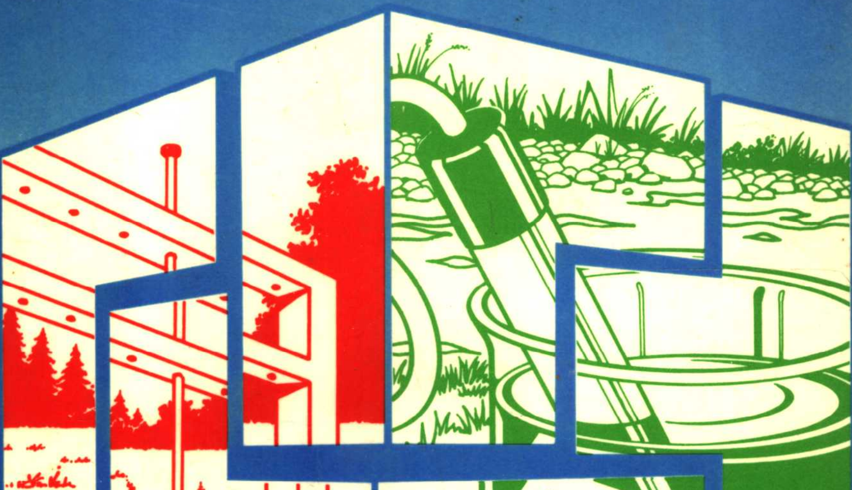
Practical Ecology

D. Slingsby and C. Cook



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PRACTICAL ECOLOGY

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PRACTICAL ECOLOGY

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To all the students of Pate's and Ripon Grammar Schools who have provided the inspiration for the writing of this book, and to the many other people who have helped and encouraged us in the project and in developing our own interest in ecology

Series Editor's Preface

This book is one in a Series designed to illustrate and explore a range of ways in which scientific knowledge is generated, and techniques are developed and applied. The volumes in this Series will certainly satisfy the needs of students at 'A' level and in first-year higher-education courses, although there is no intention to bridge any apparent gap in the transfer from secondary to tertiary stages. Indeed, the notion that a scientific education is both continuous and continuing is implicit in the approach which the authors have taken.

Working from a base of 'common core' 'A'-level knowledge and principles, each book demonstrates how that knowledge and those principles can be extended in academic terms, and also how they are applied in a variety of contexts which give relevance to the study of the subject. The subject matter is developed both in depth (in intellectual terms) and in breadth (in relevance). A significant feature is the way in which each text makes explicit some aspect of the fundamental processes of science, or shows science, and scientists, 'in action'. In some cases this is made clear by highlighting the methods used by scientists in, for example, employing a systematic approach to the collection of information, or the setting up of an experiment. In other cases the treatment traces a series of related steps in the scientific process, such as investigation, hypothesising, evaluating and problem-solving. The fact that there are many dimensions to the creation of knowledge and to its application by scientists and technologists is the title and consistent theme of all the books in the Series.

The authors are all authorities in the fields in which they have written, and share a common interest in the enjoyment of their work in science. We feel sure that something of that satisfaction will be imparted to their readers in the continuing study of the subject.

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How to Use This Book

This book is designed to help you carry out your own field studies by describing and explaining techniques, offering suggestions and providing enough theoretical background information to enable you to organise your work and interpret your results. It is not intended to be read from cover to cover but it is suggested that you read chapters 1 and 2 before you start and carry out exercise 2.1 as an introduction to sampling. Chapter 8 also contains important principles about the relationship between organisms and their physical and chemical environment. Chapters 9 and 10 suggest how you could implement these principles either in terrestrial or seashore habitats. Chapters 6 and 7 contain a variety of exercises illustrating aspects of animal ecology, each a complete study in itself.

Other chapters are to be dipped into to 'service' chapters 9 and 10, and chapters 5, 6 and 7 also provide methods and suggestions for describing and comparing terrestrial and freshwater plant and animal communities. Chapters 3 and 4 provide methods for measuring physical and chemical factors on land, the seashore and freshwater habitats.

Chapter 11 is concerned with carrying out experiments to test hypotheses you have made during the course of your field studies and, like chapters 1, 2 and 8, contains principles which apply to whatever form your course has taken.

To aid cross-referencing, each chapter is written in numbered sections. For example, '(8.2)' refers to the second section in chapter 8. Tables, figures and exercises are numbered separately prefixed by a chapter number; for example, 'table 3.1' is the first table in chapter 3.

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1 Ecology — Some Basic Principles

1.1 WHAT IS ECOLOGY?

Ecology is the study of plants and animals in relation to each other and to the physical and chemical environment in which they naturally occur. Much of a biology course emphasises the individual organism whether it involves dissection of a rat which has been bred in a cage, a Pelargonium taken from a greenhouse for a photosynthesis experiment or Garden Peas grown in Mendel's monastery garden. A cabbage may be homogenised just to provide chloroplasts for a biochemistry experiment or to provide material for electron microscopy. Classification involves more variety of species, but often they are dead and preserved in a jar. All these approaches to biology are important but it is also important to complete the picture by looking at the subject ecologically. Ecology means literally 'the study of the hearth' – the study of plants and animals 'at home' in the systems of which they are a part, which they rely on, help to create and maintain, and in which they have evolved.

Ecological field studies are also an important part of a biology course because they offer much scope for putting the scientific process into practice yourself rather than simply learning about it. Most aspects of biology can only be studied from books or laboratory experiments which, if correctly carried out, always produce the same result. Every site used in field studies is to some extent unique, and your observations original. You have the experience of genuinely being 'at the sharp end' of scientific research.

1.2 THE SCIENTIFIC METHOD

This is a philosophical approach to seeking after truth which involves the following aspects.

(a) Observation
Scientific observation involves accurate and detailed recording. It can take the form of diagrams and photographs, but often it seeks to be numerical. Observations may be made by simply using your unaided eyes, but for many you need equipment like microscopes, pH meters and light sensors.

(b) Data analysis, presentation and interpretation
Large amounts of data need to be presented in an easily interpreted form (such as a graph). It may be analysed by a branch of mathematics called statistics, in which a computer can be useful.

(c) Hypothesis
Observations alone do not prove anything, but they suggest possible explanations called hypotheses (8.2, 8.10, 11.1, exercise 11.1).

(d) Experiments
These are designed to test hypotheses (chapter 11).

(e) Reproducibility
To be scientifically acceptable, observations and experimental results should be capable of being confirmed by other people. They must always be accompanied by precise details of how they were made. Others may dispute your conclusions but they must never be able to doubt your data. Dubious results (such as those obtained by unreliable equipment) should be thrown away.

(f) Literature research
Reading about the findings and ideas of others is often essential to deciding where to start an investigation and to the interpretation of your data. In addition to using the background information in this book, you will find that access to a library is important in scientific research.

1.3 COMMUNITIES

An ecological community is an assemblage of plant, animal and microbial species in a particular place. Because different methods are involved, often plant, animal and microbial communities are considered separately. Daisy is a species frequently used as an example in this book because it is a common plant that everyone is familiar with. It is, however, only common in certain types of plant community (along with other species like Dandelion) of which it is a distinctive member, namely grazed or mown grassland. It is very rare in other communities like woods, heaths, ponds and those of the seashore. The reason certain species tend to occur together is that they share certain environmental requirements. The herbs of grassland are adapted to tolerate trampling and grazing but because the plants are small, they cannot compete with taller plants species unless mowing and grazing keeps them down.

1.4 ECOSYSTEMS

An ecosystem is an assemblage of plant, animal and microbial species in a particular place which interact with each other and with their physical and chemical environment in such a way as to constitute a self-maintaining and self-regulating system. A Beechwood represents, at one level, a community, but at a deeper one, it functions as an intricate ecosystem which can maintain itself without the help of any forester, and stays the same for thousands of years. An ecosystem has the following features.

(a) Ecosystems require an external energy source
Green plants are photosynthetic autotrophes. They absorb solar energy and use it to convert carbon dioxide into organic substances like sugars, starch, cellulose, lignin and proteins. The only substances they require for this are water and small amounts of inorganic ions like nitrate. The energy absorbed becomes incorporated into the organic molecules, and is available to the heterotrophic animals and microbes when they feed on plants (or plant-eating animals). The green plants are the primary producers of the system because they produce the energy containing organic matter which fuels the rest of it. The heterotrophes also rely on this organic matter as a source of raw materials for growth (mainly protein). Plants are also the ultimate source for mineral salts, and for many heterotrophes, most of their water (since plants, unlike animals, have roots). Herbivores (including many birds and invertebrates) represent the majority of animals and are secondary producers since they provide organic matter for carnivores. Herbivores are also regarded as primary consumers, since they feed on primary producers, and carnivores are secondary, tertiary or quaternary consumers depending on where they come in the food chain of which they are a part. All food chains (for example, grass–rabbit–fox) start ultimately with primary producers. Estuaries are rich in animal life because they receive organic matter washed down by a river as well as that derived from its own plant communities (including microscopic algae), but are often considered as 'incomplete' or 'open' ecosystems, annexes of the ecosystem upstream which provided the 'extra' organic matter. Similarly, a cave is

not a 'complete' or 'closed' ecosystem since it lacks any primary producers. The bats and the fungi which feed on their droppings are at the ends of food chains which start outside in nearby fields and woods.

Unless you consider the World as a whole, no site or even a whole continent represents an absolutely complete or closed system since all are influenced by neighbouring systems to some extent. The terms 'complete' and 'incomplete' are relative. It is convenient to regard a particular forest as a relatively complete ecosystem, but really it is but a part of the World ecosystem or biosphere. Migratory birds, for example, divide their time between this forest and another perhaps thousands of miles away.

The productivity of an ecosystem is the rate at which new organic matter (or biomass) is produced and is usually expressed as grams per unit area per unit time. Where primary productivity is high or there is an external source of organic matter, as in an estuary or a pond enriched by fallen leaves or run-off from surrounding farmland, the ecosystem supports a large number of heterotrophes. A lake in a valley composed of hard granitic rock has low productivity and consequently small animal populations because of the lack of mineral salts required by the primary producers (mainly planktonic algae).

Food chains which start with live plants are grazing foodchains.

(b) Ecosystems recycle inorganic substances

Food chains which start with dead organic matter, including animal faeces (derived originally from live plants), are detritus foodchains which include saprophytic bacteria and fungi, woodlice, earthworms and birds like thrushes (which occupy the end of the chain, feeding on invertebrates). These provide 'nature's waste-disposal system' and ultimately convert the organic matter to carbon dioxide, salts and water, and these substances are thus continually replenished or recycled. Green plants recycle oxygen, a waste product of photosynthesis.

Woodlands have a higher productivity than meadows, but much of their biomass is in the form of cellulose and lignin which most animals cannot digest. Although their grazing food chains represent few individuals, they are rich in species of fungi and other detritus feeders which are able to utilise these substances. Often these saprophytic fungi are very specialised. For example, Jew's Ear (*Auricularia auricula*) is a jelly fungus which only feeds on dead (and sometimes on living) Elder (*Sambucus niger*). Similarly, *Daldinia concentrica* feeds on Ash (*Fraxinus excelsior*). In peat bogs, acidity and anaerobic conditions greatly limit microbial activity, and much of the productivity gives rise to peat accumulation. Such places have relatively low productivity owing to poor mineral salt recycling. Carnivorous plants, such as Sundew (*Drosera rotundifolia*) are adapted to this by being able to supplement their mineral salt supply by digesting insects.

(c) Ecosystems control population sizes

All populations of organisms tend to rise because all species over-produce. One plant produces many seeds and one pair of Great Tits produces about 12 offspring in a season, and yet over a period of years, populations in a stable ecosystem remain more or less the same.

(i) Plants – as a result of competition for space and grazing by herbivores.
(ii) Herbivores – partly by competition for food but mainly by predation by carnivores.
(iii) Carnivores (and some herbivores) – partly by direct competition for food, but in many cases because their reproductive rate is reduced when food is in short supply (a kind of natural birth-control).

Basically, in a stable ecosystem, mortality is at equilibrium with natality (birth-rate) because many forms of mortality (competition for food and places to hide from predators, and disease) become more serious as the population rises, and so mortality is density-dependent. Predation is important in controlling herbivore populations because otherwise it will happen by competition for food in which case the vegetation gets over-grazed, and there is a fall in the ecosystem's productivity. In extreme cases, the vegetation dies, leading to soil erosion, and so the ecosystem has been seriously damaged and its carrying capacity has been reduced. Normally, in stable ecosystems, this never happens, or it ceases to be stable. In many places in Britain, the ecosystem still has not fully recovered from the introduction of rabbits by the Normans a mere 1000 years ago, especially as wolves and other carnivores apart from foxes have been exterminated in the meantime. Since its deliberate introduction into Britain (1952/3), myxomatosis (whose outbreaks are density-dependent) has improved the situation. A similar principle applies with animals like Robins. These are territorial, and instead of vicious competition for food decimating the prey populations, a ritualistic competition for nesting sites (in which birds do not usually get hurt) precedes breeding. Territory size is related to its productivity, and only birds with territories produce offspring.

1.5 ECOLOGICAL NICHES

A consequence of density-dependent mortality is what Darwin called 'the struggle for survival', which is so ruthless that only a few individuals live long enough to reproduce, passing on the genes which made them a success to the next generation. Thus it is the driving force behind evolution by Natural Selection, and it explains the remarkable way in which species are adapted to survive in the biological, physical and chemical environment in which they naturally occur. The harsh reality of Darwin's principle of 'survival of the fittest' is that unless a species has at least somewhere where it can be a winner in the struggle, it will become extinct. Two similar species must be genetically different, otherwise they would not be recognised as separate species. If environmental conditions were completely uniform throughout the World, one would be at least slightly better adapted to survive, and the other would become extinct.

The remarkable diversity of species arises because environmental conditions, as you will find in your field studies, vary from place to place, and because in any one place interspecific competition is reduced because there is more than one way of exploiting the situation. Daisies and grass may look as though they are in direct competition in a lawn, but the Daisy has deeper roots, and so it absorbs water and nutrients from a different layer of soil than the more shallow-rooted grass. A beetle in the same place does not compete with the grass for light or mineral salts. In fact, being a carnivore, it may help the grass by keeping herbovorous invertebrate populations under control. All three species share the same place, and yet occupy different ecological niches. An ecological niche is a way of exploiting an ecosystem rather than a geographical location.

The Mutual Exclusion Principle states that each niche can only be occupied by one species, and that if two species compete for the same niche, one will prove more successful and the other will fail. This implies that one habitat will include numerous ecological niches, each occupied by a different species. To understand this (very abstract) notion, you consider individual species and how they exploit the ecosystem (autoecology), and the habitat as a whole, with its patchwork of species and varying environmental factors (synecology). The Mutual Exclusion Principle is a fascinating concept, but is very slippery when it comes to defining a Niche precisely, since niches can 'overlap'. You should be able, however, to attempt to gain some understanding of the niches occupied by particular species you study, but to define them precisely you need to measure a large number of variables and plot them on a graph with a large number of axes. There are computer techniques which help to deal with this task, but it is beyond the scope of most field courses!

1.6 SUCCESSION, CLIMAX AND STABILITY

A stable ecosystem is usually the product of centuries if not millennia of development. A well-tended garden is ecologically very unstable and requires constant attention. Most of the species would not be there normally. Many are exotic, thousands of miles from the places in which they evolved and need your help in coping with the British climate, soil, pests and the species of the local flora, whose seeds keep arriving, brought by wind and animals. Only weeding prevents them out-competing the aliens. If you abandoned the garden, it would slowly revert to a wild state, but would remain very unstable for years, its species composition constantly fluctuating, as delicate equilibria develop. A similar process would take place in a newly made pond if it was not freqeuntly cleaned out.

Ecological succession is said to take place when the vegetation (and associated fauna and micro-organism population) in a particular place changes with time, and one unstable community progressively gives way to another until a stable climax community becomes established. Often, the intermediate communities modify the environment in such a way as to create the conditions necessary for the establishment of the next, and, ultimately, of the climax (9.2 and 9.3).

A climatic climax community is a stable one which usually becomes established through a successional process. Its nature is determined by the climate and geology of the place. Chapters 3, 4 and 10 discuss important abiotic (non-biological) ecological factors as they apply on land, in water, and on the seashore. A climax community such as a natural (or semi-natural) forest represents a stable ecosystem in which thousands of plant, animal and microbial species interact, come into existence and die every day, and yet the whole thing represents a dynamic equilibrium which stays the same for thousands of years. Climax communities usually have a high species diversity (5.6), reflecting the numerous links of food chains, recycling and population controls which contribute to their stability.

The natural climax communities of over 60 per cent of Britain are considered to be various types of forest because of the temperate, oceanic climate. It is believed that this is the way our pioneering Stone Age ancestors found it and that it would revert to the same state if human influences were removed. Every time you neglect a garden, the long process in which the local climax reasserts itself begins. Trees will not grow above 500 metres in Britain, and here, the natural climax is grassland, bog or heath (8.4). Below the tree-line, climax is also affected by soil (3.2), as well as climate. Ash and Beechwoods are often the climax of limestone soils, Oak of the deep soils of the Midlands and Scots Pine of the upper parts of Scottish glens.