*"An 'expert system' approach to development of decision tools for use in maintenance of invertebrate biodiversity in forests"*

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**Introduction**

There may be as many as 50,000 invertebrate species occurring in Europe's forests. Whatever the exact figure might be, it is a daunting number, and biodiversity is a holistic concept, embracing all living components of the ecosystem and, in the present context, all of Europe's forest invertebrate species. Nonetheless, it is unrealistic to imagine some approach to handling this wealth of organisms that would deal with them all, at this point in time. Attention inevitably turns to ways of using subsets of the fauna, in order to make some sort of progress. Many and varied are the approaches that have been adopted, but between them they offer little encouragement that they can provide answers to biodiversity issues NOW, or that they could evolve into predictive tools, allowing us to recognise forestry management decisions with potentially disastrous consequences to biodiversity or what we might expect to achieve by proactive biodiversity management. Attempts made to apply ecological theory to the problem are particularly disheartening. The tendency for ecologists to inhabit separate conceptual universes, untroubled by each other's conflicting paradigms, is well argued by Austin *et al* (1999).

One approach that does offer both rapid application and a diagnostic i.e. predictive capability in respect of invertebrates is the "expert system". Based on computerisation of available data about the individual species of particular taxonomic groups and taking macrohabitat, microhabitat of developmental stages, various traits and distributional data categories as variables, the expert system approach leads to compilation of databases that can be interrogated in various ways. Codification of species traits has a long and respectable history in ecology, as shown by Statzner *et al* (2001). But codification of macrohabitat and microhabitat data is a more novel development. The particular advantage of an expert system is clear from its Oxford English Dictionary definition: "a computer programme into which has been incorporated the knowledge of experts on a particular subject so that non-experts can use it for making decisions, evaluations or inferences". Information on various aquatic groups of invertebrates has been databased, prompted by use of invertebrates in water quality assessment (e.g. Sladecek, 1973), and various applications of these databases have subsequently been developed (see, for example, Chessman and Royal, 2004; Statzner *et al*, 1997; Usseglio-Polatera et al, 2000). The AQEM system now covers more than 9000 species of European invertebrate (Hering et al, 2004). The more terrestrial organisms have so far received less attention, though there are published databases available for 200 of Europe's gastropod species (Falkner *et al*, 2001) and 600 European species of hoverfly (Speight *et al*, 2003).

## Database anatomy

Digitisation of species' attributes is achieved by use of fuzzy coding (Castella and Speight, 1996), which allows registration of a number of different states of each attribute. In the syrphid and gastropod databases the different states are coded 3, 2, 1 or blank (0). A coding of 3 indicates a maximum degree of association between attribute and species. A coding of 2 indicates that association between this species and this attribute is predicted, while 1 indicates that association is not predicted but can occur under particular conditions. A blank indicates no association between attribute and species. Using this simple system, and generally available software, diverse information pertaining to hundreds of species of invertebrates can easily be both stored and used, creating a situation quite different from that even 20 years ago. The off-putting problem of how to handle the sheer numbers of invertebrate species has gone, to be replaced by problems of which taxonomic groups to digitise, how to gather the available data, what array of attributes to code, etc. All of the species representative of the taxonomic groups chosen can be digitised, since, logistically, there is no need to confine attention to particular subgroups, like threatened species. Choice of taxonomic groups to use is largely dictated by requirements intrinsic to the expert system approach itself, and relevant criteria can be listed.

## Criteria for selection of taxonomic groups

The overall objective of the selection procedure should be to put together a resource of taxonomic groups that between them provide data for all habitats and all structural components of habitats, while ensuring inclusion of plant feeders, predators and decomposers among the groups chosen. Coverage of a notional 5% of the European forest fauna would require data for some 2,500 species. Existing information sources are not immediately obvious, since publications providing the basic data required are rarely referred to in abstraction journals, being mostly located in so-called naturalist or "amateur" journals. Further, specialists in particular taxonomic groups carry in their heads much relevant information that has never been published and its availability can only be recognised through personal contact. One example of a taxonomic group for which an abundance of information exists, but cannot be used effectively because databasing has not been carried out, is the butterflies (Lepidoptera: Rhopalocera). That biodiversity related work on butterflies could benefit from better availability of predictive systems is obvious (see, for example, Bergman *et al*, 2004; Tudor et al, 2004). Limited use has been made of traits coded for part of the European butterfly fauna (Shreeve *et al*, 2001), but the database involved is not published.

1. A primary criterion is that the information available about the species of a taxonomic group under consideration should be sufficient to characterise their macrohabitat associations and their microhabitat associations, for digitisation.

2. Less than 5% of the genera should pose significant identification problems and the taxonomic literature should be readily accessible, even if scattered.

3. Reliable on-site sampling techniques should be available and open to standardisation.

4. Sampling should be effective within short periods, using generally available equipment that does not require daily site visits or direct involvement of experts in sample collection.

5. Processing of samples should be undemanding in terms of labour and facilities.

Availability of data on microhabitat of developmental stages is of significance because developmental stages are rarely accessible to survey, which is thus normally based on adults. Coded microhabitat data links the adults to the habitat components in which they develop. Lack of coded microhabitat data limits the value of biodiversity-related publications on some actively-mobile groups of invertebrates, such as ground beetles (Coleoptera: Carabidae, see, for example Koivula and Niemela, 2003), since without it there is no clear basis for deciding which species developed where they were trapped as adults.

The inclusion of criteria relating to field survey derives from the potential of these databases to be used for comparison between predicted and observed faunas. There is little virtue in selecting for databasing taxonomic groups for which no reliable sampling methodology exists, or that require prolonged field campaigns and daily presence of field workers - the logistic support required for use of such groups on any scale is unlikely to be forthcoming, in terms of either manpower or finance.

**Expert system application in biodiversity maintenance**

Linking, as it does, the names of the species with the macrohabitats and microhabitats with which they can be expected to occur, this type of database reconstructs, within the computer, a model, albeit rather crude and approximate, of the ecosystem. The model is of necessity approximate, being based on use of the categories employed in systems like Corine/Eunis (Devillers *et al*, 1991) as proxies for actual macrohabitats, and on use of structural components of the ecosystem as proxies for microhabitats. It is through this form of ecosystem modelling that this type of database gains its predictive power. And it is its predictive power that makes it a particularly valuable tool in endeavours to maintain biodiversity of forest invertebrates. At their simplest, biodiversity maintenance issues boil down to deciding what role a given piece of land should play in maintaining biodiversity and how this is to be accomplished. Deciding what role it should play is a multifaceted process, but ultimately depends on some form of site quality assessment. From a knowledge of which habitats are available, or in question, this type of database can be used to predict and compare the potential invertebrate biodiversity of different forest habitats, occurring in combination or separately. Augmented by invertebrate site survey data it can be used to compare the expected and observed faunas of a forest. The capacity to facilitate this sort of comparison is probably one of the most generally useful attributes of this type of database, since the coupled microhabitat information helps to identify which structural components of a forest are "underperforming" in respect of biodiversity maintenance and that, in turn, indicates where changes to management practices could be beneficial. An example, involving use of the syrphid database (Speight et al, 2003) is provided by Goeldlin *et al* (2003). The procedure employed combines use of the database and field survey data. Essentially, the databased information is first filtered in various ways, to derive a list of the species predicted to occur in the habitats observed in the target forest, in the part of Europe that the target forest is located. Comparison between the predicted and observed species lists for that forest is then used to establish how well the predicted fauna of the different habitats in that forest is represented. A habitat whose fauna is poorly represented (either in comparison with the fauna of other habitats present, or in comparison with a pre-determined set of target values) may then be further investigated, by comparison between expected and observed faunal occupancy levels of different microhabitat/structural features. Figure 1 shows the results achieved in respect of the same structural features in two very different European forests with very different histories. The Montricher forests data are derived from Goeldlin *et al* (2003), the Bosco della Fontana material from Mason et al (2002). Faunal occupancy levels are generally closer to the expected in the case of Montricher than in Bosco della Fontana, reflecting both management history and degree of isolation of the two forests: see Neet et al (2003) and Mason (2002), respectively.

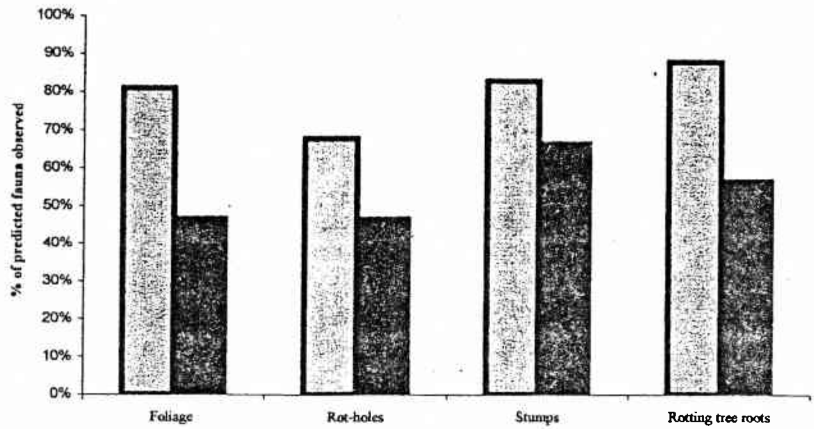


**Fig.1:** Observed faunal occupancy levels for Syrphidae (Diptera), for four structural features (foliage, rot-holes, stumps and rotting tree roots) of particular forest habitat types in two contrasting forests, Montricher, in the Swiss Jura and Bosco della Fontana, on the ancient flood plain of the R.Po, in Italy.

Grey columns: Montricher, *Fagus/Picea* forest

Black columns: Bosco della Fontana, *Carpinus/Quercus* forest

The comparative under-representation of species associated with microhabitats dependent upon old, living trees (such as rot-holes) has led to designation of parts of the Montricher forests as areas where trees will henceforth remain unharvested, so that they may grow old and die *in situ*. In Bosco della Fontana management techniques to augment resources of various forest microhabitats identified as under-represented have been both developed and put in place (Mason, 2003), especially in respect of structural features that support saproxylic organisms (Cavalli and Mason, 2003).

The above is but one, rather basic, example of application of invertebrate information transposed into an "expert system" database. For terrestrial taxonomic groups, databases of this type have been available for less than 10 years and the range of ways in which they are being applied to biodiversity maintenance issues continues to expand, as does the number of countries in which they are employed. It is apparent that they have application at national and international levels, as well as at site level (see Speight and Good, 2003; Speight, 2004). But their very novelty dictates that little is yet published on their use, their existence is not widely known and their potential is as yet inadequately explored. Experience to-date suggests that such a database can operate as an expert system at two levels. Firstly, it can bring all specialists in a taxonomic group covered by the database to the same level of knowledge, while simultaneously providing them with a standardised tool for their use and helping to keep them up-to-date with advances in knowledge of that taxonomic group (the content of the syrphid database, for instance, is annually updated). Secondly, it can provide a tool that can be operated by people who are not specialists in the taxonomic groups covered by the database.

It has often been said that, in Europe, it is difficult to find habitats anywhere below 2000m that have not been modified by human influence. Use of the type of database described here gives a more precise interpretation of the scale of that impact and how management of land in man's interests causes that impact. An inescapable conclusion of its use is that, in forests commercially managed for production of a timber crop, only a reduced invertebrate fauna can be expected to survive. It is difficult to see how maintenance of Europe's biodiversity of forest invertebrates can be achieved within the minute fraction of Europe's forests that are now protected. But, if biodiversity maintenance measures have to be extended into commercial forests, use of this type of database demonstrates that it is not biodiversity maintenance that is required there, but *biodiversity restoration*. With time, some impact can be made on this problem simply by cessation of certain forest management practices (see, for instance, Ranius and Kindvall, 2004). But there is no indication that the necessary resources of man-power, finance and expertise would, or could, be made available to introduce *pro-active management measures* (such as many of those developed by Cavalli and Mason, 2003) aimed specifically at biodiversity restoration.

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