Species inventories as ecological databases in a Geographical Information System

by John R. HASLETT

Abstract

The acquisition of lists of species present in a particular area has always been an important aspect of field biology. However, the ecological usefulness of such inventories has proved to be extremely variable, and depends on a number of factors. These may be listed as follows:
a) The size of the area under consideration and the scale of the work
b) Habitat heterogeneity within the area
c) habitat heterogeneity of the surroundings
d) Spatial accuracy of the field observations
e) The availability of supplementary information (relative abundances, known biology, etc.)
f) The aims of the work and the type of analysis undertaken.
One way in which all these parameters may be taken into account is through the use of a computerised Geographical Information System.

Key-words: Geographical Information System, species inventories, distribution patterns, scaling, habitat heterogeneity, Syrphidae.

Introduction

The title of this Colloquium, "Faunal inventories of sites for cartography and nature conservation", draws attention to an inherent and certainly very important aspect of field recording of organism presence: the information is spatially referenced and can thus be directly related to some form of map. Unfortunately, whether the data are used to study the variety of sites at which any particular species occurs (distribution patterns), or to study the range of species occurring at any specified site (inventories), failure to select the appropriate forms of data storage, analysis, display and interpretation continue to severely limit the scientific value of the work. These difficulties have taken on a new and deeper significance since increased ecological and environmental awareness have provoked the use of species distributions and inventory lists as evaluation methods in various site management and conservation issues (see, for example, GOLDSMITH, 1991).

This shift in perspective, from merely descriptive to functional and applied ecology, has coincided with major advances in computer technology that can provide solutions to the problems, but that have been only partially taken up by biologists. Computerised Geographical Information Systems (GIS) interface a sophisticated graphics programme with a powerful data management system. The graphics option allows "layers" of digitised cartographic data to be viewed in any combination across a theoretically infinite range of scales, while the information database provides for the storage and manipulation of non-graphical details associated with particular map features. An introduction to GIS function and its relevance to ecology is given in the review article by HASLETT (1990) and in HASLETT (in press).

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To appreciate the range of advantages offered by Geographical Information Systems for biological recording, it is necessary to examine the precise nature of the problems associated with the more conventional methods that presently limit the usefulness of inventory-type data. Much of the difficulty may, in fact, be attributed to a single phenomenon: spatial scaling.

Problems of scale

The importance of scaling to ecology is now rather well known, to the extent that the term "scale" has been referred to as a "new ecological buzzword" (WIENS, 1989). The relevance of scaling to species inventory work has not so much to do with technical cartography (although this is clearly a part), but rather with the definition of a habitat and how habitats are perceived by animals other than ourselves.

If a piece of landscape is examined at different scales (different "magnifications" if you like), different levels of heterogeneity and complexity are revealed. Thus for example, a woodland that looks rather homogeneous to us is certainly a very heterogeneous habitat mosaic to a small beetle or fly. Yet this fact is rarely taken into account during the planning or execution of distribution and inventory studies. Species distributions and habitat preferences still tend to be described under human terms of reference, even though these may be irrelevant to the ecology of the species concerned. The situation is made even more difficult when it is remembered that for practical reasons, as the size of the area under consideration increases, the accuracy with which the study is portrayed (the "grain") tends to decrease (WIENS, 1989). Quite apart from the loss of information, this ultimately promotes the continued acceptability of inexact field recording and poor input data quality.

Given these problems, How can a GIS help to improve matters? To answer this I turn to an example, the case of the European hoverfly (Diptera, Syrphidae) fauna.

Hoverfly faunas in a GIS

Syrphid flies are the subjects of a National species distribution survey in the United Kingdom, based on a standardised recording card input and a 10 km square grid map covering the country. Such a system is used to record a variety of different groups of organisms in the UK, and is clearly described by HARDING (1991).

Under this conventional system of biological recording in Britain, records of syrphids appear as a single large dot signifying presence within a grid square. From this, some large-scale trends in distribution patterns can be elucidated (for example, *Eristalis rupium* appears to be mainly confined to mountainous areas of Britain, see ENTWISTLE & STUBBS (1983)), but the maps themselves provide no information about frequencies of occurrence, habitat usage and preferences, or any of a host of other important ecological parameters. For this the worker must endeavour to extract whatever limited information is available from a separate part of the database. The result is then a summary of the present knowledge of the species as seen from the human viewpoint. This is perhaps interesting for the insect collecting fraternity, but is of little further value.
If the same recording were to be undertaken within the framework of a vector-based GIS in which selected environmental information was already available, a whole range of *new* ecological

information may be obtained; this in addition to a substantially increased data handling efficiency. Within the GIS, the species records are treated as a separate layers of cartographic data. The sites of records may be specified as points, or be given as lines or areas defined by the user, at any scale. The information may be superimposed upon maps of any other spatial variables or attributes included in the system (altitude, slope, vegetation cover, soil type, etc). Thus the GIS can be made to act as a sieve, sorting records of species according to any of the other mapped variables at a *relevant scale* within the limitations of the original data input. This has not yet been done for syrphids, but it would make it possible, for example, to identify the set of specific habitat conditions with which any particular species or group of species is most frequently associated. It would also allow extrapolations in the form of maps of potential occurrence in other areas. Alternatively, the system may be used to obtain inventory lists of species found within specified areas or combinations of habitat variables. Of course, non-cartographical information, such as relative abundances or life cycle stage may also be included in the analyses.

Such GIS-orientated distributional research has not yet been realised at the National level within Europe, but it is by no means hypothetical and is already well under way within National Parks and other protected areas in Germany, and is now also beginning in the Austrian Hohe Tauern National Park.

In Germany, in the Berchtesgaden National Park, other work on syrphid faunas provides an illustration of some further capabilities of the GIS when applied to inventory studies. In this instance, the computer system was used to provide the framework for a comparative study of the hoverfly faunas of different montane meadow habitats, the aim being to determine the overall sensitivity of the group to changes in habitat type and quality, as reported previously for ski slopes (HASLETT, 1991). The GIS was employed first to define and select standardised habitats in the field, such that each site differed from the others in only a few, predefined parameters. Syrphids were collected from these sites using Malaise traps (represented by points in the GIS) and the resulting species lists and relative abundance data were interpreted by referring to the habitat mosaic of the region, within the "catchment area" of each trap (defined, for practical purposes as a circle of radius 300 m, with the trap as the centre) and also in the surrounding landscape. The scale employed (1:10,000) was sufficient to distinguish between major plant community types and small landscape features within the meadows, so was of relevance to the behaviour of the flies under investigation.

The results of this work indicate that at constant altitude, habitat heterogeneity within and outside the collecting sites, together with vegetation type and aspect of slope, are important in determining the spectrum and relative abundances of species occurring at any site (HASLETT, in press and in preparation).

Concluding remarks

Clearly, the two examples outlined above are somewhat different in their aims and approaches, but it may be noted that the GIS principles involved apply equally to both. Certainly Geographical Information Systems exist in both raster (grid square) and vector (points, lines and areas) forms, and in some circumstances, particularly where a very large area has to be covered, or where the central aim is purely to monitor rather than to interpret species distributions, a raster system using remote sensing data may prove sufficient. However, even here, care must be taken to select a working scale relevant to the organisms being studied, and to take account of the influence of surrounding habitat types. With any GIS, the accuracy of the analyses and the correct interpretation of the results relies heavily upon high quality data input and an appreciation of scaling phenomena. The variety of factors that can lead to inaccuracies in spatial data are dealt with by GOODCHILD & GOPAL (1989).

Despite these and other shortcomings, it may be predicted that GIS will become a normal way of using maps in the near future. The present move towards the use of GIS-based recording within protected areas is an excellent starting-point from which to expand. It is the protected areas worldwide that are now acting as centres for research on natural ecosystems, and it is to these same areas that we already look for guidance in making management decisions. The Geographical Information System is an essential, if still slightly expensive, tool for all concerned!

Acknowledgements

I thank Professor Hans ADAM for his support in recent years in Salzburg. My work on syrphids in the Berchtesgaden National Park was financed by the "Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen."

References

ENTWISTLE, P.F. & STUBBS, A.E. (Eds), 1983. Preliminary atlas of the hoverflies (Diptera: Syrphidae) of the British Isles. Biological Records Centre, Monks Wood, England.

GOLDSMITH, F.B. (Ed.), 1991. Monitoring for conservation and ecology. Chapman and Hall, London, 275 pp.

GOODCHILD, M. & GOPAL, S. (Eds), 1989. The accuracy of spatial data. Taylor & Francis, London.

HARDING, P.T., 1991. National species distribution surveys. *In*: GOLDSMITH, F.B. (Ed.), Monitoring for conservation and ecology. Chapman and Hall, London, pp. 133-154.

HASLETT, J.R., 1990. Geographic Information Systems: A new approach to habitat definition and the study of distributions. *Trends in Ecology and Evolution*, 5: 214-218.

HASLETT, J.R., 1991. Habitat deterioration on ski slopes: A comparative study of hoverfly (Diptera: Syrphidae) assemblages occurring on skied and unskied meadows in Austria. *In*: RAVERA, O. (Ed.), Terrestrial and aquatic ecosystems: Perturbation and recovery. Ellis Horwood, Chichester, pp. 366-371.

HASLETT, J.R., in press. Geographische Informationssysteme und die künftige Entwicklung ökologischer Theorien. *Verhandlungen der Gesellschaft für Ökologie*, Band XX, 1990

WIENS, J.A., 1989. Spatial scaling in ecology. *Functional Ecology*, 3: 385-397.

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