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Excerpt
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CHAPTER 1

Introduction to environmental biology

By the end of this chapter you should be able to:

1. explain the meanings of the terms *habitat*, *microhabitat*, *niche* and *population*;
2. distinguish between a *community* and an *ecosystem*;
3. describe similarities and differences between the growth in numbers of the human population and other animal populations;
4. outline the effects of human activity on the natural environment;
5. explain the value of monitoring the environment.

What is ecology?

This book is about ecology and conservation. **Ecology** is the study of organisms in their natural surroundings. The word ecology comes from two Greek words – *oikos* meaning home and *logos* meaning understanding. So ecology is all about understanding the homes of animals, plants and other organisms. The surroundings of an organism are known as its **environment**. Environments consist of many components including both *physical* features, such as climate and soil type, and *biological* features, such as predators and prey. The term **environmental biology** has wider connotations than ecology because it includes the study of humans in the environment, so you will find such subjects as agriculture, pollution and the unnatural surroundings we create in this book too.

Understanding the ecology of an area is like trying to put together a gigantic, multidimensional jigsaw. Some pieces are the individual species in the area. In an oak wood, for example (*figure 1.1*), the species might include bluebells, oak trees, earthworms, snails, hedgehogs, wood ants and tawny owls. Other pieces in the jigsaw are the important aspects of the physical environment, for example the pH of the rainwater, the total amount that falls in a year, how it is distributed throughout the seasons, and significant information about the temperature, sunlight and soil type. The jigsaw pieces interlock with one another in numerous, subtle ways.

In many ways ecology is a relatively new science. Indeed, the word was only coined by the German biologist Ernst Haeckel in 1869, fully ten years after Charles Darwin published his theory of

● **Figure 1.1** Stoneywell Wood, Leicestershire, in spring. The leaves on the oak trees are just emerging above the carpet of bluebells.

natural selection. Yet, in little over a century ecology has grown to become one of the most important disciplines within biology. Like all branches of science, it has its own language. This includes the terms habitat, population, community and ecosystem, which you will have already met in *Biology 1*.

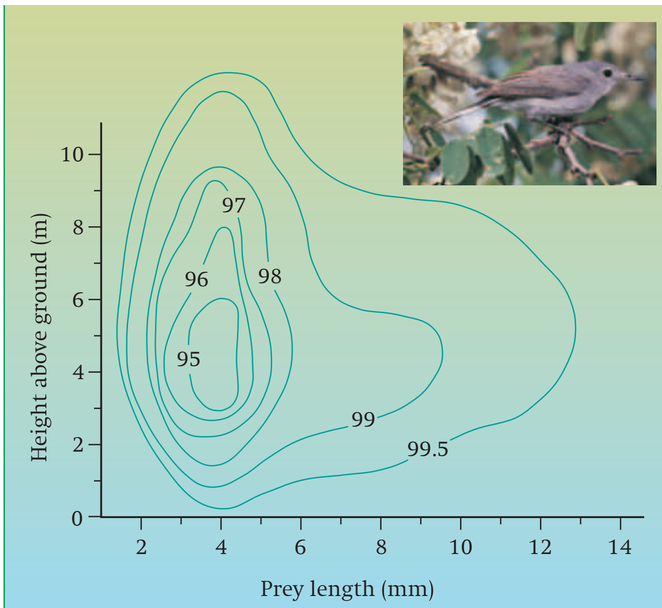
A **habitat** is the place where an organism lives. The word is Latin and literally means 'it dwells'. Actually, organisms from a single species can live in a number of habitats. For example, the common rat (*Rattus norvegicus*) is typically found associated with farms, refuse tips, sewers and warehouses. However, it also occurs in hedgerows close to cereal crops or sugar beet, and in salt marshes. On islands (e.g. the Isle of Man, Rhum and Lundy) rats also occupy grassland and the sea shore.

With small organisms, especially those living in a restricted area such as in the soil or on a single plant or animal, it is worth being more precise about exactly where they live. The term **microhabitat** – 'a small habitat' – is used to describe this. A single habitat may have many microhabitats. For example, if you are an insect living on an oak tree, life is very different depending on whether you live on the upper surface of the leaves, the lower surface of the leaves or inside them. It is even more different if you live under the bark, next to the roots or inside an acorn. Each of these different places is a microhabitat.

A **niche** is a complete description of *how* the organism relates to its physical and biological environment. Just as in a jigsaw puzzle each piece has its own unique shape and pattern, and only fits in one place, so each species has a unique niche – the way it fits into its environment.

Consider a particular species, the grey heron (*Ardea cinerea*). Its habitats are water meadows, rivers, lakes and the sea shore. A complete account of its niche would include a description both of its physical environment (such as the type of water it needs, the temperature range in which it can survive and reproduce) and of its biological environment (such as the prey it eats, its competitors and the vegetation it needs for its nest).

It is difficult to provide a quantitative description of an organism's niche. *Figure 1.2* shows the feeding niche of the blue-grey gnatcatcher,



● **Figure 1.2** The feeding niche of the blue-grey gnatcatcher (*Polioptila caerulea*). The contours show the feeding frequencies for adult birds during the nesting period in July and August in oak woodlands in California. 95% of their diet is taken within the contour marked 95, 96% within the contour marked 96, and so on.

Polioptila caerulea, a North American bird. This is an **insectivore** and the horizontal axis shows the length of the insects on which it feeds. The vertical axis shows the height above ground at which it forages. The contour lines with numbers indicate the frequency with which the birds feed at a particular height and on a particular length of prey. You can see that the birds concentrate on prey 4 mm in length, which they catch about 3–6 m off the ground.

However, there are many other aspects to an organism's niche in addition to its feeding niche. In theory, other axes could be added at right-angles to those in *figure 1.2*. Temperature could be shown on a third axis, risk of predation at different times of the year on a fourth, height above ground of the bird's nest on a fifth, and so on. In practice, though, no more than two or three axes can be shown on a graph. Computers, however, can store and compute data for many more.

The ecological principle that each species has its own unique niche and that no two species can coexist if they occupy the same niche is known as **Gause's competitive exclusion principle**. The biologist G. F. Gause gets the credit because of his research on single-celled ciliates in the genus *Paramecium*.

A **population** is a group of individuals within a species that have the opportunity to breed with one another because they live in the same area at the same time. It follows from this definition that individuals from two different species cannot belong to the same population. This is because, with occasional exceptions, species are **reproductively isolated** from one another. Tawny owls do not breed with short-eared owls, for example.

Most species are divided into many populations that are geographically separated. Bluebells in one wood, for example, will belong to a different population from the bluebells in another wood several kilometres away. Indeed, in a large wood there may be several populations of bluebells, though the boundaries between populations may be somewhat arbitrary.

A **community** is an association of species that live together in some common environment or habitat. Most communities are composed of a mixture of prokaryotes, protoctists, fungi, plants and animals. The organisms in a community interact with one another in all sorts of ways. For a start, there will be feeding relationships. In most communities, **autotrophs** (also known as **producers** and comprising green plants, photosynthetic algae, photosynthetic bacteria and chemosynthetic bacteria) provide food for **herbivores** (also known as **primary consumers**). In turn, herbivores are eaten by **first-level carnivores** (also known as **secondary consumers**), and these may be eaten by **second-level carnivores** (or **tertiary consumers**). Eventually organisms die and their remains are broken down by **decomposers**. These feeding relationships can be represented by **food chains** or by **food webs** that show the interrelationships between the various food chains in a community.

The species in a community also interact with one another in other ways. They may rely on one another for reproduction, as is the case in insect-pollinated plants. Or one species may act as a home for another, as a humpback whale carries barnacles. Or the interaction may be more subtle – all the species in a woodland, for example, rely on the activities of the various soil organisms which recycle nutrients.

The term ‘community’ is a valuable one in ecology. However, in 1935 Sir Arthur Tansley invented the term **ecosystem** because he realised that the organisms that make up a community cannot realistically be considered independently of their physical environment. The term ecosystem, therefore, applies to a community of organisms and its associated physical environment.

There is one other feature of ecosystems and their associated communities worth stressing. This is that ecosystems are *dynamic*. Indeed, some ecosystems change as new species invade and others die out. A grassland invaded by shrubs and trees will change gradually as scrubland and then woodland develops. In a mature ecosystem, such as oak woodland, the population sizes and activities of the different species will alter from season to season and year to year. The bluebells in *figure 1.1* flower so beautifully in spring, but by late summer they have set seed, the leaves have died back and the bluebell bulbs are ready to lie dormant until the next spring.

SAQ 1.1

Arrange the following terms in a hierarchy of descending size and complexity: community, habitat, ecosystem, microhabitat.

SAQ 1.2

What parts of an ecosystem are also found in its community?

Humans in the environment

We have given ourselves a Latin binomial, *Homo sapiens*, just like all the other species we have classified. However, it is obvious that the impact humans have on the environment is unlike that of any other species. Ancient humans evolved in Africa and migrated out into Asia and Europe a million or more years ago. A second wave of migration of modern humans spread out of Africa about 130 000 years ago resulting in the colonisation of every continent.

Before humans evolved, of course, all the communities in the world were natural. In Britain,

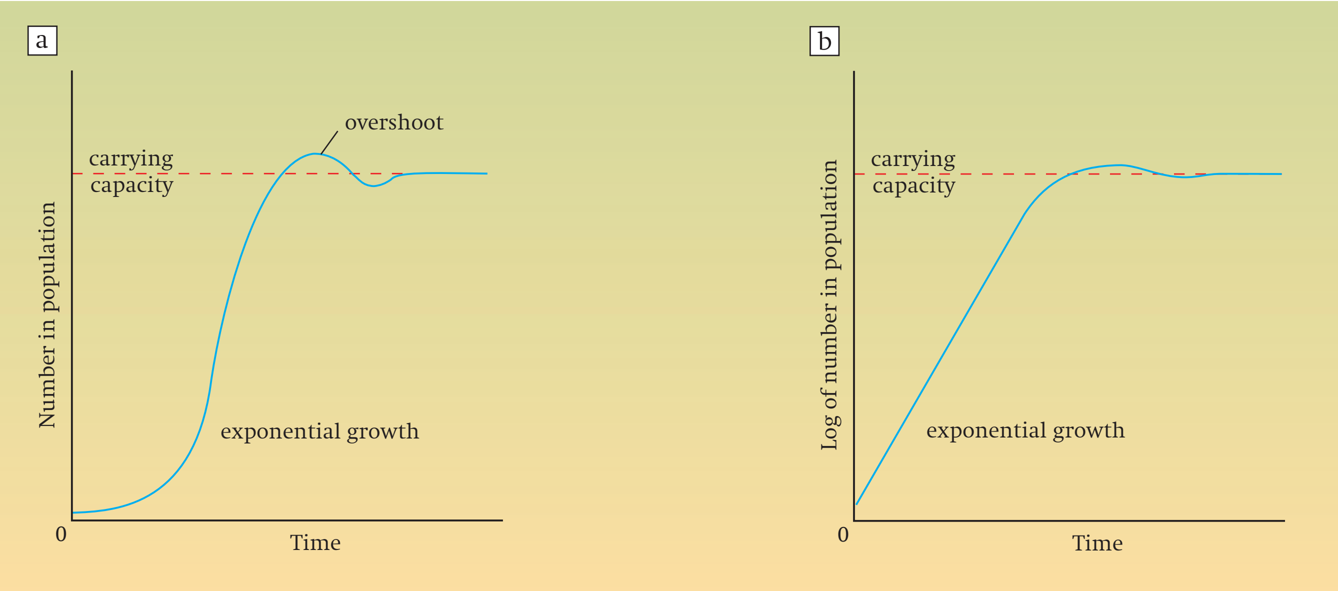


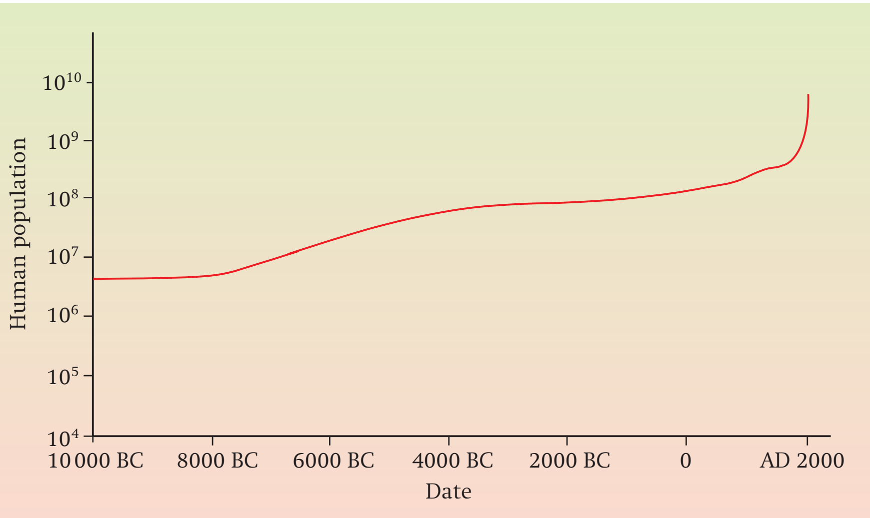
Figure 1.3 Population growth. **a** Normal plot of population increasing exponentially until the carrying capacity is reached, when the population stabilises. **b** A log-normal plot of the same data as **a**. With population plotted on a log scale an exponential curve is represented by a straight line.

natural vegetation during the Ice Ages was treeless Arctic grassland called tundra; during warmer interglacials, after the ice sheets melted, trees invaded. In the south, forests of oaks, ash, lime and hornbeam grew; in the Scottish highlands, the main vegetation was Scots pine conifer forest. These mature forests are called the **climax vegetation**, but such vegetation is now rare due to human activities.

Humans learned to make and use fire early in their history, about half a million years ago – very useful during Ice Ages! Before this, only lightning started wildfires that had the potential to damage vegetation. About 10 000 years ago humans also began to change the natural vegetation by cultivating crops. Animals were domesticated at about the same time. Captive animals graze areas of vegetation in much greater densities than natural animal populations do. The practice of burning and grazing led to the vegetation in many areas of the world developing into grasslands (see page 10). As human populations grew, their dwellings – in villages, towns and then cities – also restructured or even destroyed the vegetation.

As humans are animals, human population biology might be expected to follow the same rules as those of other animal populations (*figure 1.3a* and *Biology 2*, chapter 3). In other animal species, the population initially grows at a rate of increase related to the reproductive rate of the species. Plotting the log of the numbers of individuals in the population against a linear plot of time gives a straight line (*figure 1.3b*). Eventually there will be **competition** for resources that are in limited supply. This competition is **intraspecific** because it occurs between individuals belonging to the one species. The result of this increasing competition is that the population growth slows down. Eventually the population should reach the maximum size that the environment can sustain, a figure known as the environment's **carrying capacity**. The population may overshoot the numbers the environment can support, but will then fall to stabilise at the carrying capacity.

However, human population biology is more complex, and seems to have gone through different phases of growth. As you can see from *figure 1.4*, anthropologists and archaeologists think that the world's human population was stable, or only rising very slowly, up to about 10 000 years ago and that it was rather small – somewhere between 5 and 10 million. Archaeological evidence indicates that about 10 000 years ago the population started to rise more rapidly; there was a change in the rate of increase of population and in the carrying capacity. This reflects the change



• **Figure 1.4** The world human population over time on a log-normal plot.

from mobile gatherer-hunter societies towards a more stationary agricultural lifestyle and the gradual development of the first towns and cities. There was another change in about 1750 with the onset of the industrial revolution. Since then world population has continued to rise sharply.

On 12th October 1999, the world population officially reached 6 billion. That's six thousand million of us. Every day, the number increases by about 250 000. In other words, each day a quarter of a million more people are born than die. We in the West are used to thinking that this is a problem of developing countries. It is true that most industrialised countries, such as the UK, the USA and France, have population growth rates that are low compared to those in other countries. Bangladesh's population, for example, is growing 12 times faster than that of the UK. Yet the average person in the industrialised world uses about 60 times more resources than someone in the developing world.

What is the carrying capacity of the UK for people? The current population of the UK is 59 million, but we have to import a large proportion of our food. Under intensive cultivation, agricultural self-sufficiency could support around 41 million people (see pages 13–15). In other words, given a population of 41 million we should be able to provide all our nutritional needs, provided we carried on farming intensively using fertilisers and pesticides (see page 28). A less intensive use of our land, which might prevent the net loss of soil through soil erosion, would probably mean a population of, at most, 35 million.

So the carrying capacity of the UK estimated from food supply may be somewhere between 35 and 41 million people. However, if we had to rely on renewable energy sources (wind, solar, tidal, wave and geothermal) rather than on fossil fuels (coal, gas, oil and peat) or nuclear power we would probably have to reduce our population to 15–20 million.

Such a reduction may seem far-fetched, though it is interesting to note that only immigration is preventing the populations of many industrialised Western European countries from falling. It has been argued that the quality of life would be much better in the UK if there were only half or a third the number of people there are today. Imagine if this were the case. There would be less pollution, more room for wildlife and no more getting stuck in traffic jams.

SAQ 1.3

If the world's population is increasing in size by about 250 000 a day, how many is that in a year?

The effects of human activity

Agriculture

Britain during the last Ice Age was treeless. Scotland and northern England were covered in a great ice sheet and the south of England was a cold, windswept landscape. After the climate warmed and the ice melted, trees colonised the area from southern and eastern Europe and dense woodland developed. At lower latitudes, in the tropics, the climate became warmer and wetter and tropical forests flourished.

The 'magic' date of 10 000 years ago, when plants and animals started to be domesticated and the human population began to rise significantly (*figure*

1.4), marks the end of the last Ice Age and the start of the warm period we live in today. Past warm periods, the interglacials, lasted about 12 000–15 000 years. We do not yet know if we are living in an interglacial, as we do not know if there is another glacial coming, when global temperatures will fall and the ice caps expand over Britain. At the moment humans are more concerned with global warming than global cooling (see pages 36–39).

In the Near East 10 000 years ago a quiet revolution was about to take place. Archaeological excavations have revealed villages with evidence of early cereal crops and herded sheep and goats: farming had begun. As farming spread, human lifestyles changed and population densities increased (see pages 3–5). Gradually the natural vegetation of many areas was modified and replaced due to the action of farmers grazing their animals and planting crops (see pages 9–11).

Agriculture seems to have first made an impact in Britain between 6000 and 5000 years ago. The gradual replacement of natural vegetation as a result of cultivation occurred throughout the next 3000 years with the introduction of ploughs, then better ploughs, and the increasing use of animals for ploughing and transport, milk and wool. By the time William I had the census taken which is recorded in the Domesday Book of 1086, only about 15% of England retained its original woodland. Intensive farming is now the normal method of food production in most of Europe and North America. Some of the biosocial consequences of modern agricultural practices are discussed in chapter 2.

Not every culture farms intensively. There are some groups, including the many small tribes of the Amazon basin and the Inuit of the Arctic, who still live in ways similar to those of our ancestral gatherer-hunters. Some, like the Dinka and Maasai in Africa, and nomads in the Middle East and Mongolia, herd animals, be they cattle, goats, camels or horses (*figure 1.5*). Many groups in South America, India, Africa and elsewhere grow mixtures of crops local to their area such as maize, cassava, sorghum, rice, vegetables and fruits, to meet their immediate needs.

Whatever way of life a group has, whether gatherer-hunter or of industrial complexity, it is important that their way of life is **sustainable**. Hunters must never overhunt their prey, gatherers must leave enough seed for the next harvest, herds must not damage their grazing land beyond recovery, villagers must not take all the trees for firewood, intensive farming must not lead to soil erosion and dustbowl creation, and industry must not pollute the land, rivers or seas beyond repair. You can judge for yourself just how sustainable many human activities are as you read the rest of this book.

● **Figure 1.5** Cattle are central to the lives of the Dinka people in the Sudan, Africa.

Pollution

Almost any substance can become a **pollutant** if it occurs in the wrong place, in the wrong concentration or at the wrong time. Hence fertilisers are excellent substances for increasing crop yields in intensive agricultural systems, but the same fertilisers running off the land into a river can pollute the water and cause the death of organisms in the natural ecosystem. Farming pollutants include fertilisers, pesticides and animal waste. Our domestic lifestyle produces distinctive pollutants too – domestic refuse, car exhaust fumes and chlorofluorocarbons (CFCs) from refrigerators and aerosol sprays.

Pollution from industrial processes has been around longer than you might think. Metal extraction was known as early as 6000 years ago and metal pollution has been found deep in the ice of Greenland, which is about 4000 years old! The Romans were determined polluters. They burned coal in their underfloor heating systems and smelted all sorts of heavy metal ores to extract lead, copper, silver and zinc. Smelting ores in open fires and crude furnaces was an inefficient process that produced considerable atmospheric pollution. Although huge quantities of metals are now smelted compared with Roman times, luckily for us the methods of extraction have improved. Metal extraction is more efficient, so more metal is extracted even from poorer grade ores and less contaminating metal escapes during the process. Pollution is, however, still a big problem in the world as you can see in chapter 3.

Threats to biodiversity

Biodiversity is a much-heard word these days, although it was probably first used as recently as 1985. It is really shorthand for biological diversity. Biological diversity can be measured at all sorts of levels: the diversity of ecosystems in a region, the number of species in each ecosystem, and the genetic diversity within the populations of each species. Biodiversity includes all these levels of complexity and can be assessed on a local, national or global scale.

Ecologists and conservationists are very concerned about the threatened and actual loss of global biodiversity. The activities of humans over the last 100 000 years have severely compromised biodiversity. Hunting large animals for food probably led to the extinction of species such as mammoths and giant, flightless birds. Clearing natural vegetation for farmland and dwelling space and the polluting of soil, sea and atmosphere have all had the effect of reducing biodiversity (*figure 1.6*). We still have no certain idea how many species there are in the world or what many of those species are. Estimates vary a lot, but there may be as many as 15 million species, of which eight million are insects.

Figure 1.6 Coral reefs like this one off Cozumel Island, Mexico, have a high biodiversity of animals and algae. Reefs are under threat from excess sediments and pollution carried out to sea by large rivers.

By far the most diverse places on land (we are not so sure about the sea as the very deep oceans are mostly unexplored) are the tropical rainforests and the largest, in the Amazon basin of South America, is the richest of all. We have still not studied the rainforests enough to know exactly what is there, or how their ecosystems function. Yet it is these forests that are disappearing at an alarming rate, cleared for subsistence farming, for cattle ranching, for timber extraction, for mining, for access, and by accidental burning.

The issues involved in conserving ecosystems and the biodiversity of UK habitats are discussed in chapter 5. Chapter 6 discusses the global aspects.

SAQ 1.4

State the three levels and the three scales at which biodiversity can be measured.

Monitoring the environment

Ecology is in many ways the most complicated of all the biological sciences. Ecologists have to know something about the structure, physiology and behaviour of organisms before they can begin to understand how such organisms interact with one another and with the physical environment. For these reasons, ecology is increasingly an *experimental* science. Ecologists constantly need to test their predictions either in natural environments, in semi-natural experiments out in the field, or in artificial, simplified laboratory experiments.

Theories can be of great value in ecology, but they must always be tested against reality, and this is where practical ecology is so important. We can only gain an understanding about the ecosystems around us by getting information about them through practical ecology. However, whole ecosystems are often far too complex to understand all in one go. It is easier to begin by choosing one or two species, or a small area of habitat, to study in detail. Practical ecology involves making observations, taking measurements and sometimes testing ideas by experimentation.

Because there is so much to study in the environment and because the environment may change considerably in the next few decades (due to global warming and pollution) anyone can do valuable research. Carefully designed and long-term observations can be of great value. Just recording when the first bluebells start to flower and the first tree leaves appear, how often late frosts damage leaves or when frogs spawn each year could be important records of the effects of changing climate. As Oliver Rackham, a leading expert on ancient woodland, put it: ‘I often lament the observations which I would have begun if I had known in the 1960s what were to be the ecological problems of the 1990s … I would urge conservation trusts to be more active in long-term research, experimentation and maintaining archives … photographing from fixed points, recording permanently marked plots or transects, or following the fate of marked individual plants.’ (*Nature in Cambridgeshire*, 1999, volume 41, page 86.)

Chapter 7 shows how investigative ecology can be pursued.

SUMMARY

- Ecology is the study of organisms in their natural surroundings.
- Environmental biology includes the study of humans in the environment.
- The number of people in the world now exceeds six billion and is still increasing rapidly.
- The carrying capacity of the UK for people is difficult to determine and depends on whether one means the carrying capacity with respect to sustainable food production or renewable energy resources.
- Agriculture first made an impact in Britain between 6000 and 5000 years ago.
- Humans have had a significant effect on biodiversity for tens of thousands of years.
- Environmental monitoring, especially if carried out over many years, can make a major contribution to ecology and conservation.

Questions

1 **a** Distinguish between the terms habitat and niche.
b How might you investigate the niche of a particular species of garden slug?

2 Describe how the world’s population of humans has changed over time and compare this with the equivalent data typical of other animal species.