CHAPTER 1

Introduction: defining nature

1.1 How little we know

Understanding the organisation of nature has never been so important. The UN declared 2010 to be International Year of Biodiversity in advance of a meeting in Nagoya to discuss the Convention on Biological Diversity. Back in April 2002 the member countries had pledged

> …to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth.[1]

It is safe to say that this target was not met; if anything the rate of extinctions increased over this time period (Butchart et al., 2010), and the continued trajectory is not promising. But was it ever an achievable goal? Problems with the statement include the very definition of biodiversity itself—what should we be counting, how do we go about it, and when will we know that the trend is reversing? How can we begin to collect the necessary information when fewer than 14% of all species have been formally identified (Mora et al., 2011)? A major theme of this book involves trying to answer these questions.

The concatenation of linked issues facing humanity, which include overpopulation, global climate change and an ongoing mass extinction (May, 2010),

has prompted some to suggest that the only future for humanity is to leave the planet and take to the stars. It has long been a trope of science fiction that natural systems could be exported beyond Earth's atmosphere. Such a bold aspiration poses immense technical challenges, but these are at least equalled by the ecological problems. Is such an achievement—or salvation—within our capabilities?

The ultimate test of our understanding of natural systems is whether we are able to construct them ourselves. This was first attempted on a realistic scale by the Biosphere 2 project (Biosphere 1 being the Earth). A sealed glasshouse was constructed in Arizona between 1987 and 1991 covering 1.27 ha; it remains the largest ever constructed. It originally contained a series of different habitats along with agricultural land. The total cost of the project was $200 million (around $0.5 billion at today's value). Two attempts were made to completely seal groups of scientists inside. One of the major problems turned out to be atmospheric control; carbon dioxide levels fluctuated wildly both daily and seasonally, and oxygen levels fell by 30% over the first 16 months, leading to an injection of oxygen on medical grounds. All pollinator species and most vertebrates went extinct, while pests such as cockroaches became superabundant. Much was learnt from these studies, but in terms of the grand ambition—conducting a pilot study for future space stations—it must be considered an abject failure. No one has tried again since the last mission

[1] For the complete text see http://www.cbd.int/decision/cop/?id=7200.

was abandoned in 1994. For all our knowledge and understanding, we still cannot build a closed, functioning ecosystem.

1.2 Pressing questions

There are several profound gaps in our understanding of the natural world. As in any branch of science, asking the questions can seem deceptively simple, but arriving at the answers is more challenging. This book attempts to address the following:

- What governs the number of species present in any one location?
- What determines the identity of these species?
- How do local and broad-scale ecological processes interact with one another?

In order to reach an appropriate level of understanding to tackle these questions, we must draw from a number of fields including diversity theory, community ecology, ecosystem functioning and biogeography.

1.3 The hierarchy of nature

First it is important to identify the major scales of organisation in nature (Figure 1.1). Knowing the differences between these is essential. Each term has a very specific meaning and conflating concepts can lead to confusion. A crucial point is that processes which operate at one scale (e.g. the local community) might be irrelevant at another (e.g. the ecoregion). For example, competition is a central structuring force in explaining species interactions within a grassland but tells us little about species distributions on the scale of an entire continent.

Ecology begins with **individuals**, typically recognised as independent reproductive organisms. This definition is less simple to enforce than it sounds and can occasionally be arbitrary in its application. Colonial organisms such as sponges and bryozoans are composed of multiple individuals which depend
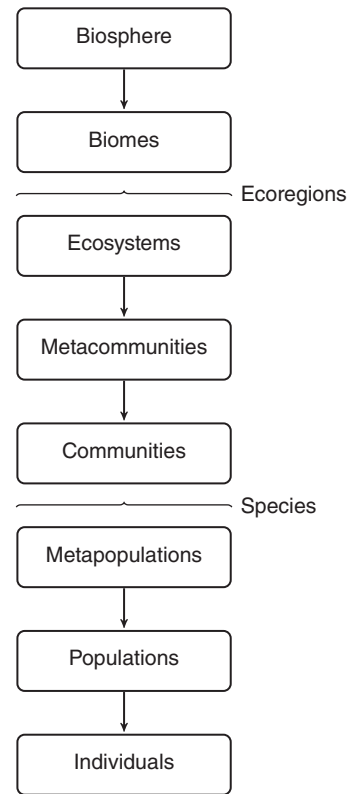

Figure 1.1 The hierarchical organisation of life on Earth. Components are linked by arrows where each level is a spatially-nested element of that above. Biomes are divided into ecoregions which are spread across the globe; likewise communities are made up of species which are not exclusive to any single community.

on their membership of a single structure to reproduce; hence it is common to count the whole colony as an individual. In some social species, such as ants, most colony members are unable to reproduce but instead support the reproduction of a single queen. Here it would make most biological sense to count each colony as an individual, yet for practical reasons (ants are easier to find and count than their nests), it is more common to count the sterile workers and treat them as individuals, which is also a more reasonable means of estimating their wider ecological impacts. Even at the individual level we have to recognise that complications can arise.

One way of identifying an individual might be to say that it is the product of a single fertilisation event,

known as a genet. This is fine for sexually reproducing organisms, but not for those which are asexual, where offspring are identical copies of their parent. In some cases both can live side by side. Strawberry plants can be grown from seed, each the result of the pollination of a single ovule in a flower. As they grow, however, they send out runners which develop their own roots and can detach to become separate plants. These are known as ramets—despite being genetically identical to their parent, they still compete for all the same resources. A patch of wild strawberries could contain any proportion of genets and ramets.

Individuals can be highly variable in their behaviour, physiology and genetics; these have profound implications for the dynamics of **populations**, which are collections of individuals of the same species linked by reproduction. Once again, defining a population is simpler than recognising one; it is difficult to determine where the boundaries of reproductive links are, and therefore for convenience we typically demarcate populations based on sensible habitat features rather than by assessing gene flow (e.g. the edge of a lake would mark the boundary for a single population of fish). In more recent ecological theory it has been recognised that populations are linked by dispersal of individuals into **metapopulations** which have their own higher-order dynamics (Hanski, 1999). In truth there is often a continuum between the two, though in cases where discrete units can be identified (e.g. islands), with a discontinuity in dispersal, the concept can be vital in appreciating how local and regional dynamics are connected.

In conventional ecological theory, the population size is the sum of all the actively (or potentially) reproducing individuals. This therefore excludes juveniles (eggs, larvae and young) and—perhaps more surprisingly—males, since they do not control the rate of reproduction. Here again the theoretical and the practical are not easily reconciled. Consider the moon jellyfish (*Aurelia aurita*). It reproduces sexually, forming larvae which sink to the sea floor and form polyps. Normally these will wait for suitable conditions before budding to generate around 20 floating jellyfish. When the environment is unfavourable, however, these polyps can instead choose to create new polyps or form resilient long-lasting cysts. Apparent explosions in jellyfish abundance occur as soon as conditions allow. A species like this foils all our idealised concepts of how we determine population size.

The sum of all individuals makes up the totality of a **species**. The precise definition used to decide where the boundaries lie between species has further implications for how we interpret patterns in nature. This is the subject of the next chapter and the starting point for thinking about natural systems.

When multiple species occur in a single location, and show stability through time, it is referred to as a **community**. Typically these species are linked by feeding relationships into a food web and through interactions including competition, mutualism and parasitism. Interpreting the dynamics of any single population requires an understanding of these linkages. In an analogous fashion to populations, communities can be joined together in **metacommunities**, which are networks of communities connected by the dispersal of species (Holyoak et al., 2005). This is a relatively recent concept in ecology but has great explanatory power when linking the processes occurring at small scales to those on a regional level and *vice versa*.

At greater scales of study we recognise another entity emerging, the ecosystem. This oft-misused term actually refers to a combination of interacting living and abiotic components (Chapin et al., 2012). Rather than organisms simply responding to their environment, they also change it. Examples include how **transpiration** of a forest generates clouds and influences regional climate or peat bogs absorb carbon and store it in the soil. A hot topic in current ecological research focusses on how the components of ecosystems contribute to the resultant processes, which is the focus of Chapter 9.

Finally we can view natural systems at the biogeographical scale, where new levels of organisation become apparent. Broad patterns of life can be identified as **ecoregions**, large patches of Earth

with consistent biotic characteristics in terms of their constituent communities and ecosystems. These can be further grouped into **biomes** which indicate the forms of the major natural systems as determined by their vegetation, general climate and dominant organisms within them. These are familiar as deserts, rain forests and other dominant communities on land and in the oceans. They are considered in more detail in Chapter 14. Ultimately these make up the whole Earth system, known as the **biosphere**. The controversial theory that life on Earth interacts with the abiotic environment to form a self-regulating complex system at a planetary scale is referred to as **Gaia** (*sensu* Lovelock, 1979). While most ecologists would hesitate to include such a maligned idea in this hierarchy (see Chapter 11), a global perspective can be useful, and problems such as climate change necessitate a scale of thinking at the level of the biosphere, representing all life on Earth.

1.4   Biodiversity

I have generally avoided the use of the word 'biodiversity' throughout the text, despite its prevalence in the media and (increasingly) the scientific literature. This may seem ironic; this is after all a book entirely about biodiversity in its most inclusive sense. As will become clear, however, such a simple word serves to obscure a vast array of important information and variation and is therefore a barrier to a full appreciation of how natural systems are constructed and operate. The term has a disputed history but is most commonly used to refer to the variety of life at all levels, which, according to the 1992 Convention on Biological Diversity,

> … includes diversity within species, between species and of ecosystems.[2]

Unfortunately this means that in practical terms it has no units; one cannot point to two lakes and state quantitatively which has the greatest biodiversity.

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[2] See http://www.cbd.int/convention/text.

Often it is used to imply species richness, a term with a precise definition as the number of species, and therefore the latter should be used in preference since it is less prone to confusion. Only a few years after the term was coined there were already at least 85 different published definitions of biodiversity (DeLong, 1996), prompting some wags to refer to it as 'biological diversity with the logical part removed'. Its origins in the legalistic language of a political treaty mean it is of little help in resolving scientific questions.

A further difficulty with the term is that it is inherently value laden—more biodiversity is assumed to be a good thing. This is often not the case; invasive species increase species richness (at least temporarily), while many important habitats (e.g. mangrove swamps) have relatively low numbers of species. On its own, therefore, biodiversity cannot be used as a criterion for making assessments for conservation purposes.

1.5   Myths to bust

In the process of building an understanding of the organisation of natural systems, we must begin from firm foundations, which means dispensing with several beliefs that are commonly held by the naïve observer of nature. The first, and most egregious, is the idea of 'the balance of nature'. One of the recurrent themes in the text will be to demonstrate that there is no such thing: everything is in flux, usually with no clear end point, and constant change is an ecological rule. Stability is often a transient illusion. This is equally important in conservation; we should guard against superficial attempts to return systems to a 'natural' state as it is seldom possible to decide with any confidence what this ought to be.

A related idea which was long ago driven from scientific theory is the principle of providence, through which it was believed that a benevolent creator would not allow any part of nature to come to harm. Yet this pattern of thinking can insidiously creep back into our reasoning when we assume

that internal checks and balances will automatically restore natural systems to some default state after being perturbed. The fallacy of this will be revealed in due course. That natural systems respond to disruption in predictable ways is demonstrable but can be explained through more prosaic, ground-level processes without the need to invoke numinous forces. Moreover there is no guarantee that systems will return to their original starting point.

A final common belief is that natural systems act as finely balanced machines in which every component is harmoniously linked and removal of any part will inevitably lead to decay or collapse. This is related in ecological thought to the idea of the 'superorganism' (Clements, 1916), whereby species are tightly and obligately connected as *gestalt* units. We will return to this theme in Chapter 10, but for now it should be stated that the concept is discredited, and it turns out that many species are replaceable or expendable. This is not to say that each is not important, but rather that extinctions do not always imply imminent disaster, and natural systems prove to be remarkably resilient.

1.6 Further information

To set the wider political context in which the ideas presented here gain their greatest importance, you might want to follow up on the work of the various non-governmental organisations (NGOs) and intergovernmental bodies tasked with addressing the challenges of our changing world. For information on the Convention on Biological Diversity (and subsequent developments), there is a wealth of information at http://www.cbd.int. More facts and figures can be obtained from the World Resources Institute (http://wri.ogc.org/wri/biodiv) or the World Conservation Monitoring Centre (http://www.unep-wcmc.org).

1.6.1 Recommended reading

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