i) test of means comparing data for occupied and unoccupied squares using, for example, a t-test or a distribution free test; ii) comparison of distributions using the Kolmogorov-Smirnov test; and iii) correlation methods. These techniques can only be used to provide an exploratory indication of the most useful climatic variables but cannot be used for significance testing. A further problem with these approaches is that, in Britain at least, many climatic variables are highly correlated. Having selected the most promising, there is no way of assessing which additional variable will be most useful.

A more satisfactory approach might be to convert the correlated climatic variables into new and a smaller number of uncorrelated variables using principle components analysis (PCA). This approach has often been used to reduce the complexity of a problem by working in a smaller number of dimensions. PCA of the seven selected climatic variables was carried out; the first two components accounting for 88% of the total variance (69% and 19%) respectively. The first component represents a contrast between warmth and wetness and the second a contrast between wetness and frostiness. These results indicate that by using principal components it might be possible to represent climate space satisfactorily in just two dimensions. Further work is planned to develop this approach.

Methods of calculating climate envelopes

Nix's (1986) method of calculating envelopes defined the data range of a climatic variable to be between the 5th and 95th percentiles of the values of that variable for occupied squares. This automatically eliminates 10% of the occupied squares from the envelope, even in those based on a single climatic variable. However this method eliminates tail values which when these represent minima or maxima, as is frequently the case in GB, is unsatisfactory (Figure 5). The Walker & Cocks (1991) approach which encompasses all occupied squares has more to commend itself in this manner.

Two alternative approaches to Nix-type climate envelopes were suggested in the 1991 report. Figures 6i and 6ii compare the predicted distribution of *Trollius europaeus* in GB calculated using the methods of logistic regression and linear discriminant analysis. Both approaches give a satisfactory fit to real data, but both are computationally time consuming and not well suited for inclusion in the Core Model Demonstrator.

Work is now being done to provide a method for defining the climate space which can be used directly within the Core Model Demonstrator. Speed and visual simplicity suggests that the ideal approach is to form envelopes based on presence on a grid basis. Both original variables and principal components might provide suitable material for forming such envelopes. The idea would be to form a grid of the climatic space, and include those cells in the climate envelope that contained an occupied square. This 'polygon' will resemble the polytope suggested by Walker & Cocks (1991) but will be more irregular, being composed of square cells. It will then be possible to calculate the proportion of occupied to total squares in each cell. This would enable mapping of various classes of suitability within the climate envelope, or further refinement by removing cells from the envelope that have a low proportion of occupancy. The early results from this work are encouraging and show a good fit between predicted distributions (Figure 6iii and 6iv) and the actual distribution of *Trollius europaeus* (Figure 5).

Some non-BRC records, such as those from Countryside Survey 1990 give an indication of density but are only available for a sample of areas within GB. The grid based approached described above will be developed to deal with these kinds of data.

4.2.2 Species dispersal modelling

Dispersal models for species movement following climate change are composed of four main elements: climate suitability, habitat suitability, growth of individuals and dispersal of propagules. It is assumed that individuals are in colonies, which are (notionally) positioned at the centres of grid squares. The first stage of the model is to set up a probability of an individual establishing (Figure 7):-

Probability of establishment =climate suitability x habitat suitability.

Once an individual has established, it needs time to reach reproductive maturity. For an annual this time is one year. For an oak tree it is 40 years. The model should take account of the time-lag. Having reached maturity, the individual produces propagules, which disperse. Typically, there is a large chance of propagules falling near the parent, and a small chance that they will be transported to a new site where they can start a new colony. The simplest representation of propagule dispersal is by means of a distribution function

Probability of travelling > R metres = F(R)

where F is a decreasing function such that $F(0)=1$ and $F(\infty)=0$.

We have constructed a preliminary model of this type, called DISPERSE. The output from this model is shown for the current and a modified climate in Fig. XX.

During 1994, we shall construct dispersal models for 10 or more species, using realistic climate scenarios, a realistic baseline climatology and realistic dispersal probability functions. These dynamic models will form a part of the Demonstrator. They will show how biological, meteorological and geographical information can be combined to make predictions of the time-scale of species spread following climate change.

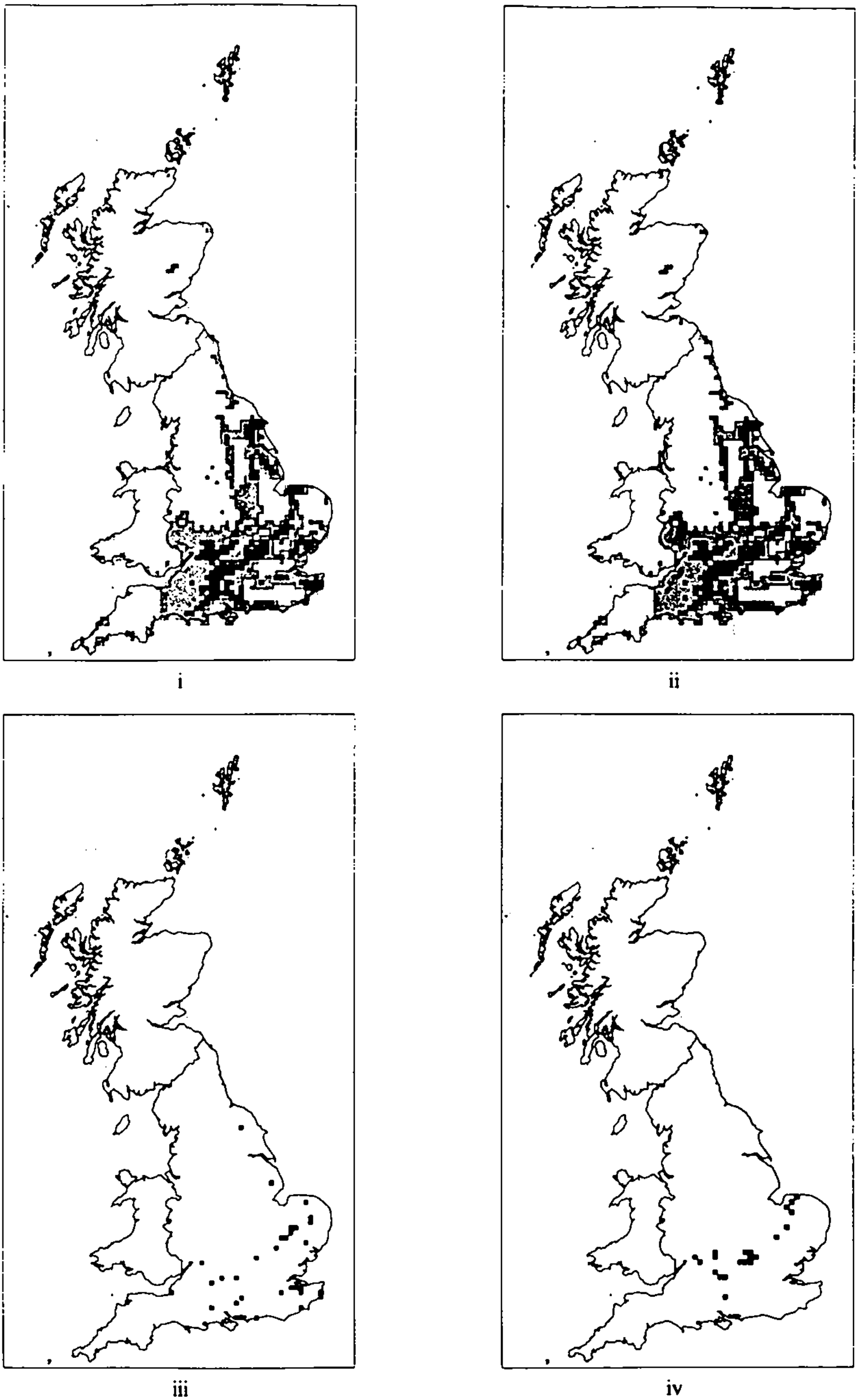


Figure 7. Predicting the distribution of the Lizard Orchid (i) present suitable climate and habitat; (ii) suitable climate and habitat with a 5% increase in soil moisture deficit; (iii) present distribution; (iv) future distribution showing very little change with this scenario.

4.2.3 Habitat change modelling

Vegetation is likely to be directly affected by climate change, in ways that not only affect its species composition and its suitability as a habitat for its current complement of species, but also its openness to invasion by new species.

UCPE are developing models of habitat/vegetation change in response to climate and land use scenarios. These models will be based on maps showing the probability of habitats occurring in a particular area together with the expected plant species composition of these habitats. Longer term changes which depend on species immigration fall outside the scope of the work.

By combining ecological concepts with laboratory and field based studies, UCPE is in a position to infer the dynamic response of vegetation to medium term changes in climate and land use. Hence, within the general framework for the Core Model work shown in figure 1, UCPE will develop models and procedures for predicting the change in distribution and quality of habitats on a 1 km scale within GB. The aim is to predict the probability of finding a habitat within each 1 km square of GB, its composition and, if possible, an indication of whether it is open or closed to invasion by other species.

To achieve this UCPE have produced a vegetation change model based on national 1 km land cover data. This model builds on the expert system model TRISTAR (produced by UCPE under contract to DOE/DRA) and will be delivered in a format compatible with the Core Mode Demonstrator currently being developed at ITE, Monks Wood.

The model consists of two parts:

(1) Classification of the land cover. The expert system within the model will use the C-S-R plant strategy theory to classify each 1 km square into a set of seven locations within C-S-R space. This method was described in more detail in the first Core Model interim report. The method will be used as the starting point for the second component of the model.

(2) Future herbaceous vegetation. the expert system will convert spatial climate and land use scenarios into stress and disturbance vectors. The vectors will alter the relevant 1 km C-S-R co-ordinates which will indicate the potential change in the underlying vegetation. The openness of the vegetation to invasion by new species can be derived from this.

Using data for heathland component of the DoE Key Habitats project, supplied by ITE Merlewood, the first part of the model has been prototyped in MS-Excel. the prototype successfully classified the dataset, so the main expert system shell has been coded in C. The C-S-R classification of this prototype dataset is now available. The predictive component of the model has been coded and successfully tested with an example scenario on a sample data set.

The work is now being linked directly to the Core Model Demonstrator.

4.2.4 Land use modelling

Changes in land use in response to climate change may be a key factor influencing the distribution and abundance of species and habitats in the future.

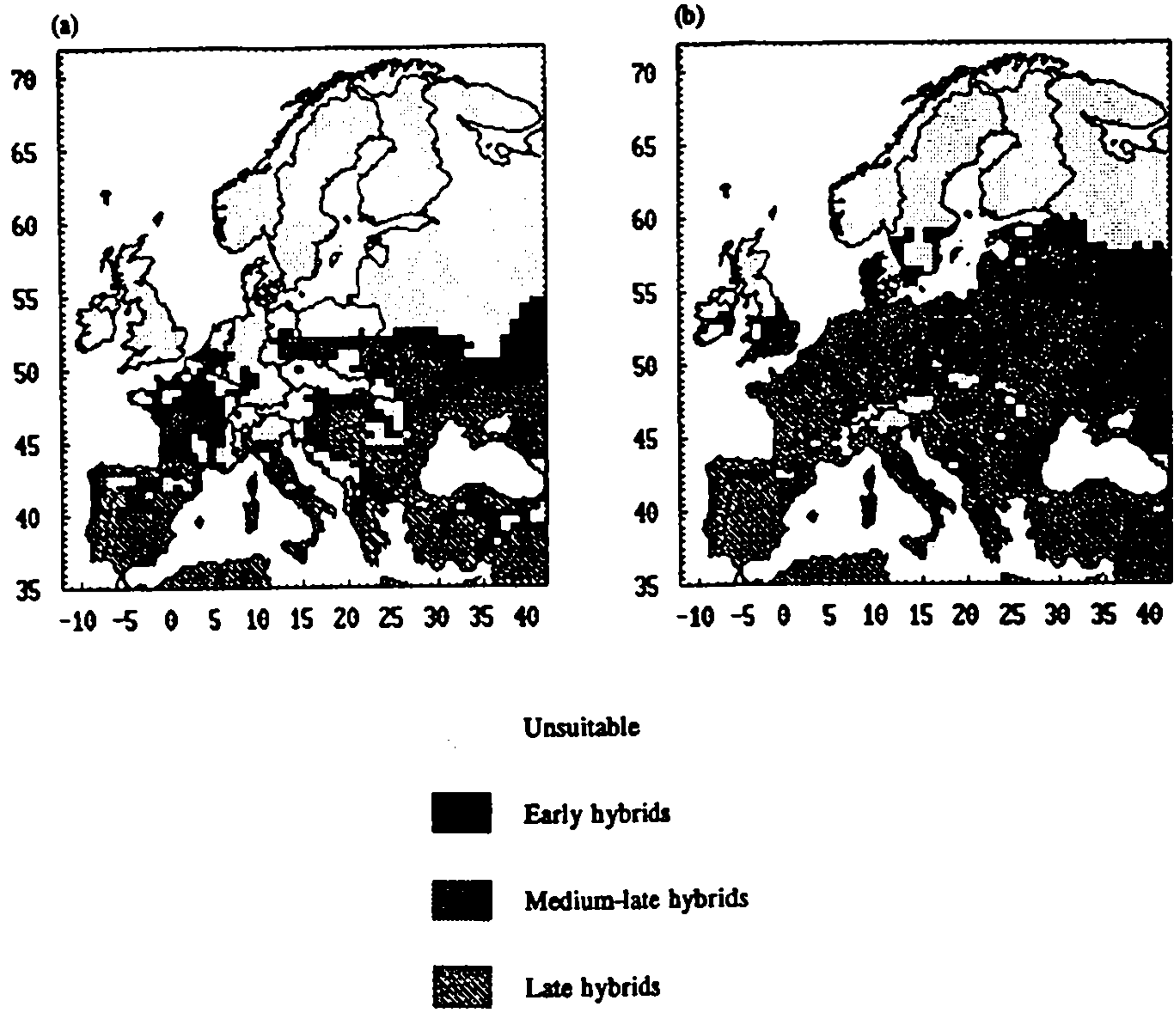
The Environmental Change Unit (ECU) are providing a module for the Core Model Demonstrator which can be used to examine and compare different methods of assessing the impacts of climatic change on agriculture and land use in Britain and Europe. It will also show how different climate change scenarios may produce strongly contrasting results when run through the same model and compares the 1951-80 climatic baseline with the 1961-90, through the use of simple indices which have been used to predict crop potential. It provides results of sensitivity studies from three different equilibrium modelling approaches and enables comparisons to be made in overlapping areas.

ECU have used their work to report results of preliminary studies of the sensitivity of (i) land use potential to climate change in England and Wales, (ii) crop potential to climate change for Europe. Models of crop potential have been used to show the impacts of climate change on crop potential (e.g. wheat & maize) at (i) a European Scale and (ii) England and Wales. The example in figure 8 shows how grain maize might spread northwards following a 2°C increase in temperature.

<u>ECU progress towards objectives</u>

ECU have completed modelling studies and results from two of the three studies have been transferred to SPANS GIS together with climate scenarios from 3 general circulation models. The emphasis of the remaining work at ECU will be on (i) reporting and (ii) provision of the demonstrator package(s) in an Arc/Info format compatible with the Core Model Demonstrator being developed at Monks Wood.

Figure 8. ECU modelling land use change studies. Crop potential before and after climate change.



(a) Northern thermal limit of grain maize for the baseline climate (1951-80) based on a seasonal thermal time calculation; (b) Sensitivity of grain maize hybrids to a +2°C change in temperature (Kenny and Harrison, 1992).

4.3 DEVELOPMENT OF THE CORE MODEL DEMONSTRATOR

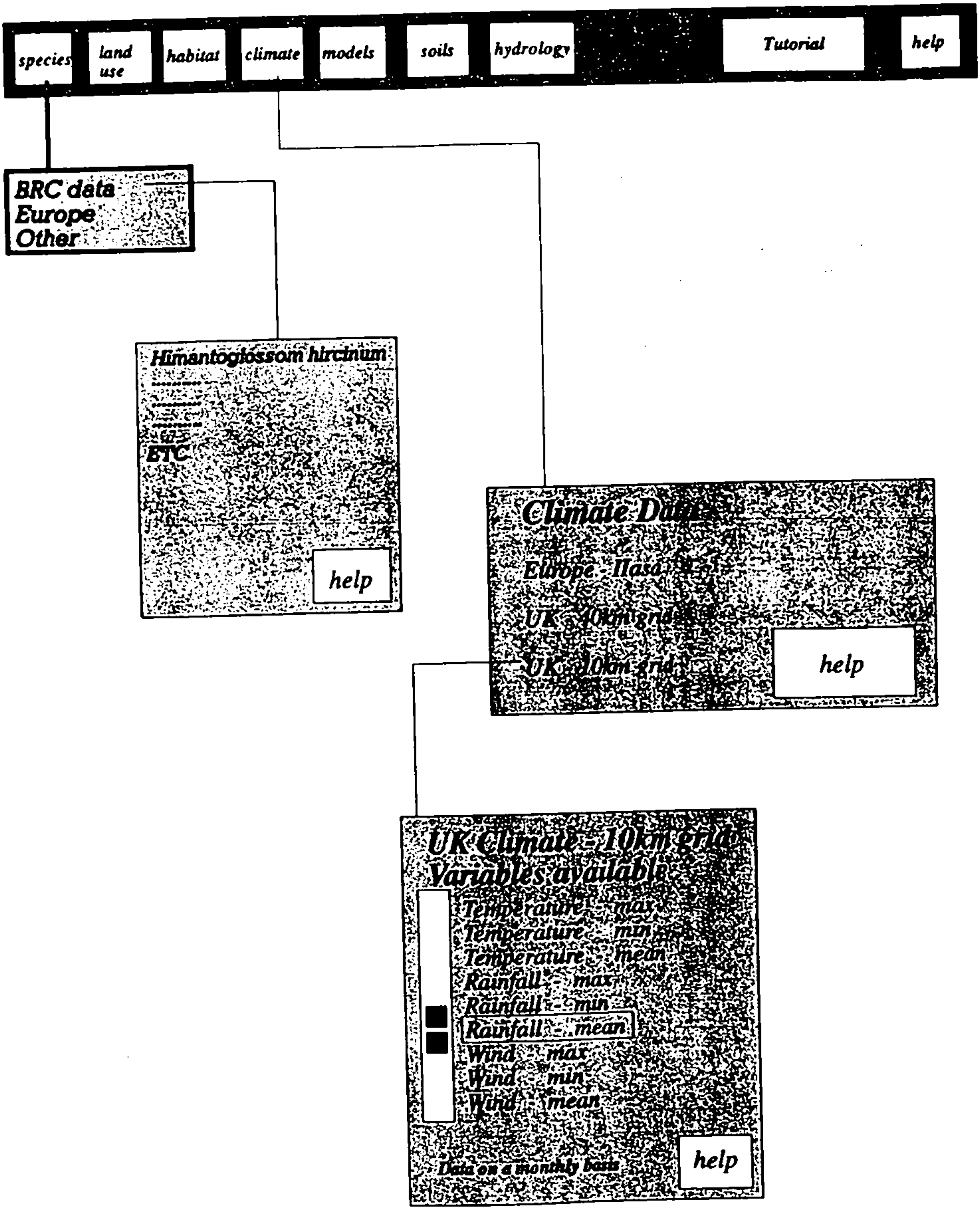
The Demonstrator currently being developed in the GIS section at ITE Monks Wood will form a focus for much of the research carried out by the various groups within the Core Model project. It is intended that this research will be brought together in a coherent fashion within a Arc/Info GIS system and be made suitable for a wide range of potential users. It will provide an interactive product behind which will sit much of the data used by the project as well many of the modelling and analysis routines created during the study of climate, habitats and species distributions. The Demonstrator will provide an analysis tool for both novice users making general enquiries and for more experienced scientists wishing to study aspects of climate change in more comprehensive ways.

Wherever necessary, appropriate forms of acknowledgement and conditions of usage regarding the data and models within the system will be included to guard against intellectual property rights and copyright infringement.

4.3.1 Usefulness to users

Members of the Core Model team are providing products covering a wide range of climatic change themes; from detailed species analysis on a regional scale to climate change on a European scale. These products have been developed within a number of different computer systems which needed to be more closely related to one another and more easily accessible to the non-expert. By bringing together these various components, it is hoped to provide an integrated set of analysis options which together give a more comprehensive analysis system than that provided by the individual parts. For example, land use and modelling studies by ECU at Oxford can be closely related to detailed land cover data provided by ITE. Studies of European species distributions can be compared to more detailed species distributions available from the BRC database. Climate data can be examined and user defined climate scenarios run to allow examination of results in comparison with habitat patterns at national and European scale.

Figure 9. Example of the menu structure from the ITE/DOE Core Model Demonstrator.



4.3.2 The Arc/Info customized menu system

The Arc/Info GIS provides a framework for the design and creation of user friendly menu systems. It is important that the final form of the demonstrator is easy to use, requiring little knowledge of the GIS or the operating system within which it is constructed. A 'beginners guide' to the demonstrator will be available in paper form as well as interactive help within the menu systems. The specific strengths of a relatively new, raster based, Arc/Info product, the Arc/Grid module have been explored and are being used throughout the Demonstrator.

The design and construction of the main menu system started with a simple overall plan based on that shown in figure 9. The Demonstrator will include 'help' information describing each componernt of the Core Model in some detail. In addition, it will contain a "guided tour" showing how it can be used, using selected examples for *Himantoglossum hircinum* dispersal in the UK and climate envelope definition for a European species distribution. These examples will make use of various datasets on species, climate and habitat as well as showing the use of vector and/or raster data methods in operation within the Arc/Info GIS.

4.3.3 Targets/Objectives

Over the next six months the Demonstrator will be developed to incorporate a variety of data sets and models. These are detailed below.

Overall aim: the development of an integrated database suitable for addressing the impacts of a changed climate by linking data and modelling activities within a GIS.

General objectives

a. Develop module for the display of distributions for UK and Europe.

b. Develop applications of UK BRC datasets.

c. Access and run species dispersal models with output to the GIS display.

d. European modelling activities.

e. Provide spatial modelling capability e.g. for analysis of habitat space.

f. Display the effects of land use change with climate change and their impacts on semi-natural vegetation.

g. Data assessment. Assess areas of uncertainty and consequent data requirements.

Specific objectives:

a. Inclusion of more detailed climate data for UK.

b. European analysis of climate and species based on TIGER work (S Wright)

c. Inclusion of climate scenario examples based on new climate database.

d. Include links to ECU climate scenarios.

e. Display (and run, if possible) dispersion models/examples by ITE Monks Wood.

f. Display impacts of climate change on species composition based on ITE Merlewood work e.g for marginal uplands on a 1 km grid basis.

g. Assessment of data costs and access restrictions/costs.

h. Assess links between Core Model demonstrator and other GIS used by the group such as LaserScan's Horizon and IGIS products.

i. Others, including inclusion of developments by:-

IH on water systems and catchments.

AFE work by Durham, where additional to AFE distributions etc.

DMAP developments (see 2nd interim report page 33)

4.3.4 Data access

At the beginning of January over 200 files had been imported onto the computer disk accessed by Arc/Info during development of the Demonstrator, and many more will be required. This could pose some problems in terms of disk space and management of data files, but this potential problem is currently being addressed by the purchase a 2 Gigabyte disk which will be dedicated to this project.

4.4 TESTING AND VALIDATION

Testing of data-sets and models which will eventually form the components of the Core Model demonstrator is a continuous process and standard procedures of data management have been adopted to provide the necessary quality assurance.

The Core Model Demonstrator will provide the means of examining the sensitivity of climate change impacts to variations in input parameters including those relating to climate, biology (ie species dispersal rates) and habitats.

The Demonstrator will also contain a variety of complementary data-sets and models which will provide the opportunity to cross-check results. For instance, the availability of:

- species distribution data at a coarse European scale or finer GB scale;
- habitat distributions derived from either soils, land cover map or BRC data;
- baseline climate data from CRU, MORECS or European agro-climatic data,

all provide complementary and overlapping information which can be used to test the robustness of results and conclusions to changes in baseline assumptions. The extent to which results from alternative approachesare in agreement with each other will provide some idea of the robustness of the system in terms of its ability to answer complex questions on potential climate change impacts.

Some of these cross-checks will be included as components of the Core Model Demonstrator. The Environmental Change Unit are contributing a package which compares baseline climate scenarios in relation to effects on the land use changes described in Section 4.2.4. The ECU package will compare baseline climate scenarios and shows areas of uncertainty where, on GB and European scales, climate data should be viewed and used with particular caution.

Further plans for testing and validating data and models within the Core Model Demonstrator will be developed and implemented during 1994.

4.5 CORE MODEL APPLICATIONS

The Core Model Demonstrator will be used illustrate some possible applications in relation to questions of applied and policy interest. *The final choice of examples will need to be agreed between DOE and Core Model contributors, but could include one or more of the following:*

(i) are there "critical loads" for climate change, in terms of the impacts of changes in climate on semi-natural communities?

(ii) will the effect of climate change on species' distributions mean that some or all of our designated areas for wildlife and landscape conservation are in the wrong place?

(iii) which species and habitats will make the best indicators of climate change and where should monitoring effort be concentrated to be most cost-effective?

4.6 LINKS WITH THE INSTITUTE OF HYDROLOGY

By moving towards a Demonstrator based on Arc/Info, ITE are now using the same platform as the Institute of Hydrology have adopted for their work within the Core Model programme. This will greatly facilitate links between these parts of the programme.

Plans to develop these links will be developed in 1994, but initial discussions have indicated some potential areas for exploration:

- *the use of IH catchment scale models to provide a dataset of soil moisture deficit across GB as an input to climate envelope work at Monks Wood and UCPE vegetation models;*
- *links between the mechanistic grassland models developed at Sheffield and habitat and species data from the ITE land cover map and Countryside Survey 1990, to provide a direct assessment of the implications of changes in grasslands to the semi-natural species and communities they suppport.*

5 DISSEMINATION: FINAL SEMINAR AND SUMMARY REPORT

ITE are contracted to make arrangements for a concluding seminar at the end of the contract period to present the results of the Core Model programme to a wider audience. The seminar will cover work done by the Institute of Hydrology, Climate Research Unit and the Institute of Terrestrial Ecology and sub-contractors within these parts of the programme. A glossy publication summarising the main results from the research in a form suitable for a wide range of readers will also be published at this time.

This seminar will provide the opportunity for DoE to present results from research it has funded on climate change impacts and to invite the impacts modelling community to make use of the tools that have been developed through the NERC Core Model Research Programme. The broad aim of the seminar will be to present some basic tools for climate change research and to provide a stimulus for further research in this field. It will also discuss the central role of climate prediction in impacts modelling and report progress made by the Hadley Centre towards providing regular climate predictions in a form most useful to the climate change impacts research community.

The seminar is being designed primarily for members of the climate change impacts and modelling community within the UK and, in addition to research scientists, a range of users in policy fields will be invited.

Provisional plans are to hold the seminar at The University of Newcastle on 14/15th December 1994. These plans will be discussed at a meeting with DOE on 14 February 1994. Papers summarising plans and proposals are presented in an appendix to this main report.

6 PROJECT CO-ORDINATION AND MEETINGS

Meetings have been held throughout the year to develop the Core Model work. These are summarised here:

19-21 April - workshop on Species Distribution In Relation to Climate (Monks Wood). The workshop was to discuss methods of relating species distributions to climate as a first step towards predicting the impacts of global change. A report of the meeting is given in Annex B. One of the conclusions from the discussions was that inference systems designed to make predictions should be circular and self-improving and that simple approaches based on common sense are desirable. The subsequent development of the Core Model Demonstrator has been based on this general philosophy in order to avoid the pitfalls and distractions often associated with "grand, unifying models".

19 May 1993 - Climate Change Core Model Meeting was held at Monks Wood as part of an overall project review. It included presentations on the key projects in the Core model programme plus 9 separate computer demonstrations. The meeting successfully presented "state-of-the science" models and showed some ways in which GIS,modelling and databases had been linked, but was perhaps less successful in presenting a clear framework for impact assessments, particularly on the ecological side. A DOE representative concluded that although technological aspects of the Core Model were important there was a clear need to distinguish between the information requirements and the technology that presents it. He added that it is important not to lose sight of what is being done (objectives), how it is being done (mechanics) and why it is being done (relevance).

The discussion at the meeting identified the need to consolidate the various contributions from the core model sub-contracts. Later DOE issued a clear instruction to ITE (Dr Mallaburn to Dr Bull 24 September 1993) to make progress towards a "complete demonstration of operational predictive capability in the form of integrated databases and models". To achieve this, a series of bipartite meetings was held between T.Parr (project manager) and all groups involved in other parts of the Core Model (with the exception of the Climate Research Unit). The objectives of each meeting were to discuss an overall framework for the Core Model components, identify and consolidate the key links with other parts of the programme and specify programmes of work for the remaining contract period. Meetings were held as follows:

6 October	- ITE, Monks Wood
22 October	- Institute of Hydrology
24 October	- Unit of Comparative Plant Ecology
October	- University of Durham (by correspondence)
25 October	- GIS/data management group at Monks Wood
25 November	- Environmental Change Unit, Oxford
December	- ITE, Biological Records Centre
16 December	- ITE(N)

All groups were encouraged to relate their work to the overall framework and to provide outputs which can be used interactively within the Core Model Demonstrator. Objectives and schedules necessary to achieve this have now been agreed with all sub-project leaders with the aim of having all parts of the Demonstrator in place by June 1994.

9 SUMMARY OF PROJECT OUTPUTS

(i) A Computer Demonstration System - progress as described in Section 4.3. On schedule for completion in June 1994.

(ii) Demonstration package for presentation at a National Conference - plans for Conference discussed in Section 5. Next panning meeting on 14 February, DOE, Marsham Street.

(iii) A PC based demonstrator for Departmental use. The option being considered is to make use of the DOE(DRA) Countryside Information System (CIS) as a presentational tool for results derived from the Core Model Demonstrator. The CIS operates on a 1 km grid of GB and can be used to provide maps and summary data for any specified region. CIS development is being done by ITE(N), but DOE requirements now need to be clarified.

(iv) Document with illustrative results - see Section 5. Final draft needs to be prepared by September 1994.

8. PUBLICATIONS ARISING FROM CORE MODEL WORK

Brignall, A.P. & Rousadl, M.D.A. 1994. the potential effects of climate change and agricultural potentuial and soil tillage opportunities in England and Wales. 1994. ECU research report #4.

Eversham, B.C.,Telfer,M.G. and Arnold,H.R. Habitat occupancy and rarity in the British flora and fauna: part 1: overview. (a discussion of species richness per major biotope, and numbers of rare species in each: also provide basis for comparison of methods of biotope mapping, with T H Sparks)

Carey,P.D. DISPERSE: a cellular automaton for predicting the distribution of species in a changed climate. Journal of Biogeography.

Carey,P.D. & Brown,N.J. The use of GIS to identify sites that will become suitable for a rare orchid, Himantoglossum hircinum L. in a future changed climate. Journal of Biogeography

Carey,P.D. & Watkinson,A.R. determinants of distribution and abundance of Vulpia ciliata. Journal of Ecology.

Eversham,B.C.,Telfer,M.G. and Arnold,H.R. Habitat occupancy and rarity in the British flora and fauna: part 2: biotic indices of habitat loss in Britain. (Changes in species distribution over time, used to measure regional variations in biotope loss and degradation).

Eversham,B.C.,Ward,L.K. and Loder,N. patterns of species richness in Britain. (Multiple regression of species richness for a range of taxonomic groups: also useful in quantifying latitudinal trends in species-richness, important in determining representation of rare species in species-richness hotspots)

Huntley, B. and Ascroft, R. 1993. DoE Core Model project. 3rd annual report. Environmental Research Centre, university of Durham.

Hulme,M., Hossell, J.E & Parry, M.L. 1993. Climate change and land use in the UK. Geographical Magazine 159(2) pp 131-47.

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Prendergast, J.R, Quinn, R.M., Lawton, J.H., Eversham, B.C. and Gibbons, D.W. 1993. Rare species, the coincidence of diversity hotspots, and conservation strategies. Nature, **365**, 335-337

Walker, P.A. & Cocks, K.D. 1991. HABITAT: A procedure for modelling a disjoint environmental envelope for a plant or animal species. Global Ecology and Biogeography Letters, **1**, 108-118.

AFE maps scanned in Helsinki and passed to Monks Wood after checking:

(* signifies that errors were found, see details below)

PTERIDOPHYTA

13 *Selaginella selaginoides
61 Cryptogramma crispa
71 Trichomanes speciosum
99 Ceterach officinarum subsp. officinarum
100 Ceterach officinarum
106 Athyrium distentifolium
119 Polystichum lonchitis
133 Dryopteris aemula
149 Azolla filiculoides

GYMNOSPERMAE

151 Abies sibirica
157 Picea abies
158 Picea abies supsp. abies
159 Picea abies subsp. obovata
161 Larix decidua
162 Larix sibirica
163 Pinus pinaster
164 Pinus nigra subsp. nigra & P. nigra subsp. dalmatica
165 Pinus nigra subsp. salzmannii
166 pinus nigra subsp. laricio
167 Pinus nigra subsp. pallasiana
168 Pinus sylvestris
169 Pinus mugo
170 Pinus uncinata
172 Pinus halepensis
174 Pinus pinea
175 Pinus cembra
176 Pinus sibirica
182 Juniperus communis subsp. communis
183 Juniperus communis subsp. hemisphaerica
184 Juniperus communis subsp. alpina
185 Juniperus oxycedrus subsp. oxycedrus
186 Juniperus oxycedrus subsp. macrocarpa
187 Juniperus oxycedrus subsp. transtagana
189 Juniperus phoenicea
190 Juniperus thurifera
193 Juniperus sabina
194 Taxus baccata

ANGIOSPERMAE

201 *Salix pentandra
202 Salix fragilis
203 Salix alba
204 *Salix triandra
205 Salix reticulata
208 Salix retusa
211 salix myrsinites
220 Salix lanata
223 Salix myrsinifolia
234 Salix atrocinerea
235 Salix cinerea
236 *Salix aurita
237 Salix salviifolia
238 *Salix caprea
243 *Salix repens
245 *Salix repens coll.
246 Salix arbuscula
251 Salix helvetica & S. lapponum
252 *Salix viminalis
254 Salix eleagnos
255 Salix purpurea & S. vinogradovii
262 *Populus alba
263 Populus canescens
264 *Populus tremula
265 *Populus nigra
267 *Myrica gale
268 Juglans regia
269 *Betula pendula
270 *Betula pubescens
271 Betula humilis
272 Betula nana
273 Alnus viridis
274 *Alnus glutinosa
275 Alnus incana
277 Alnus cordata
278 *Carpinus betulus
279 Carpinus orientalis
280 *Ostrya carpinifolia
281 *Corylus avellana
286 Castanea sativa
287 Quercus coccifera
289 Quercus rotundifolia
290 Quercus suber
294 Quercus cerris
297 *Quercus petraea
299 *Quercus petraea sensu lato
301 *Quercus robur subsp. robur
302 Quercus robur subsp. brutia
305 Quercus pyrenaica
307 Quercus pubescens sensu lato
309 Quercus faginea
311 Ulmus glabra
312 Ulmus minor coll.
313 Ulmus laevis
315 Celtis australis
318 Ficus carica
319 Humulus lupus
362 Loranthus europaeus
364 Viscum album
365 Viscum album subsp. abietis
366 Viscum album subsp. austriacum
531 Halimione portulacoides
807 Minuartia sedoides
1097 Silene otites group
1098 Silene otites subsp. otites
1557 Trollius europaeus
1668 *Pulsatilla vulgaris subsp. vulgaris & P.vulgaris subsp. gotlandica
1669 Pulsatilla vulgaris subsp. grandis

MEETING REPORT

MONKS WOOD WORKSHOP ON SPECIES DISTRIBUTION IN RELATION TO CLIMATE

19-21 APRIL 1993

Organized by M.P. Austin, M.O. Hill and J. Leathwick

with the support of
Department of the Environment (GB)

BACKGROUND

At a meeting on biodiversity and climate change, held in Australia and New Zealand in early 1992, we agreed to arrange a workshop, based in Britain, on species distribution in relation to climate. The emphasis was methodological, comparing methods for determining environmental controls of species occurrence and biodiversity, preparatory to predicting impact of global change.

The theme of the workshop fitted well with current work at Monks Wood, supported by the GB Department of the Environment. The Department generously agreed to support the workshop, enabling us to increase the number of overseas visitors and to support several people who did not have an expenses budget.

THE WORKSHOP

The proposal at the 1992 meeting was to examine continental comparisons of the major environmental determinants and methodological difficulties of predicting current species and biodiversity distributions. The following components were identified.

- Methodology of correlative environmental analysis
- Patterns of biodiversity in relation to environment
- Relative importance of different environmental variables
- Improvement of predictor variables in terms of functionality
- Relative success of environmental variables as opposed to spatial properties of landscape.

Twenty-six people attended all or part of the meeting. Most were British, but we had contributors from Australia (2), Finland, Germany (2), Netherlands, New Zealand.

The format of the meeting consisted mainly of short talks followed by discussion. These were supplemented by longer periods of discussion between sessions.

OUTPUTS

Because of its full timescale, the workshop was, in effect, more of a symposium than a workshop. There was only a brief plenary discussion at the end. The workshop was useful in bringing together people from a wide range of disciplines. As often with

IMPROVEMENT OF PREDICTOR VARIABLES IN TERMS OF FUNCTIONAL TYPES

Functional types had been the subject of a recent international meeting in Virginia, USA. This topic was covered by two speakers, who were able to bring participants up to data with the most recent thinking. However, the idea is not a new one, being at least 99 years old. Aim is to identify recurring patterns of attributes, so that generalized predictions can be made. This is the bottom-up approach of Grime, Raunkiaer and Noble. It can be distinguished from the top-down approach of Box, Woodward and Prentice, whose aim is to define entities that suffice for definition of biomes.

With insects too, there is a need for functional types. Some insects show almost no temperature response ($Q_{10} = 1$).

In the discussion, it was emphasized that we should make choices and not just throw in data.

PATTERNS OF BIODIVERSITY IN RELATION TO ENVIRONMENT

Theories of species richness were given names "Structural Theory", "Dynamic Theory", "Historical Theory". They were ranged against commensurate tests. Testing in the past has often been neglected. At a local scale, the problem of species hotspots and coldspots was considered, these being difficult to separate from recorder effort. Scale important here, as are variables such as habitat age, which may be hard to ascertain from databases. When climate warms, do we expect diversity to increase, irrespective of large-scale migration? Some groups of species, such as those with a Lusitanian distribution in Britain, may occupy very discontinuous habitat. The diversity of these may be determined more by land use than climate.

Other problems are those of vicariant taxa (an extreme case of functional types?) and of the fact that different groups are predicted by different variables. The question of whether summer temperature is relevant to overwintering birds was considered. AET may predict trees; PET predicting reptiles.

DISPERSAL AND PROCESS MODELLING

Dispersal properties of seeds can be inferred from habitats in which plants appear. Those of highly-disturbed places are either wind-dispersed or (frequently) carried in soil and mud, where the persistence of a seedbank may be crucial to spatial dispersal. Explicit models of dispersal can represent a metapopulation equilibrium, but the value of the metapopulation concept for most plants is still in doubt. The relevance of physiological models with a short time-scale was considered in relation to catchment hydrology. The aim is to link these to stream chemistry and apply to grid squares across GB.

DISCUSSION

The pattern of information-flow within an established modelling framework (starting with data, ending with predictions) was contrasted with the way in which we attack new problems. There, problem-formulation is the main task; we never start with data. An inference system should be circular and self-improving. Simplicity is valuable and should be pursued. Grand, unifying models may be a distraction and an irrelevance. Models should be more explicitly based on theory. Ad hoc statistical models remain fraught with danger.

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6 July 1993

Circulation
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