Field and Laboratory Exercises in Ecology

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Preface

The aim of this book is to show how modern numerical techniques in plant and animal ecology can be used practically at school, college and undergraduate level to demonstrate many of the fundamental principles of the subject. Ecology is becoming increasingly quantitative but the application of this approach to practical classes is often restricted by timetables, availability of materials, size of classes and the need for lengthy preparation time. The exercises presented here are intended to show how practical ecology taught at this level need not suffer from the above restrictions and need not be confined to descriptive studies, while still fitting into a practical period of three hours or less.

Ecology is by definition a field subject but there are analytical elements which are well suited to laboratory investigation and simulation. In fact, most ecological investigations need a laboratory as well as a field component, as reference to modern journals will show. The arrangement of exercises in this book reflects this balance; they are presented in complementary field and laboratory pairs, each exercise of the pair using organisms and techniques according to the restrictions imposed by the experimental conditions and the aspect of the topic being investigated. For instance, in a pair of exercises on the dynamics of predation, the laboratory investigation concerns a simulation of the short-term behaviour of searching predators while the field exercise concerns the longer-term and larger-scale numerical response of predators to changes in the numbers of their prey. In the latter case, only a field approach provides the necessary realism.

As an introduction to each pair of exercises, the fundamental principles on which they are based are summarized. In each case this is followed by sections in which *apparatus, preparation* and *procedure* are described in detail for each exercise. A common *discussion* and *conclusions* section interprets the data collected and the reader is referred to published work to enable the results to be considered in a wider ecological context. This 'packaging' of exercises is a deliberate attempt to allow students to collect data from which meaningful ecological conclusions can be drawn in the limited time available. Such a guided discovery approach has been a frequent demand from teachers and lecturers in recent years. Many of the exercises incorporate modern ecological themes in a practical way for the first time at this level and a wide range of numerical techniques is employed. Through the inclusion of up-to-date introduction and conclusion sections the book is intended to be of use as a student manual rather than a teachers' guide.

Fifty-six exercises are described in detail, but in addition each pair is followed by a number of suggestions for related investigations so that the book contains almost two hundred workable practical ideas. Many of these are suitable for expansion into small research projects or for use on field courses when more time is available. With a little modification and extra preparation, many of the field exercises could be made into laboratory practicals.

The exercises are arranged in five subdivisions of the subject which obviate the often artificial segregation of plant and animal ecology: sampling, spatial pattern, populations, population interactions and community ecology. Each of these sections is preceded by a brief introduction which shows how the exercises relate to established work, but which for reasons of space is not an attempt at a full introduction to that ecological field.

Organisms used in these exercises all occur in Britain but related species in other temperate regions can easily be substituted without affecting the fundamentals of the methods. The choice of organisms and exercises is obviously biased towards our research and teaching interests, but in spite of this restriction the book includes exercises on fungi, algae, higher plants, crustaceans, insects, molluscs, birds and mammals. Wherever possible, procedures have been explained without the use of worked examples as these often give the impression that there is a 'correct' answer. Obviously the details of the results will change according to experimental conditions, so algebraic notation is used instead and the expected general trend of the results is indicated in the discussion. The appropriate statistical techniques are suggested for the analysis of results in each exercise and readers are referred to statistical textbooks (Bailey, 1959; Parker, 1979) for the detailed rationale of these tests. In those exercises in which invertebrates have to be identified to order or family, we recommend the illustrated keys in Lewis and Taylor (1967) and Chinery (1973). Field techniques and apparatus about which further information is required may be found in Chapman (1975) (plants) and Southwood (1971) (animals).

We are grateful to our colleagues Drs J. A. Allen and R. J. Putman who provided the ideas for exercises 41 and 43 (J. A. A.) and 55 (R. J. P.), to Mrs S. Meacock for helpful criticism of the manuscript, and to Mrs M. Lovell for doing most of the typing. Mrs J. Clayton agreed to our referring to an unpublished method. We would be pleased to receive comments on the success or otherwise of these exercises, which have given useful results when we have used them!

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Section One

Sampling

Introduction

Sampling is one of the most important yet often neglected parts of any ecological investigation. Since conclusions based on samples are used to make hypotheses about populations as a whole, the sampling procedure must be correct or the generalizations are invalid. Much attention is given to these aspects, for the study of plant populations by Greig-Smith (1964), and for animal populations by Southwood (1971). In this section the emphasis is on the general principles involved in sampling, and their application to a number of selected problems.

For the animal ecologist the problem of sampling is sometimes much reduced by the presence of natural sampling units. These are usually habitat units, for instance trees, dung, carrion, flowers or leaves. In contrast, most plant ecologists are forced to construct artificial sampling units. When this happens we have to decide where to place these units in space and what to record in them, how many are required to reflect the population accurately and sometimes how long the recording should progress.

Data collection procedures should aim to provide the maximum information within the experimental constraints of time, finance and manpower. Obviously no one method could be recommended for general usage since the effectiveness of any method depends on the study objectives and, in particular, the nature of subsequent analysis. However, two stages can be isolated for separate consideration; these are

1 *Sampling Strategies* A sampling strategy defines the sites, i.e. the positions in space, from which records are obtained. Sites are usually defined by reference to spatial co-ordinates but may relate directly to the position of an organism (or part thereof) which may or may not be actually included in the sample, or even the population, under study, e.g. insects per leaf, seedlings in relation to parent trees.

The strategy has a profound effect on the choice and limitations of subsequent data processing procedures. Decisions at this stage include, for instance, whether the samples should be distributed at random, systematically or a combination of both; whether the samples should be taken from one, two or three dimensions; or whether they should be plotless or consist of quadrats.

2 *Sampling Techniques* This stage covers the mechanics of obtaining

plant or animal records from the sample sites. These records may be merely records of 'presence' or some measure of quantity obtained either as absolute values or some estimate derived from sub-samples at each site. Techniques are generally less restrictive than strategies on subsequent data processing. Nevertheless, the type of measure used and the degree of sub-sampling will affect the statistical reliability of the results.

In plant ecology, decisions at this stage are related to the choice of vegetation feature to be recorded. For quantitative records, percentage cover, shoot density, and measures of bulk are commonly used.

In animal ecology the choice of spatial and temporal characteristics to be recorded, the use of baits in traps, marking of individual animals, length of time between samples, duration of a sweep sample etc., is also important.

In this section the exercises aim to provide students with situations which will focus their attention on some of these problems. The selection of which population feature to record and the size of sample required for reliability of the data are examined in some detail.

Exercises 1 and 2

The number of sampling units

Principles

If a large number n (> 30) of sampling units is taken and the numbers of a plant or animal counted in each, it is possible to erect confidence limits around the mean number/sample. Although the true population mean (μ) is constant, the value of the sample mean ($\bar{x}$) varies from one sample to the next. However, whatever the actual nature of the distribution of x (the individual counts), the *central-limit theorem* tells us that $\bar{x}$ is distributed approximately normally around μ.

The standard deviation of the sample means (or standard error as it is often called in this context) can be estimated as

$$\text{SE of sample mean} = \sqrt{\frac{\text{variance of } x}{\text{number of sample units}}}$$

$$\text{i.e.} \quad \text{SE}_{\bar{x}} = \sqrt{\frac{\sigma^2}{n}}$$

When the sample size is large (> 30), the distribution of sample means approximates to normality with a mean μ and the standard error can be estimated from

$$\text{SE}_{\bar{x}} = \sqrt{\frac{s^2}{n}} \quad \text{where } s^2 \text{ is the variance of the sample.}$$

Then from tables of the normal distribution the 95% confidence limits are given by

$$\bar{x} \pm 1.96\ \text{SE}_{\bar{x}}$$

A full account of the estimation of sample accuracy can be found in most statistical texts. Here the emphasis will be on the estimation of the number of sample units required to reflect accurately the population mean. Two examples investigating this aspect are considered: the calculation of the necessary sample size from a pilot sample of insects and the calculation of sample size in a plant community to ensure a representative picture of its species composition.

In the laboratory exercise, for a pilot sample of an insect population the number of samples required (N) may be obtained from the following formula

$$N = \frac{4s^2}{D^2\bar{x}^2}$$

where s^2 = variance of the pilot counts, $\bar{x}$ = the mean and D = the relative error in terms of percentage confidence limits of the mean. For example, if we are satisfied with 95% confidence limits with a range of ±40% of the mean (i.e. a standard error of c.20% of the mean), then $D = 0.4$. The sample size necessary to give an estimate of the population mean within ±40% of the true value is given by the above formula with $D = 0.4$. The formula then simplifies

$$N = \frac{4s^2}{D^2\bar{x}^2} = \frac{4s^2}{0{\cdot}4^2\bar{x}^2} = \frac{25s^2}{\bar{x}^2}$$

See Elliott (1977) for further explanation.

This formula enables the required number of samples to be estimated for a wide range of ecological situations both in animal and plant studies, providing it can be assumed that the data are derived from a homogeneous environment. Although N will vary markedly through the season, it is not usual to calculate it on each sampling occasion so a rough initial estimate is all that is required.

Calculating the number of sampling units required in plant ecology presents similar problems. Where quadrat methods are used to record density or performance it is usual to construct a travelling mean from a pilot survey of 100 quadrats. The mean is calculated for the first 10 quadrats, 20 quadrats, 30, 40 etc. and plotted against quadrat number. Graphs constructed this way resemble that shown in Fig. 1/2.1. From the shape of the graph it is possible to determine when the mean is a reliable value; it is usual to stop sampling when the graph fluctuates within 10% of a mean value.

When, on the other hand, the requirement is to establish whether the sample has accurately reflected the species composition of a community a different approach is necessary. One of the possible approaches is based on species-area curves which are used to define minimal area—the smallest area which can contain the characteristic species complement and structure of a plant community. The concept of minimal area is essential to the understanding of vegetational homogeneity and an important concept for the classification and mapping of vegetation (Greig-Smith, 1964; Hopkins, 1957; Shimwell, 1971). A more recent approach uses the concept of the minimal quadrat number which is obviously related to area. Empirical investigations have demonstrated that the relationship between species and quadrat number provides curves similar to species-area curves and further that the equivalence point (i.e. when the number of species and number of quadrats equate) on the curve can be used to define the minimum number of quadrats required. The curve below the equivalence point represents the zone in

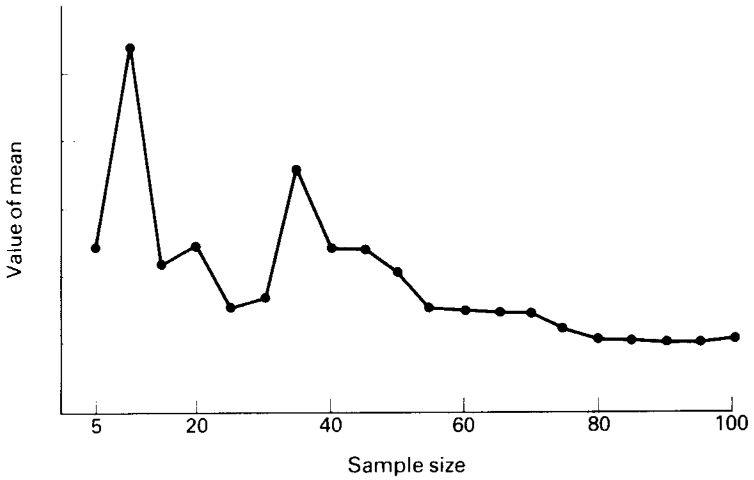

Fig. 1/2.1 A travelling mean demonstrating the reduction in the variation as the sample size is increased (after Kershaw, K. A. (1973). *Quantitative and Dynamic Plant Ecology*, 2nd edition. Edward Arnold, London.).

which species number increases rapidly with respect to quadrat number; above the equivalence point the quadrat number increases rapidly with respect to species number.

Exercise 1
Sampling a population of unknown density

Apparatus

For each student pair: jam jar with screw top containing *Tribolium* (or any small beetle) and *c*. 500 g of finely-sieved (0.5 mm mesh) wholemeal flour; sampling spoon—this can be constructed from a plastic medicine spoon with the bowl bent at right angles to the stem after softening by immersion in boiling water; 0.5 mm and 0.75 mm diameter mesh sieves; paint brush size 00; 2 Petri dishes; single-pan balance (accuracy 0.01 g); large beaker (*c*. 750 ml); plastic cup.

Preparation

From a large stock culture of *Tribolium* transfer several hundred beetles to each jam jar and add flour to half fill. A range of densities from approximately 250 to 1000 beetles per jar has been found suitable.

Procedure

1 Gently roll and invert jar to homogenize the cultures.
2 Weigh the beaker or use the tare on the balance to bring the reading to zero.
3 Carefully transfer culture from jam jar to beaker and reweigh the beaker.
4 Remove singly 20 samples with the sampling spoon—level spoons give an acceptably constant sample—to a Petri-dish where the number of beetles (x) is recorded. Flour and beetles are returned to the culture and mixed after the last sample.
5 Calculate required sample number for 40% (0.4) level of accuracy from

$$N = \frac{25s^2}{\bar{x}^2}$$

$$\bar{x} = \frac{\Sigma x}{n}$$

$$s^2 = \frac{1}{n-1}\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right)$$

where x = no. of beetles taken/sample and n = no. of samples.
6 Using the value N continue sampling until the total number of samples reaches N, if there is enough flour to do this.
7 Calculate the new $\bar{x}$ value.
8 Weigh 20 samples and calculate mean weight per sample.
9 Calculate the total number of samples contained in the culture from

Total Samples (T) = Weight of culture/mean weight of sample.

10 Population size is estimated from $T\bar{x}$.
11 Sieve the whole culture and count the actual population P.
12 Compare the true population size with the estimated size ($T\bar{x}$) and the sample mean (P/T) with the estimated sample mean ($\bar{x}$) (from 7). Is the estimated sample mean within 40% of the sample mean? Would a few large samples be more accurate than several small ones?

Exercise 2
The effects of quadrat number on the sampling of vegetation

Apparatus

For each student pair: m^2 quadrats; metre rules.

Preparation

If a large class (> 20 students) is used for the exercise then a wide range of vegetation types may be investigated but to investigate some of