Research applications using data from species surveys in Britain

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Abstract

Recent research by the Biological Records Centre has used species survey data from Britain to examine changes in the distribution of species, the effects of recorder effort, patterns of biodiversity and the occurrence of ecological assemblages of species. The development of a Biotope Preference Database, for use with data from national species surveys, is described.

Introduction

National or regional biological surveys now operate in many European countries. These surveys, such as those co-ordinated by the Biological Records Centre (BRC) in Britain, provide data for species distribution maps and information on individual sites, particularly valuable for nature conservation. Opportunities exist for other applications using data from such surveys, for example in development and resource planning, and in research. This paper describes recent developments in research uses of data from Britain compiled at the Biological Records Centre, with special reference to data for invertebrates. The applications described are relevant to data for most taxonomic groups, and to similar data from any comparable area where coverage of recording is adequate.

The Biological Records Centre database

BRC was set up in 1964 to map the distribution of the flora and fauna of Britain and Ireland. The development of the Centre during the first 25 years is described by HARDING (1990a) and HARDING and SHEAIL (in press), and the operation of species distribution surveys in the United Kingdom is summarised by HARDING (1990b).

BRC has compiled over 5 million records of the occurrence of more than 9000 species as a computerised database using the ORACLE database management system on VAX computers. The database includes terrestrial and freshwater flora and fauna, and is structured as a series of tables, each table being for a discrete taxonomic group (for example Odonata) or for a selection of species in a group. Each table contains rows (usually one row per record) made up of columns. Each column represents a separate field covering taxon, geographical and temporal information, details of recorder/determiner and in some cases details of habitat, abundance or developmental stage, as appropriate to the scope of the survey. Although much of the database consists of site-relatable information, in some of the earlier datasets (particularly for vascular plants and macro-lepidoptera) geographical information is limited to the 10-km squares of the British/Irish national grids, but more detailed information is often contained in the archive of original field record cards.

The analyses and applications described use only subsets of data from the database, where the geographical information has been summarised to the level of 10-km squares. Most of these analyses are numerical, but can be summarised in the form of national maps. Similar, spatially referenced datasets, on environmental factors such as climate, topography, geology and land use, are held by other units of the Environmental Information Centre. These datasets are being used to aid the analysis of species distribution data and the results can be summarised graphically through the use of a Laserscan Geographical Information System and other automatic cartographic processes.

Changes in the distribution of species

Changes in the geographical ranges of species have been detected for many species. Changes may be caused by, for example:

- altered land-use (leading to loss of one habitat type in favour of another),
- altered management of habitat/vegetation,
- deliberate action to favour or to control a species,
- increased pollution or the amelioration of pollution,
- changes in climatic conditions,
- changes in the ecological requirements of species,
- changes in the genetic make-up of species,
- naturalisation of non-native species.

Examples of species affected by such changes are familiar, although some of the best documented instances are of vascular plants and vertebrates.

The strong temporal component in data from Britain, which results from a long tradition of biological recording by amateur specialists, makes it possible to obtain a measure of the changes in geographical range of many species (see for example authors in HAWKESWORTH, 1974 and in HARDING, in press).

A potential cause of changes in the distribution of species is climate change resulting from a build-up of 'greenhouse gases'. Current climate change models forecast a range of increases in global temperature and the concentrations of gases such as CO_2 and NOx. The Biological Records Centre is collaborating with researchers in ITE and universities to assist the UK programme of research into the potential effects of climate change (see for example WATT, WARD & EVERSHAM, 1990). Much of this work is at an early stage, but a recent paper (HILL, 1991) dealt with aspects of the modelling techniques being developed. By modelling the 'climate space' occupied by a species under present conditions, together with selected environmental factors, it is possible to predict the geographical range of a species under different climate change scenarios (CAREY, in preparation).

Although the developmental work on climate change response modelling has been with data for vascular plants and birds, the models will be applied to data for selected invertebrates. It is widely considered that invertebrates (with generally short life-cycles) will respond rapidly to climate change and evidence from the Flandrian record (reviewed by COOPE, 1979) supports this opinion.

Trends in biodiversity

Maps of the distribution of single species have been a familiar product of data centres, such as BRC, for decades. These maps normally show distribution summarised at the level of grid cells; in the United Kingdom 10-km squares of the national grids are used. Maps of the overall coverage of records have been included in published atlases of species distribution maps, and for some groups these coverage maps have been enhanced to show the number of species recorded in each grid cell used for mapping (see for example the atlas for non-marine Mollusca (KERNEY, 1976)).

Representation of biodiversity in this form is meaningful only if there is good general coverage of recording and if any variation in coverage can be quantified. The map included by KERNEY (1976) illustrates this problem: the species richness demonstrated for Britain confirms the general expectation that southern Britain has more species than the north, but the coverage and species richness shown for Ireland is very patchy and reflects recorder effort rather than true richness.

Recorder effort

In assessing the results of national surveys, the effects of recorder effort and bias are inadequately understood. Particular aspects of variation in recorder effort are discussed by PRESTON & EVERSHAM (in preparation) and HARDING (1991b).

Recording by volunteers tends to favour accessible sites with semi-natural vegetation and sites likely to be rewarding for uncommon species. Remote sites, or those with degraded habitats, are less frequently visited. For sufficiently detailed datasets it should be possible to quantify recorder effort at a site using several criteria:

- number of different recorders who visited,
- number of dated visits,
- time of each visit,
- length of each visit,
- weather conditions at time of visit,
- habitats sampled at each visit,
- sampling technique,
- species sampling bias of recorder,
- competence of recorder.

In reality, few of these variables are recorded except in very specialised surveys. One approach being developed at the Biological Records Centre is based on the numbers of visits to a site/area, a statistic which is included in most data sets. This simple count may be refined by weighting for 'recorder competence', which may be quantified by categorising species according to ease of recording, then ranking recorders by the number of records of each grade of species that they have provided. The values may be calculated regionally, which can remove the effects of underlying patterns of species-richness.

Species richness mapping

Using datasets (from Britain only), in which coverage is known to be good, species richness mapping techniques have been developed as part of an undergraduate training project. Scales of richness, using a range of symbols to indicate the number of species recorded per 10-km square, can be varied and mapped. These maps can reveal patterns of species richness and can reveal broad trends in the biodiversity of a taxonomic group (Fig. 1) or of a suite of ecologically associated species (Fig. 2). For most taxonomic groups in Britain, the general trend is for a gradient of species richness from south-east (high diversity) to north-west (low diversity). This trend follows the gradients of the main environmental factors such as temperature, insolation, rainfall, topography, geology and soils, and also of land use.

Data smoothing

One of the programs developed during work on species richness mapping was for 'smoothing' of data by averaging the number of species recorded over blocks of 10-km squares. Each individual 10-km square takes the mean species richness of itself and the 8 or 24 adjacent 10-km squares in a block of 30 x 30 km or 50 x 50 km (Fig. 3). The technique is conceptually similar to that employed in the classification of remote-sensed imagery, for example of land use. The program can be applied to single species to provide a measure of the probability of a species occurring in any given 30-km or 50-km square. Having 'graded' the potential occurrence of a species, it is possible to select contours to represent the range-edge of a species.

Biodiversity 'hotspots'

Development of species richness mapping techniques, and of a means of smoothing data which help to suppress the effects of irregular recording effort, reveal broad trends in biodiversity and have opened up new areas for research.

There are certain sites or areas which are apparently much richer in species than the surrounding countryside. In some cases this may be due to a unique and often very stable history of land use, an unusual diversity of habitats in a small area, a long history of survey and recording,or any combination of these factors. In addition there are areas, detectable at the level of 10-km squares, which apparently are unusually rich in species for other reasons, possibly due to topographic and/or local climatic reasons. Fig. 1 illustrates a selection of 'hotspots' for butterfly species-richness. Areas 1, 2, 5 and 6 appear to be genuinely richer than their surroundings, due partly to topography (1, 2 and 5 contain many south-facing slopes), and partly to the presence of semi-natural habitats of long continuity. Area 3 has been thoroughly recorded for over a century, due to its proximity to a centre of population (the town of Doncaster), and so shows an accumulation of records over time. Area 4 was the home of a very active and competent recorder, and may represent a recorder-effort artefact. Further research on these 'hotspots' is being undertaken at the Biological Records Centre.

Biotope Preference Database (BPD)

In the course of research on the effects of climate on invertebrate distributions, species richness mapping has emphasised the coincidence of species range edges and even concurrent changes in the range of ecologically associated species (EVERSHAM, unpublished).

To investigate the possible role of climate in determining the distributions of species occupying the same habitat, a Biotope Preference Database has been compiled from existing British published sources. The information derived from the literature has been supplemented and validated by relevant taxonomic experts.

Content of the Biotope Preference Database

The database originally contained only invertebrate groups: Mollusca, Macrolepidoptera, Odonata, Orthoptera, Chilopoda, terrestrial Isopoda, Diptera (Dixidae, Sepsidae), Coleoptera (Coccinellidae, Staphylinidae (part)) and Hirudinea, drawn from readily available computer data sets.

Habitat data were later entered for the breeding birds and selected vascular plants. The use of a broad range of groups for each biotope lessens the effects of recorder effort, because of the low level of correlation of activity between botanists, entomologists, ornithologists, etc.

Habitat information is given for each species in the dataset two formats: firstly, the principle overall habitat preference, then a series of coded habitats in which the species is also known to occur, in descending order of preference. It was not possible to enter a single preferred habitat for eurytopic and/or ubiquitous species such as *Pieris rapae* (L.) or *Oniscus asellus* (L.).

Sources are cited for each species examined. For each invertebrate species its rarity is also given following BALL (1986). Maps of species-richness of nationally scarce and Red Data Book invertebrates can thus be produced.

At the outset, a habitat classification scheme had to be devised. Authors of taxonomic works use descriptive habitat terms which are tailored to the needs of their particular group; no standard classification exists. For the Biotope Preference Database, a general all-inclusive classification was used, which broadly reflected the quality of information available in the literature. This comprised 14 main habitat categories, such as woodland, grassland, wetland etc., most of which had numerous qualifiers, such as calcareous, upland, coastal, etc.

During the preliminary analyses using the BPD, two simple criteria were used to select usable habitat types. These were: that the habitats support an adequate number of species, with a high degree of specificity; and that those species represent a broad taxonomic range i.e. with no one group dominant (to minimise recorder effects). The 9 suitable habitats used in the preliminary studies are:

Wetland,	fen
	bog
	salt marsh
Woodland,	deciduous
Grassland,	calcareous
	neutral/acid
Heathland,	lowland
	upland/moorland
Sand dune.	

Biotope maps of each of the above habitats have been produced; the Lowland Heath map is shown.

However, successful as these maps may be, they are based entirely on literature searches: none of these habitat maps has yet been thoroughly ground-truthed, nor has strength of the affinity of a species for a habitat been examined in detail. No allowance has been made for regional variation in habitat occupancy (e.g. THOMAS *et al.*, 1989).

To test the appropriateness of the inclusion of certain species within a habitat category, their affinity with other members of the habitat assemblage was tested by measuring the proportion of other habitat indicators with which a species was found to co-occur.

The results for a moorland moth, *Celaena haworthii* (CURTIS), are shown in Fig. 4a. This species appears to co-occur with species from many different habitats, and is at least as well correlated with woodland as it is with moorland. This first comparison takes no account of the distribution and frequency of each habitat in the countryside. The pattern must be compared with the mean proportion of habitat indicator species found in each square (Fig. 4b), which provides a baseline against which the habitat affinities of a species can be judged. If *C. haworthii* were distributed randomly with respect to the habitats in question, it would be expected to co-occur with the national mean proportion in each habitat. If it has a real affinity for a habitat, it will occur with more than the national average proportion. Adjusted habitat affinities are shown in Fig. 4c. They show a high habitat affinity with moorland, a strong affinity for lowland heath and bog (two closely related habitats), but a negative correlation with all the other habitats.

Further methods for assessing the success of the BPD by comparing with actual site lists are discussed later under Validation.

Species frequencies in different habitats

Having defined assemblages of species typical of each broad habitat type, it is possible to assess differences in species frequencies in different habitats. For example, in a habitat such as a saltmarsh, defined by a single over-riding physicochemical characteristic, there is an all-or-nothing of species occurrence: a site either contains a large proportion of the typical salt-marsh species, or none at all. Conversely, many habitats accumulate species gradually: few sites contain the full range, and much of the wider countryside supports just one or two species.

Validation of the Biotope Preference Database

The accuracy of the literature search used in compiling BPD has been tested by reference to actual field data. Sites were selected which contained a single main habitat, and which were well recorded for a wide range of groups. The number and proportion of habitat indicators, classified by the BPD, was calculated for each site. A few examples are shown in Table 1.

Table 1. Proportion of habitat-indicator moths recorded at selected sites

	Spurn Point	Borth	Wicken Fen	Arne Heath	Castle Eden Dene
Grassland	40.7	8.6	33.3	12.3	19.8
Heathland	8.3	6.9	9.7	15.3	1.4
Coastal	39.3	0.0	5.4	12.5	3.6
Wetland	28.9	10.5	50.0	10.5	13.2
Fen	25.0	0.0	75.0	12.5	16.7
Woodland	17.3	8.3	24.4	22.4	24.0
Cultivated	47.4	5.3	39.5	26.3	26.3
Ubiquitous	96.3	29.6	96.3	59.3	81.5

Conclusions

National species distribution surveys are a valuable resource of data for research on the factors influencing the occurrence of species. Through the analysis of spatial and temporal information, changes in the distribution of species (for example over the last 100 years) have been detected. Many changes are known to have occurred as a result of changes in land-use or of management practices within the same land-use type. As a result of research on the possible effects of climatic changes on wild fauna and flora, past changes affecting ecological assemblages of species have been detected. Using the broad taxonomic coverage of datasets held by the Biological Records Centre, and a newly compiled Biotope Preference Database, it will be possible to examine these changes in more detail.

Within the matrix of species richness in Britain, determined largely by environmental factors such a climate, topography and geology and by land-use, some areas of greater biodiversity are apparent across many taxonomic groups. The causes of these 'biodiversity hotspots' are to be investigated as part of a research programme being developed at the Biological Records Centre and involving several universities. This programme is also investigating the influence of variable recorder effort and bias on apparent patterns of biodiversity.

A multidisciplinary data centre, such as the Environmental Information Centre of which the Biological Records Centre is a component, is able to provide the range of resources necessary to analyse and interpret the distribution of species using modern statistical, data management and data display techniques. Analyses of data on species, such as those described, augment the results of more intensive and specialised surveys commissioned for wildlife conservation and environmental planning.

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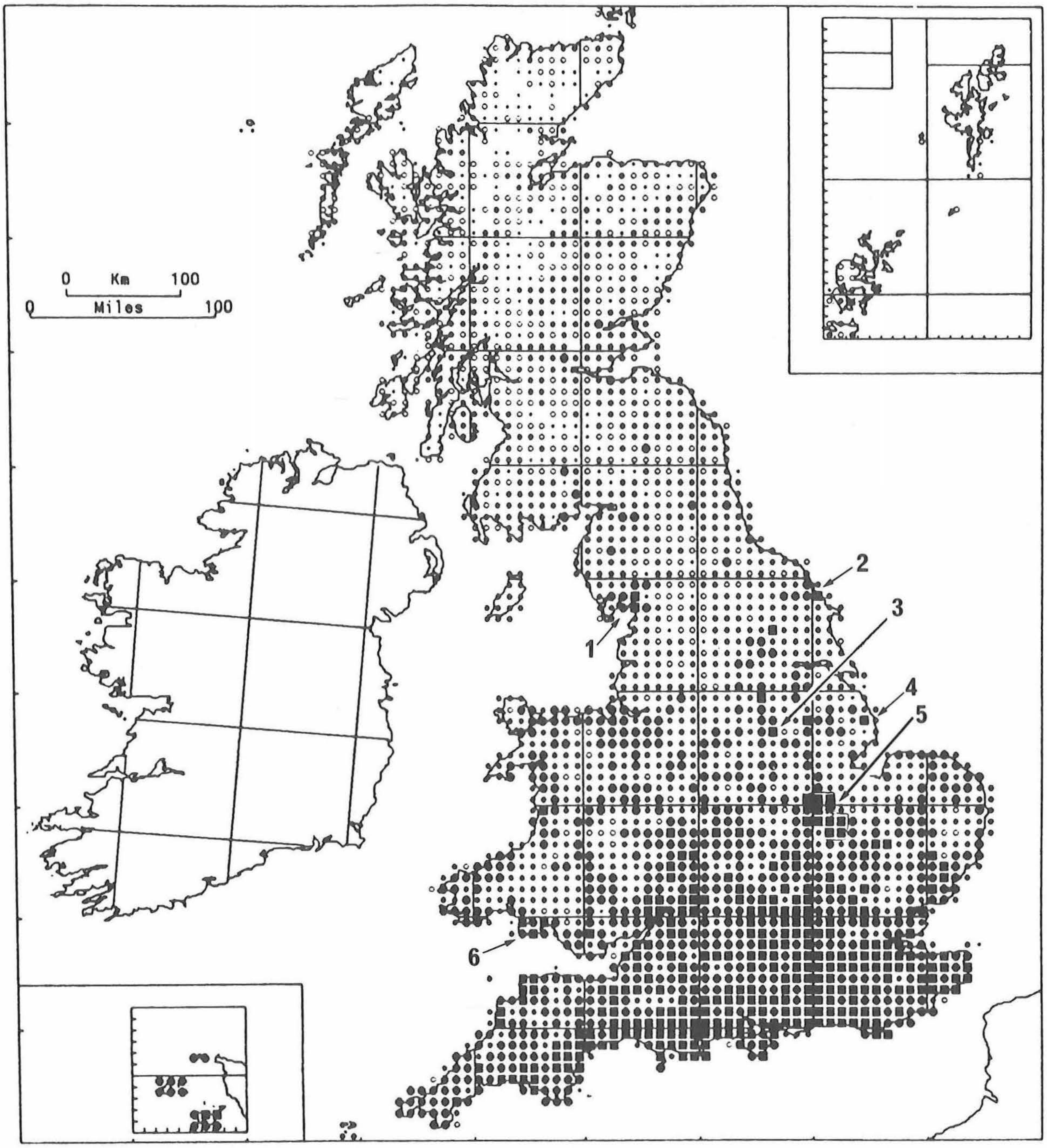
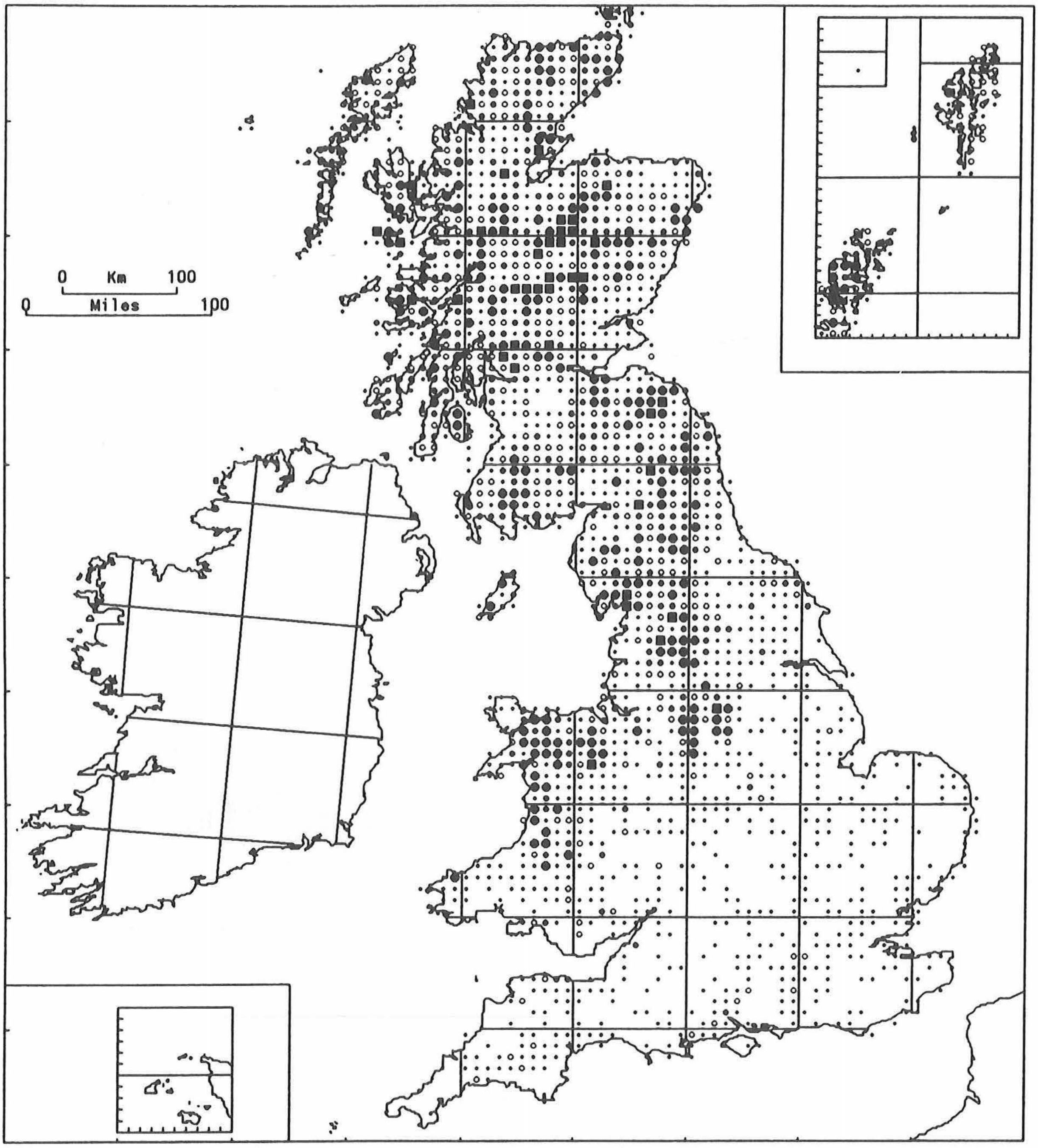


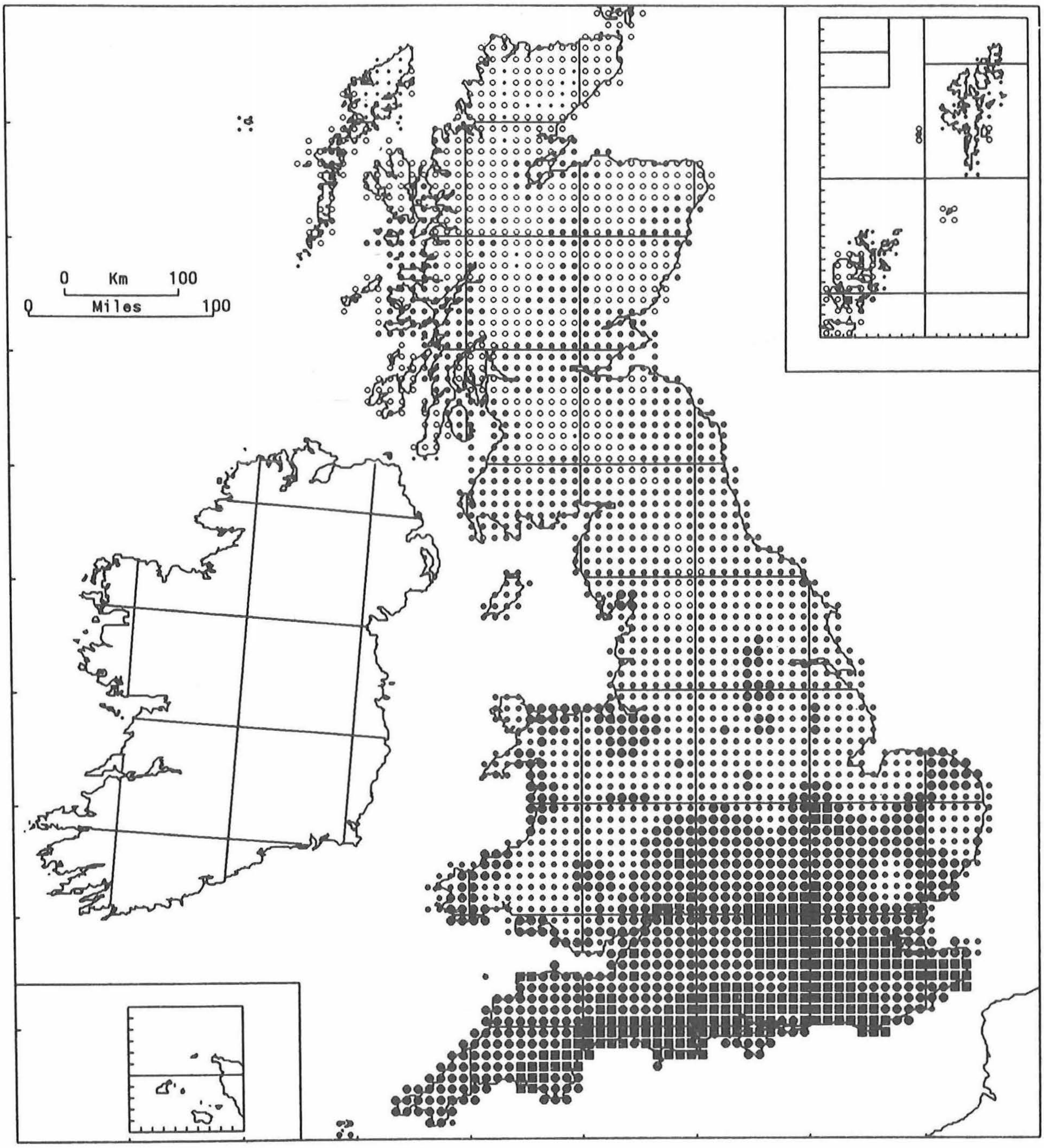
■	37+	species (>100%) 10.85%	(GB-292, Ir-0, Ch.Is-2)
●	25-36	species (89.04%)21.67%	(GB-589, Ir-0, Ch.Is-12)
•	10-24	species (67.37%)40.27%	(GB-1068, Ir-0, Ch.Is-0)
○	4-9	species (27.10%)18.23%	(GB-487, Ir-0, Ch.Is-0)
·	1-3	species (8.87%) 8.87%	(GB-234, Ir-0, Ch.Is-0)

Fig. 1. Species richness of butterflies in Britain. Scaled symbols indicate the number of species recorded in each 10-km square of the British national grid.
Areas marked 1 to 6 are recognisable biodiversity 'hotspots'.



■ 17+ species(10%) (GB-40, Ir-0, Ch.Is-0)
● 10-16 species(27%) (GB-213, Ir-0, Ch.Is-0)
• 7-9 species(20%) (GB-298, Ir-0, Ch.Is-0)
○ 5-6 species(20%) (GB-382, Ir-0, Ch.Is-0)
· 1-4 species(23%) (GB-1133, Ir-0, Ch.Is-6)

Fig. 2. Species richness of an assemblage of species which are characteristic of wet moorland in Britain. Scaled symbols indicate the number of species recorded in each 10-km square.



■ 37+ species (GB-232, Ir-0, Ch.Is-0)
● 25-36 species (GB-657, Ir-0, Ch.Is-0)
• 10-24 species (GB-1222, Ir-0, Ch.Is-0)
○ 4-9 species (GB-621, Ir-0, Ch.Is-0)
· 1-3 species (GB-109, Ir-0, Ch.Is-0)

Fig. 3. Species richness of butterflies in Britain, smoothed over groups of 9 adjacent 10-km squares, showing the average number of species in each square using scaled symbols.

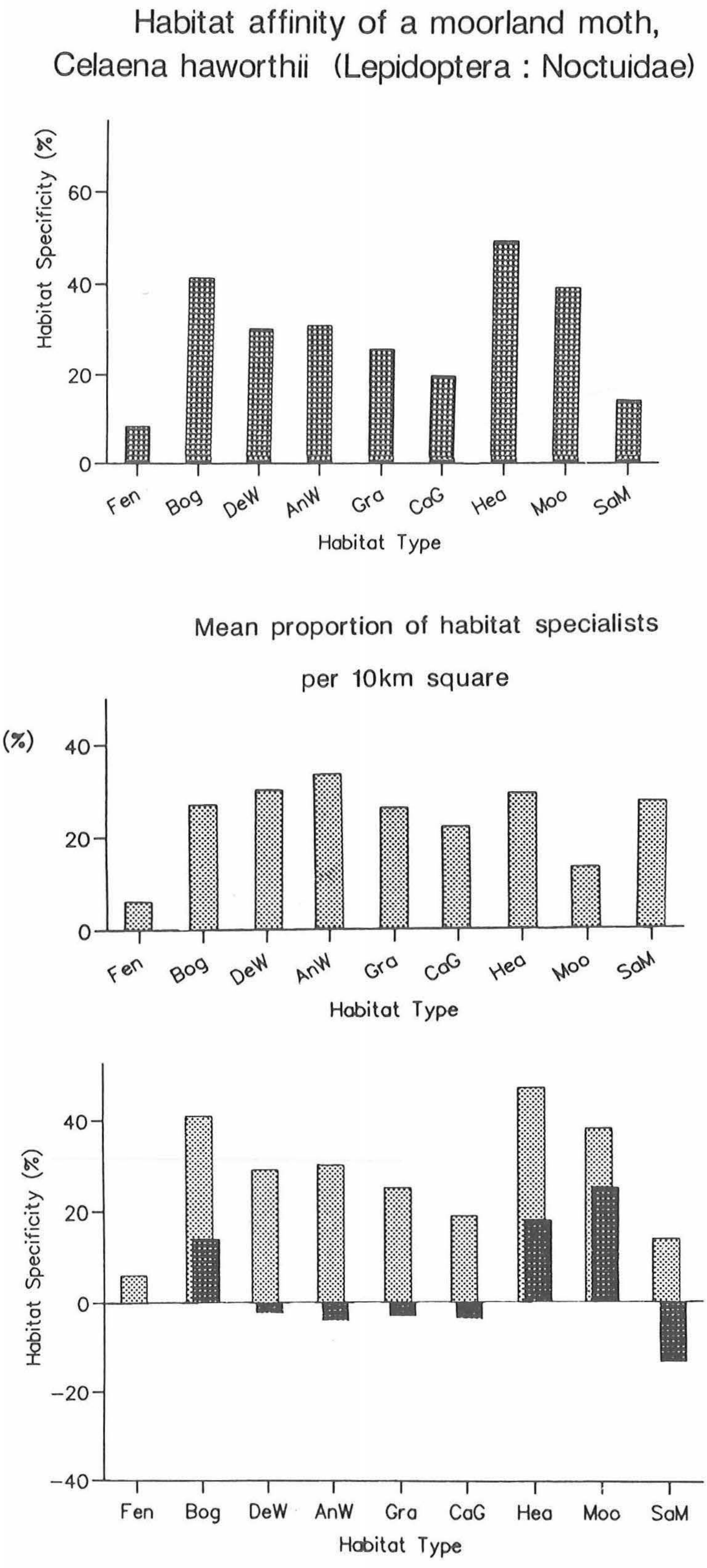


Fig. 4. Habitat affinity of a moorland moth, *Celaena haworthii* (Lepidoptera: Noctuidae). For explanation see text.