Chapter (non-refereed)

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I INTRODUCTION

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I suspect that most readers of this volume will automatically assume that it is concerned with the mapping of plants and plant assemblages, possibly also touching upon the location of animals and features of topographical interest (mountains, bodies of freshwater whether static or flowing ....). But why shouldn't we also be concerned with the distribution of microbes when it is remembered that the assemblages of parasitic and non-parasitic microbes on plant surfaces (roots and leaves), ecosystems in miniature, are subject to the same natural laws as those more readily and more usually studied by ecologists. Because ecosystems, whether micro- or macro-, have features in common, and because the problems of mapping cryptogams will not be discussed elsewhere, I have decided to highlight some of the main issues of ecological mapping by discussing the distribution, around trees, of toadstools produced by fungi that form sheathing (ecto-) mycorrhizas.

Over the years, I have enjoyed being involved, at one and the same time, with the unstructured approach at weekends of fungus forays, and with the more disciplined attitudes of quantitative microbial ecology on weekdays. However, bearing in mind the effort expended when searching for, and identifying, toadstools associated with trees, a simple statement that x species of fungi were found in a birch woodland - the typical summary of a fungus foray - is, for me, a totally unrewarding outcome. Couldn't something more ecologically worthwhile have been achieved? In 1977, my colleagues and I counted and identified 19 096 toadstools, noting, at the same time, that they were associated with 60 birch (*Betula* spp.) trees in an area of 540 m^2 or 0.054 ha. Thus, with the minimum of additional information, we were able to extend the value of our observations: we were able to quote the occurrence of fruitbodies as numbers per tree (320) or numbers per ha (350 000) (Mason *et al.* 1982).

Even to the uninitiated, it should be perfectly obvious that toadstools are not produced at random (Figure 1). By taking the co-ordinates of every

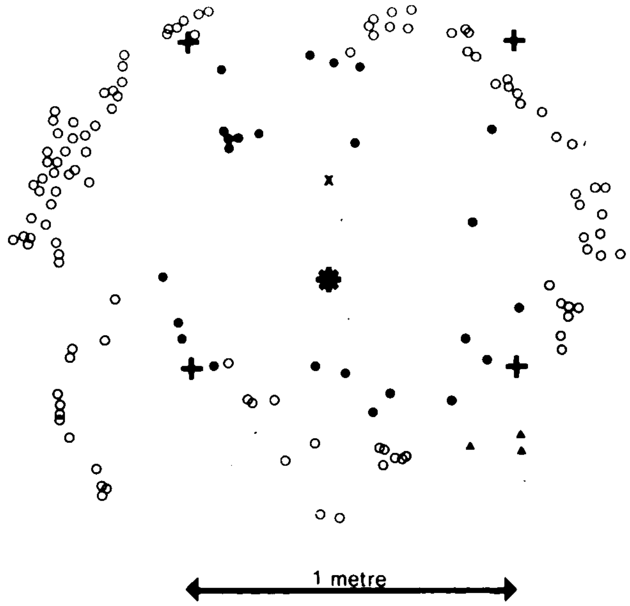

Figure 1 Distribution of fruitbodies of sheathing mycorrhizal fungi in 1977 around one of 60 birch trees (✱ *)* (Betula pendula) *growing at Bush Estate near Edinburgh. (The tree was planted, with others, in 1971)*

o Hebeloma; • Lactarius; x Leccinum; ▲ Ramaria toadstool, it soon became possible, with the help of an appropriate computer program, to show that toadstools of different fungi occupy different spaces. While there were differences from tree to tree, *Hebeloma, Inocybe, Laccaria* and *Lactarius* were usually the most abundant genera, with toadstools of *Hebeloma crustuliniforme*, poison pie, being concentrated in a concentric zone at a distance of 1 m (radius) from replicate birch trees, whereas those of *Lactarius pubescens* were densest at a radius of 640 mm. In contrast, *Inocybe lanuginella* toadstools, like those of *Laccaria*, were more or less equally densely distributed (numbers m^{-2}) except at the periphery of the laterally spreading system of roots. Thus, by taking co-ordinates, it was possible to record and characterize two different patterns of distribution, one of which was subdivided as a result of subsequent analyses. Whereas the toadstools of *Inocybe lanuginella* were randomly distributed within concentric annuli (zones), those of *Laccaria* were conspicuously aggregated to form linear patterns, probably paralleling the environs of secondarily thickened roots which, unlike most roots which become mycorrhizal, are not ephemeral.

At this stage, I would like to summarize what has been achieved. By adding *details of habitat*, in this instance 'numbers of trees' and 'areas occupied' (in other circumstances, details of ground vegetation, soil type, etc, may be added or substituted), the value of the toadstool observations was greatly enhanced - the exercise has become infinitely more rewarding with increased *time-effectiveness*, a major consideration. By punctiliously recording co-ordinates, distributions which are not always obvious to the eye can be identified if the data are held in a form facilitating subsequent analyses. Nowadays, this implies *computer-compatibility*, a desirable objective which can be readily achieved if *data collection* is arranged correctly from the outset.

As I will indicate later, much more needs to be known about pattern, and its analysis, an area of weakness in ecological understanding. I should also draw attention to statistical aspects because I would wish to challenge the need for many of the complete enumerations beloved by conservationists and ecological mappers, among whom I include physical planners.

As it happens, the 60 birch trees already referred to include specimens of silver birch (*B. pendula*) and downy birch (*B. pubescens*) grown from seeds collected at latitudes ranging from 50°N to 66°N. While specimens of *B. pendula* and *B. pubescens* had similar mean numbers of toadstools, appreciably more species of fungi were associated with the former (20) than with the latter (16). Further, and totally unexpectedly, an average of 50 toadstools was associated with trees from seed collected at 55°N but only 2.5 with those from seed collected at more northerly locations, latitude 66°N. This being so, shouldn't the team have taken notice of the benefits of *stratification*, not just as a result of hindsight? We started with 2 species of *Betula* and a range of seed collections made at latitudes sufficiently widely spaced to expect genotypic differences - 'between' and 'within' species differences should have been used as *strata* from the inception of the project (Table 1). The discerning reader would be right to question the necessity to record and identify 19 000 toadstools. However, I have to admit, somewhat ashamedly, that the fungal survey which I have been describing developed like 'Topsy' - a poor way of implementing objective research. Essentially - I was incorrectly going to write ideally - I should have tackled the problems of stratification and subsampling at the outset to minimize the effort needed to acquire data of predetermined statistical reliability. As so often happens in biological research, the data were variable with standard errors increasing with increasingly large means, a statistical aspect having a profound influence on the choice of *transformation*, also of subsampling procedures. To some extent, I would justify some of the deficiencies that I have admitted. The 60 birch trees were planted to form a living gene-bank; they were not planted to enable a study of toadstool ecology. Fortunately, the replicate trees of each seedlot were arranged at random within the experi-

TABLE 1 Effects of seed collections (provenances) on numbers of toadstools associated with *B. pendula* and *B. pubescens* grown at the same site in Midlothian, Scotland (Mason *et al.* 1982)

	Numbers of toadstools per tree					
	1975	1976				
Origin of seed	TOTAL	*Laccaria*	*Hebeloma*	*Inocybe*	*Lactarius*	TOTAL
I *Betula pendula**						
Lat. 57°N	219	76	287	11	10	384
Lat. 66°N	Nil	Nil	Nil	Nil	Nil	Nil
II *Betula pubescens**						
Lat. 52°N	231	23	359	Nil	15	397
Lat. 61°N	Nil	Nil	16	Nil	Nil	16

*seedlings transplanted to the field in November 1971

mental plot, and this design enabled the toadstool survey to be made without fearing that differences were attributable to positional effects, as would have been the case had replicate trees been grouped. Nevertheless, the experience emphasizes the need to think and rethink the objectives of making a survey, whether utilizing pencils and rulers or the most sophisticated forms of imagery. Why is a particular survey being made? Are the data being abstracted in a way that is generally useful? Do we need to have complete enumerations, or will a reliable picture be obtained from much less effort directed in a more purposeful manner, eg by following statistically correct sampling procedures?

While surveys, in themselves, are of value, their usefulness is often greatly enhanced if they are made repeatedly, but at what frequency? With hindsight, I think we all regret the paucity, irregularity and very often incompleteness of surveys made in the past, whether statistical surveys, the preparation and revision of traditional maps, the procurement of aerial photographic records (using fixed-wing aircraft or satellites). We have been slow to appreciate the worth of monitoring, necessitating repeated surveys, and often suffer as a result from an inability to reconcile the results of sequential surveys made using different methods. We have regrettably deprived ourselves of the opportunity of learning as much as we should from past management changes. For the future, I believe much more thought needs to be given to the ways in which our environment, and changes in our environment, are recorded. However, without considering how the potentially vast accumulations of data will be handled, this exercise would be worthless. Why monitor? - a good question. For the last time, I would like to revert to the plot of birches. As a result of sequential surveys, it was found that the toadstools of the slower spreading *Lactarius pubescens* were about the same mean distance from the trees in 1977 as were the toadstools of the more rapidly spreading *Hebeloma crustuliniforme* 2 years previously. By superimposing the relevant sets of data, a task aided by the use of markers, it was found, not without surprise, that the spaces 'occupied' by *L. pubescens* in 1977 were not those occupied by *H. crustuliniforme* in 1975 (Ford *et al.* 1980). The superimposed distributions suggest that there is a very considerable degree of mutual exclusion between the 2 fungi, a feature of their ecology that was not foreseen. How many other exciting and totally unexpected phenomena will be revealed by monitoring? We tend to forget that ecosystems, both micro- and macro-, are dynamic. Their components are constantly changing, but our methods of surveying must retain a degree of constancy, whether using simple and often disarmingly effective methods, or resorting to the excitements of sometimes ill-considered sophistication.

But, irrespective of method, I would, in summary, stress the virtues of:

1. enumerating objectives,

2. attempting to be time-effective: consider the benefits to be obtained from statistical procedures, subsampling by strata (stratification), enabling confidence limits to be calculated in a rational manner,

3. making repeated compatible surveys so as to assess temporal and spatial changes,

and, finally,

4. ensuring that data are collected in a form, in most instances computer compatible, that facilitates their subsequent analysis.

We are not here to decide "Which is the best technique?" Instead we should aim to learn the strengths and weaknesses of a variety of techniques so as to be in a position to match them against the requirements of our objectives.

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