All questions in ecology – however scientifically fundamental, however crucial to immediate human needs and aspirations – can be reduced to attempts to understand the distributions and abundances of organisms, and the processes – birth, death and movement – that determine distribution and abundance. In this chapter, these processes, the methods of monitoring them and their consequences are introduced.

5.1 Introduction

what is a population?

As ecologists, we try to describe and understand the distribution and abundance of organisms. We may do so because we wish to control a pest or conserve an endangered species, or simply because we are fascinated by the world around us and the forces that govern it. A major part of our task, therefore, involves studying changes in the size of populations. We use the term *population* to describe a group of individuals of one species. What actually constitutes a population, though, varies from species to species and from study to study. In some cases, the boundaries of a population are obvious: the sticklebacks occupying a small lake are 'the stickleback population of the lake'. In other cases, boundaries are determined more by an investigator's purpose or convenience. Thus, we may study the population of lime aphids inhabiting one leaf, one tree, one stand of trees or a whole woodland. What is common to all uses of *population* is that it is defined by the number of individuals that compose it: populations grow or decline by changes in those numbers.

birth, death and movement change the size of populations

The processes that change the size of populations are birth, death and movement into and out of that population. Trying to understand the causes of changes in population size is important because the science of ecology is not just about understanding nature but often also about predicting or controlling it. We might, for example, wish to reduce the size of a population of rabbits that can do serious harm to crops. We might do this by increasing the death rate by introducing the myxomatosis virus to the population, or by decreasing the birth rate by offering them food that contains a contraceptive. We might encourage their emigration by bringing in dogs, or prevent their immigration by fencing.

Similarly, a nature conservationist may wish to increase the population of a rare endangered species. In the 1970s, the numbers of bald eagles, ospreys and other birds of prey in the United States began a rapid decline. This might have been because their birth rate had fallen, or their death rate had risen, or because the populations were normally maintained by immigration and this had fallen, or because individuals had emigrated and settled elsewhere. Eventually the decline was traced to reduced birth rates. The insecticide DDT (dichlorodiphenyltrichloroethane) was widely used at the time (it is now banned in the United States) and had been absorbed by many species on which the birds preyed. As a result, it accumulated in the bodies of the birds themselves and affected their physiological processes so that the shells of their eggs became so thin that the chicks often died in the egg. Conservationists charged with restoring the bald eagle population had to find a way to increase the birds' birth rate. The banning of DDT achieved this end.

5.1.1 What is an individual?

unitary and modular organisms

A population is characterized by the number of individuals it contains, but for some kinds of organism it is not always clear what we mean by an individual. Often there is no problem, especially for *unitary* organisms. Birds, insects, reptiles and mammals are all unitary organisms. The whole form of such organisms, and their program of development from the moment when a sperm fuses with an egg, is predictable and *determinate*. An individual spider has eight legs. A spider that lived a long life would not grow more legs.

But none of this is so simple for *modular* organisms such as trees, shrubs and herbs, corals, sponges and very many other marine invertebrates. These grow by the repeated production of modules (leaves, coral polyps, etc.) and almost always form a branching structure. Such organisms have an architecture: most are rooted or fixed, not motile (Figure 5.1). Both their structure and their precise program of development are not predictable but *indeterminate*. We could count the individual trees in a forest, but would this signify the 'size' of the tree population? Not unless we also noted whether the trees were young saplings (few leaves and branches each), or old individuals, each with many more such modules. Indeed, it may make more sense not to count the individual trees themselves but the total number of modules instead.

modular organisms are themselves populations of modules

In modular organisms, then, we need to distinguish between the genet – the genetic individual – and the module. The *genet* is the individual that starts life as a single-celled zygote and is considered dead only when all its component modules have died. A *module* starts life as a multicellular outgrowth from another module and proceeds through a life cycle to maturity and death even though the form and development of the whole genet are indeterminate. We usually think of unitary organisms when we write or talk about populations, perhaps because we ourselves are unitary, and there are certainly many more species of unitary than of modular organisms. But modular organisms are not rare exceptions and oddities. Most of the living matter (biomass) on Earth and a large part of that in the sea is of modular organisms: the forests, grasslands, coral reefs and peat-forming mosses.

5.1.2 Counting individuals, births and deaths

Even with unitary organisms, we face enormous technical problems when we try to count what is happening to populations in nature. A great many ecological questions remain unanswered because of these problems. For example, resources can only be focused on controlling a pest effectively if it is known when its birth rate is highest. But this can only be known by monitoring accurately either births themselves or rising total numbers – neither of which is ever easy.

the difficulties of counting

If we want to know how many fish there are in a pond we might obtain an accurate count by putting in poison and counting the dead bodies. But apart from the questionable morality of doing this, we usually want to continue studying a population after we have counted it. Occasionally it may be possible to trap alive