Ecological Census Techniques
a handbook

Edited by

WILLIAM J. SUTHERLAND
University of East Anglia

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1 Why census?

William J. Sutherland

School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom

Table 1.1. *Contents of Chapter 1*

Introduction

The aim of this book is to outline the main techniques for ecological censusing. There are many reasons for deciding to carry out a census. It may be to determine the importance of a site, the population size of a species, the habitat requirements of a species, the reasons for the species' decline, or whether habitat management has been a success, or to understand the population dynamics. In this chapter I will outline the different approaches necessary for tackling each of these questions and describe some common problems and mistakes.

It is important to plan the work carefully. Many studies are overambitious and thus waste time and effort and often fail. For example, it is a common mistake to collect far more samples than can ever be analysed.

The data must be stored in a way that can be retrieved and understood by others in the future. Notebooks are rarely sufficient and it is usually important that data are stored elsewhere in a form that can be readily interpreted, such as data sheets in files or computer records. It is often useful to document the exact locations where species of particular interest were found.

Describing the interest of sites

One of the major priorities for conservationists is to determine the most important areas for a given species or group. Questions may include: How important is a particular country?

Which are the major areas within a country? Which sites within an area are most important?

Often a major objective is to describe the importance of a site for a range of species. The objective then is perhaps to provide a species list with only a rough assessment of abundance. In this case use as wide a range of different techniques as possible. Thus sample in as many habitats, over as wide a period of time as is practical. Especially for invertebrates, it is best to sample at different times of day, on different dates if possible, under different weather conditions and using different modifications of the same techniques. Even minor modifications, such as changing the preservative in pitfall traps or the colour of a water trap, will influence the species caught.

When preparing species lists for an area it is often useful to draw a species incidence curve. This plots cumulative total number of species seen against number of days spent searching. This gives a good indication as to whether further searching will increase the number of species recorded.

Box 1.1. **Determining the ornithological importance of Gola Forest**

The Upper Guinea forest block in West Africa holds 22 endemic and 8 globally threatened bird species. The Gola Forest Reserves in south-east Sierra Leone are among the last fragments of this formerly extensive habitat, yet they had been visited by only one ornithologist, and only 3 of the threatened species had been positively identified.

In 1988/9 a team of surveyors set out to determine the importance of the Gola Forest Reserves. A major objective was locating the most important species and this entailed using a range of techniques. Bees' nests were watched for feeding Yellow-footed Honeyguide *Melignomon eisentrauti* and the canopy was searched for this as well as Nimba Flycatcher *Melaenornis annamarulae* and Western Wattled Cuckoo-shrike *Campephaga lobata*. White-breasted Guineafowl *Agelastes meleagrides* was detected from its calls and from the scratching noise it made when foraging in litter on the forest floor. Stretches of rivers were watched at dusk for Rufous Fishing Owl *Scotopelia ussheri* and trees beside watercourses were searched during the day for roosting birds. Parties of birds were searched for Yellow-throated Olive Greenbul *Criniger olivaceus*, Spot-winged Greenbul *Phyllastrephus leucolepis* and Gola Malimbe *Malimbus ballmanni*. Rocky areas and cliffs were searched for the distinctive swallow-like mud cup nests of White-necked Picathartes *Picathartes gymnocephalus*. Other techniques used included watching fruiting and flowering trees, checking ant columns for associated birds, imitating bird calls, and using tapes of bird calls to attract birds (Allport *et al.* 1989).

This project was successful in recording 274 species, locating 7 globally threatened species and glimpsing a sunbird almost certainly new to science. The resulting recognition of the importance of this site led to the Gola Rain Forest Conservation Programme.

If the aim is to describe the distribution of a species it is important also to document the area searched. It is essential to be able to tease apart the distribution of the species from the distribution of observers.

Estimating population size

A common objective is to estimate the numbers in an area or even the size of the whole population.

One approach is to try to count all individuals in the entire area. However, this is often impractical, so it is necessary to select sample sites to visit. One common mistake is just to visit the known sites or what is considered to be the best habitat for the species, for example, by visiting all the remaining areas of primary forest but ignoring all the secondary forest. This is only acceptable if it is absolutely certain that the species is restricted to primary forest. It may be that the secondary forest does hold a lower density but also has a greater area and thus actually contains more individuals. Without coverage of all suitable habitats it is impossible to estimate the total population.

The best approach is usually random sampling, since this overcomes such biases and should result in representative coverage. Divide the area into blocks. These could, for example, be 1-km squares or natural divisions, such as lakes or bogs. The more blocks that can be visited the greater the accuracy.

Exactly the same technique is used in sampling with quadrats or soil cores, although the area sampled is likely to be a minute fraction of the total area. The area can be considered as a grid with potential sampling points at the intersections of the grid lines. Thus the study area may be 150 m long and 500 m wide. Draw pairs of random numbers between 0 and 150 and between 0 and 500 and sample at the intersection of these random numbers. Most study areas will not, however, be neat rectangles. In this case overlay a grid that is larger than the study area but ignore those pairs of points that lie outside the study area (see Box 2.21).

The blocks should be numbered and the ones to be surveyed selected using random numbers. Guessing random numbers, however, has been shown to be highly non-random. Random numbers are best determined using random-number tables (one is given in Table 2.6) or a calculator random-number function. However, they can also be improvised by a number of mechanisms, such as using the last digits from a telephone directory, from randomly stopping digital watches and reading the number of hundredths of a second or by guessing a four digit number (e.g. 7217), adding the digits together (17), and repeating until reduced to a single digit (8).

If there are obvious differences in habitat within the survey area then a useful approach is stratified random sampling. This involves dividing the area into different habitats (e.g. mangrove forest, mudflats, and sand banks) and then randomly sampling areas within each. It is then possible to provide an estimate of the number in each habitat and thus the total population size.

Box 1.2. **Surveying the Fuerteventura Stonechat *Saxicola dacotiae***

Bibby and Hill (1987) set out to estimate the total population of this species and its habitat requirements. Twenty-one blocks, each of twelve 1-km^2 grid squares (or a smaller area if the block overlapped the sea), were selected at random. Each of the twelve 1-km squares in each block was visited once for about 2–3 hours, which was thought to be sufficient to detect all individuals of this conspicuous species. The habitat in each square was described.

From this survey of 12.7% of the island it was possible to extrapolate to estimate the total population at 750 ± 100 pairs. As the methods and areas surveyed are described precisely, it would be possible to repeat exactly the same survey to look for changes in the population.

Monitoring population changes

Many studies attempt to determine whether and to what extent populations are changing. This may be to monitor the fate of a species of conservation interest or to see whether a pest species is increasing. It is often not necessary to have an absolute population estimate and a relative measure of abundance may be sufficient.

It is essential to ensure that exactly the same techniques of monitoring are used each time. It is very tempting to wander from a transect line to include particularly good patches, or to improve a technique in a way that results in encountering more individuals, but this, of course, makes comparisons with previous years invalid. If the decision is made to change techniques, then it is necessary to have a period of overlap in which both methods are used so the relative efficiency of each can be determined and the data can be calibrated.

It is very useful to monitor environmental variables in such a way that site managers can detect changes and so relate them to changes in populations. For example, if the salinity and water level on a coastal lagoon are recorded on a regular basis, then a warden can tell whether a particular measurement is within the typical range of fluctuations or an indication of an atypical event.

In describing methods for monitoring it is essential to be extremely specific about the exact techniques used so that they can be repeated by another observer in the future. Small and sensible modifications, such a not censusing if the wind is above a certain speed, must be specified so that future observers collect comparable data.

How regularly the censuses need to be made will depend upon the likely rate of change. Censusing trees each decade may be sufficient, while phytoplankton may vary from week to week. The date of the census should ideally be standardised, but if the season is particularly early or late, then it may be sensible to alter the census accordingly.

Box 1.3. **Determining ecological changes in Breckland heaths**

Breckland is an area of early successional lowland grass heath in eastern England of considerable conservation interest. To document the changes in plants, birds and insects four main techniques were used (Dolman and Sutherland 1991, 1992). Each involved locating and collating past records and comparing them with the current situation.

(1) The location of sites of the rare plant species was well documented although there was little information on abundance. Resurveying these sites showed that, for the different species, between 29 to 93% of these populations had disappeared and that in the sites in which they had disappeared, much of the loss was attributable to succession to rank grasslands. (2) On nature reserves there were a few sites with annual bird counts, a few complete surveys, including one in 1949 and one in 1968, and scattered records for a large number of sites extracted from a wide array of sources. These data could be compared with current numbers which showed that many of the characteristic species had since disappeared (Woodlark *Lullula arborea*, Ringed Plover *Charadrius hiaticula*) or plummeted in numbers (Wheatear *Oenanthe oenanthe*, Stone Curlew *Burhinus oedicnemus*). (3) A series of quadrats had been carried out in 1981; they were then resurveyed and this showed a change from the characteristic community of lichens and annual plants towards competitive grasses, shrubs and trees. (4) It was hard to find data for determining any changes in invertebrate abundance. Moths were the best documented and a number of characteristic species had gone extinct. This study thus showed that there had been considerable loss of conservation interest even on nature reserves and it seemed this could be linked to the lack of habitat disturbance by humans and rabbits. Such disturbance is essential for maintaining this habitat.

Determining the habitat requirements of a species

One common and useful objective is to try and determine the habitat requirements of a particular species. This work may be relatively easy and a lot of further studies of this sort are needed. For such studies it is not necessary to have absolute population estimates and relative numbers are often almost as good.

A frequent mistake is just to visit all the best areas in which the species is found and measure various factors relating to the habitat. Without any comparison of sites in which the species is missing, this is of little use. One useful technique is to compare the points at which the species is located with a random collection of points. In such a comparison it may be possible to include prey abundance, predator abundance and nesting sites, habitat structure and environmental variables. Instead of comparing presence and absence, an alternative is to relate relative density to habitat variables, but it is again essential to visit the poorer sites to determine why they are poor.

An alternative approach makes use of the possibility that the area may be readily divisible into ponds, fields or forest blocks. The analysis can then be either to compare blocks which contain the species with those without or to see what, if any, obvious differences there are. For example, a survey of gardens, using a simple questionnaire, showed that snails *Cepea nemoralis* were abundant in gardens with cats (which scare off the predatory Song Thrushes *Turdus philomelus*) but infrequent in gardens with dogs – which chase off the cats. Such studies comparing sites may be carried out on a range of scales using slightly different techniques. For example, compare the woods in which a species occurs with those in which it does not; within a wood compare the locations in which it is observed feeding with random locations, and the trees it breeds in with a random sample of those in which it does not.

Especially for studies of invertebrates, it may be necessary to compare the fine details of the habitat. For example, various different studies of different species of butterflies have shown that females may only lay eggs on sunny leaves, plants adjacent to bare ground, large leaves or plants rooted in deep soil.

Such studies are most useful when combined with research into the natural history of the species. Where possible, studying the diet by means of observations or analysis of prey-remains in faeces is a very useful step.

Determining why species have declined

Many species of conservation interest are declining and understanding why is an important first step in maintaining and enhancing the population. One useful approach is to determine the requirements of a species as described earlier and try and determine whether the factors meeting these requirements have changed. Another very useful approach is to compare the sites in which the species still occurs with the sites from which it has disappeared.

A further approach is to estimate the life history parameters such as fecundity, survival of the early stages, or adult survival. Theoretically, it is then possible to see if the population is capable of sustaining itself, but in practice it is often difficult to measure these parameters with sufficient accuracy. Such measurements may, however, succeed in indicating problems. For example, in many plant species the mature plants survive well, are pollinated and carry reasonable numbers of seeds but fail to germinate successfully. Often in these cases disturbing the ground is necessary for the species to flourish (of course, many plants are largely dependent on clonal growth and in these species seedling recruitment is less important). Alternatively seedling survival may be high but seed set is low owing to grazing. In this case a reduction in livestock is the solution.

Another useful approach is to assess the limiting factors – the factors which reduce the breeding output and survival. Is the breeding success low because the nests were flooded, because few eggs hatched, because insufficient food was brought to the young who then starved or because many young were eaten by predators? Such knowledge leads to suggestions for conservation measures. One approach is to determine whether these limiting factors have changed. Another is to compare the limiting factors in different areas and relate this to population size or population trends.

There are pitfalls with this approach. On a number of occasions studies of rare plants have shown that many of the flowers are grazed which has led to the recommendation that stock is excluded. This, however, often has disastrous consequences for the rare plant, since, although flowering and seed set is initially improved, without the bare ground produced by grazing, little regeneration takes place. Similarly, fire initially seems disasterous, but for many communities such as the American pairies and the woodlands of northern Australia it is essential for the persistance of many species. This pitfall is best overcome either by detailed research into the habitat requirements or by management experiments.

Box 1.4. **Why has the Silver-spotted Skipper butterfly declined?**

Records showed that the Silver-spotted Skipper butterfly *Hesperia comma* had disappeared from many sites on semi-natural chalk grassland in Britain including a quarter of the populations that once bred on nature reserves. Detailed observations showed that the females laid their eggs on the grass *Festuca ovina* especially adjacent to bare areas (Thomas *et al.* 1986). A comparison of sites showed that the population persisted in sites with stock grazing (which creates gaps) but had gone extinct in those without. The decline could then be related to a reduction in grazing and reintroducing stock grazing has proved successful in enhancing population size.

A subsequent experiment showed that, surprisingly, the population was lower in blocks with summer grazing than in those without. However, observations showed that females tended not to lay eggs on grazed leaves. Thus the ideal management for this species seems to be heavy winter grazing to create bare patches followed by removal of stock grazing to allow the grass to regrow.

Monitoring habitat management

A major failing of nature reserve management is that little has been learnt from the huge amount of management that has been carried out. When experiments have been carried out the results may be surprising. For example, conservationists sometimes control the biennial weed, Marsh Ragwort *Senecio aquaticus*, by pulling it up by hand, but when this was analysed in an experiment it turned out that this practice actually increased the ragwort population, probably by disturbing the ground (Ausden 1993). Such experiments can be used to tackle a range of subjects: Which grazing regime is the best? Do human visitors affect the population? Does harvesting have long-term consequences?

The usual non-experimental approach is to notice that two aspects change in parallel (e.g. there has been an increase in number of visitors to an area and at the same time a decrease in a species). From this it is argued that the increase in visitors is the cause of the decline. Although this may be the case, it may also be that the species has changed for other reasons, such as a change in habitat, and there are innumerable examples of such faulty reasoning. A properly designed experiment overcomes this problem.

An experiment should be controlled, randomised and replicated. Controls are areas in which the management has not been altered. Thus an experiment may compare areas that have been flooded with those that have not. The control means it is possible to separate population changes, for example due to the weather, from the consequences of management.

The treatments (for example flooding versus not flooding) need to be allocated at random. One common failing is to assume that the management will be beneficial and thus manage the best areas. It is then of course difficult to make comparisons and this may give the impression that the management has been successful (as there are more individuals in the managed areas) when it was not. There may be good reasons for managing part of a site in a particular way. Rather than pretending this is part of a randomised design, it is better to exclude such areas from the experiments, divide the remaining area into blocks, and then genuinely randomise the treatments.

Experiments need to be large enough for sufficient individuals to occupy the treatments. If only a few individuals occur in the area then any change could be attributed to chance. For example, if the total population increases in the managed areas from 4 to 6 but stays at 4 in the control areas, it is difficult to determine if this is due to chance.

Replication is important as any two sites are bound to differ anyway. By using say ten blocks and flooding half at random it is then possible to see if the pattern is consistent.

Contrary to widespread belief, it is not essential to carry out a census before the management occurs. With a suitable randomised, replicated, and controlled experiment the effect of treatment is determined by the simple comparison of the managed areas with the controls.

Another useful approach is to pick a number of sites, such as fields, and manipulate part of each. Again it is essential to select randomly which part is manipulated and which is the control. Thus an experiment may consist of five fields, in which half of each field is cattle grazed and the other half is sheep grazed. This is a useful experimental design when the sites differ.

Box 1.5. **When should prairies be burnt?**

Fire is known to be essential in maintaining tallgrass prairies in North America. Natural fires are usually caused by lightning and occur in late summer, while conservationists usually burn prairies before the growing season. Does this matter? Howe (1994) divided an experimental prairie into 21 plots, each of 12 m by 15 m, and burnt 7 on 31 March and 7 on 15 July, while a further 7 were left unburnt. The vegetation was recorded in 12 randomly placed 1-m^2 quadrats within each of the 21 plots. The results showed that late burns resulted in a different community of greater diversity which consisted of smaller and early flowering species.

Population dynamics

By measuring life history parameters and estimating the population size it is possible to consider a range of questions. Why does the population fluctuate from year to year? What determines the level of abundance? How strong is density dependence and at what life stage does it operate? What are the consequences of competitors, herbivores or predators on the population?

There are, however, considerable problems in answering such questions from observational data. Density manipulation (for example by adding or removing seeds) is invaluable in tackling such questions.

Box 1.6. **Population dynamics of the Brent Goose**

The Dark-bellied Brent Goose *Branta bernicla bernicla* breeds in arctic Russia and access to the breeding grounds is very difficult. Much has been learnt of the population biology simply by counting the birds every winter since 1955 in their European breeding grounds. Juveniles have pale bars on their wings and thus can also be counted separately.

The percentage of juveniles varies markedly between years from over half the population to less than 0.1%. This was assumed to be related to the variation in the snow cover in the breeding grounds, but Summers and Underhill (1987) showed that the percentage of juveniles follows a clear three-year cycle in which there is a good breeding success, followed by a poor breeding success, followed by an unpredictable season. It was suggested that this was linked to the lemming cycle in the Arctic with Arctic Foxes *Alopex lagopus* feeding on eggs and young when the lemming population was low. Subsequent field studies in Russia (Underhill *et al.* 1993) confirmed this hypothesis. The population increases markedly after a good breeding season and as a result of this research it has proved possible to predict the population changes in subsequent years.

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