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Part I

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Chapter 1

The natural world

In order to understand and evaluate the threat that human activity poses to the natural world we must first consider what the natural world consists of and how to describe it. This chapter sets the scene by introducing the term biodiversity and considering how our living heritage is quantified and distributed, both geographically and among taxonomic groups. The different ways in which we value natural resources are also considered to help us understand the need for their conservation.

By reading this chapter students will gain knowledge of how biodiversity has developed historically and how it is now distributed taxonomically and globally. They will also gain an understanding of some of the possible natural causes of these patterns and of the value of natural resources to human civilisation.

What have we got to lose?

Life has existed on Earth for around four billion years, constantly evolving to form the spectacular richness of our current living world. In fact the fossil record indicates that, on average, life has steadily increased in diversity and complexity over time to produce the richness we see today (Box 1.1). We have benefited from this natural richness in so many ways, we ourselves are products of it and we continue to benefit from it. How strange it would look, then, to any historian looking back in several thousand years time, that the most intelligent species on earth should, in such a short period, destroy and degrade the environment on which it depends to the degree we have, and continue to do.

Box 1.1 Historical changes in biodiversity – lessons from the past

The increasingly well-catalogued fossil record provides us with a window on levels of biodiversity throughout geological time and a fascinating measure of change. The first and most obvious pattern is that biodiversity has increased over time. We started with nothing and now we have a lot. A closer look suggests that biodiversity has not

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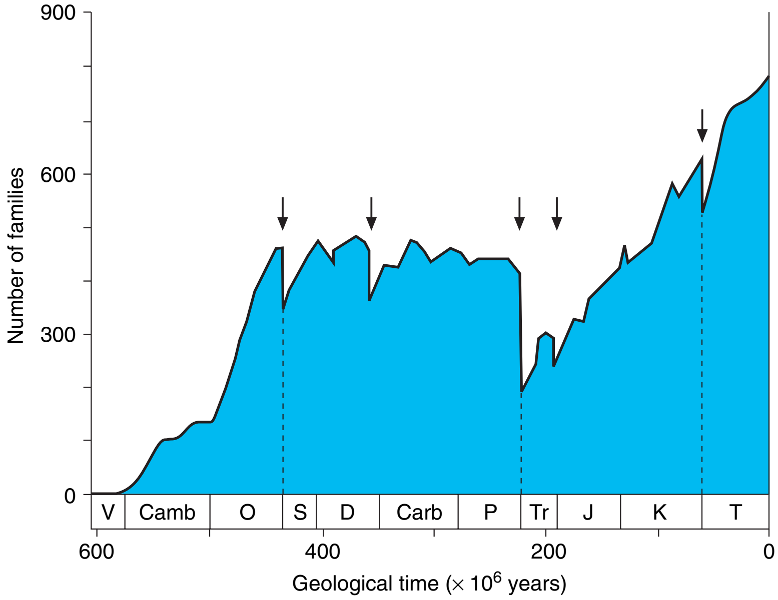
Fig. 1.1 Change in biodiversity over time represented by the taxonomic richness of marine skeletonised animals. The arrows mark mass extinction events. The current mass extinction is not shown. Reproduced from Erwin *et al.* (1987) with kind permission of the Society for the Study of Evolution.



increased at a steady rate, but is punctuated by sharp drops in biodiversity when many taxa disappear (so-called megaextinction events), usually followed by rapid recovery as many new taxa appear in their place (Fig. 1.1).

The megaextinction events are thought to have been caused by major climatic changes at these times. Many species were not able to cope with the rapid changes in their environments and so perished. Subsequent rapid radiation of life forms could have been because of the empty niches left behind. However, whilst there is some evidence to support the climatic reasons for megaextinction (see below), we do not as yet understand what conditions favour rapid increases in biodiversity. Such a major increase occurred during the Cambrian era, 550 My before present (BP), before any recorded megaextinction. This period has been richly described by Gould (1989) in his account of the Burgess Shale fossils which record a rapid diversification of multicellular hard-bodied animals (metazoans). This may have been due to an evolutionary advance in body form that enabled the exploitation of new niches.

A useful lesson for our future comes from the evidence that megaextinctions may be caused by rapid environmental change. The last and most famous megaextinction event of all, which led to the demise of the dinosaurs, was almost certainly the result of rapid environmental change, caused either by intrinsic climatic factors or by extraterrestrial impact. The evidence we shall consider in the next few chapters of this book suggests that we are currently experiencing the sixth megaextinction event. This is the result of rapid environmental change as before, but this time the change is faster than ever before and we are the driving force of that change. Whether or not we suffer the same fate as the dinosaurs is a matter for debate; what is not in doubt is that, if we continue with our increasing impact on the natural environment, many other species will suffer that fate.

As we begin a new Millennium, it is interesting to consider what we, the few generations of *Homo sapiens* to traverse this point in time, might be remembered for. I wager it will not be for the Cold War between East and West, the rise and fall of communism, not for various wars in the

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Middle East or for terrorist acts; not for rises in living standards or widespread famine. All of these will be continuations of normal historical events. We will probably be celebrated for putting the first person on the Moon, and the computer/information revolution, but we will certainly be condemned for presiding over large-scale habitat destruction and the mass extinction of species on earth. The latter is the crime of our generations for which future generations will never forgive us. It is happening now, concentrated over just a few decades, destroying what four billion years of evolution has created. We must find ways of limiting the severity of this crime, for although history will find us guilty of it, it is not we who will be sentenced, but our children.

Our actions look increasingly short-sighted when we consider how much we depend on our environment for goods and services. It would be a supremely arrogant person who claimed that humans were in control of their environment, yet this is what our political actions appear to presume or at least seek. We are still almost totally dependent on natural resources for the production of our food, the air that we breathe and the water that we drink. The natural environment frequently reminds us of our vulnerability in the form of natural disasters that appear on our television sets almost daily. Our lack of control is blatantly obvious, even more so if you consider that some of the disasters are not entirely natural but result in part from our attempts at control. But there are some reasons for optimism. There are signs that human society has begun to realise that it is part of the natural environment and that our future depends not on control but on coexistence. The science of conservation biology has a crucial part to play in providing the tools for this environmental revolution.

We will look in more detail at our impact on the natural environment in later chapters but in order to understand the problems that we face in conserving our natural heritage we must first know something of what we have got to lose. We therefore start with an appraisal of our assets.

Diversity among living organisms

One of the major reasons why I became a biologist was my early impression of the bewildering diversity of species that were apparently out there in the wild, living lives that I did not (and in most cases still do not) understand. My direct experience as a child living in the British countryside is partly responsible for this. I was able to walk out of my parents' front door in a Wiltshire village and stroll down to the local river, wander through rich chalk grassland and play in woodland dominated by oak and beech. Diversity was all around me. But, just as influential, was the increasing number of high-quality nature programmes on television. These showed me the contrasting diversity of other places and the bewildering facts of their existence. Along with these experiences came the desire to see and understand more. I was hooked.

Many other people are also hooked on nature, but don't necessarily recognise it. You just have to look at the traffic pouring out of our cities

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Table 1.1 General explanations of the term 'biodiversity'

1. Term commonly used to describe the number, variety and variability of living organisms (Groombridge 1992)
2. The variety among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Article 2, Biodiversity Convention)
3. The total variability of life on earth (Heywood 1995)

to try and find the open countryside during fine summer weekends. They are looking for many things, but one is that feeling of wildness and richness that, in contrast to concrete, even a small patch of woodland or grassland can offer. Nature seems to be a reference that we seek, a comfort to help us cope with our increasingly stressful lives, estranged from the natural world. The aesthetic or spiritual value of nature may be argument enough for its conservation but, in comparison with the value of economic development, estimating the hard value of nature can be difficult and illusive.

As a science, conservation biology must formalise the value of the natural world by quantifying its richness and diversity. The current popular term for the richness and diversity of life is **biodiversity**. This is simply short for **biological diversity** and it has no strict scientific definition (Table 1.1). However, it has become widely used in both the scientific and political fields as a measure of the value of the living world and we need to try and understand what it means. It is used in the literature to cover both the number of different populations and species that exist and the complex interactions that occur among them. Biodiversity is therefore commonly considered at three different levels:

1. within-species (intraspecific) diversity; usually measured in terms of genetic differences between individuals or populations;
2. species (interspecific) diversity; measured as a combination of the number and evenness of abundance of species;
3. community or ecosystem diversity; measured as the number of different species assemblages.

Biodiversity is therefore an expression of both numbers and difference and can be seen as a measure of complexity (Gaston & Spicer 1998). Its measurement at all levels presents significant challenges to the conservation biologist and we still largely rely on descriptive rather than quantitative measure of biodiversity to assess value, as illustrated in later chapters.

Biodiversity varies at all spatial scales from the 1 cm^3 sample of water or soil through the 1 m^2 quadrat vegetation sample to the continental scale. No one book can hope to describe these changes in full detail, but a general overview at the ecosystem scale is illustrative of the biodiversity and living resources we are fortunate enough to be borrowing from future generations. This is provided in the following chapter,

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where we also explore how major environmental factors influence diversity among ecosystems. Below, we try to draw some conclusions about general patterns of biodiversity.

Patterns of biodiversity

A fundamental starting point for conservation is to have a record of the living world in terms of the number of species that currently exist and how they are distributed. A pressing and difficult task for taxonomists, mostly working out of museums, is to painstakingly catalogue and report the discovery of new species. Unfortunately there are far too few taxonomists for this task. We are still very uncertain of how many species we have and there is a very long way to go. In fact it is certain that we will never be able to describe and name all species (to date approximately 1.5 million species have been described). It has therefore become necessary to try and estimate the total number of species currently present on earth. Box 1.2 summarises a method used for this daunting task.

Box 1.2 Estimates of the current number of species on Earth

In order to arrive at an estimate of total number of species, the most common method employed is to sample and then scale up to the whole. An early estimate that initiated considerable debate on this problem was made by Erwin (1982), who was interested in the beetle fauna of tropical forest canopies. He collected beetles from a single species of tree by canopy fogging (an insecticide is released into the canopy of the tree and the insects collected as they fall to the ground). By estimating the number of species confined to that species of tree (162) and scaling this up by multiplying by the number of tree species in tropical forests (50,000) he estimated that tropical forests might contain as many as 8 million beetle species. He then further scaled up by assuming beetles were only 40% of total canopy arthropods and that canopy arthropods were only two thirds of the total arthropod fauna. This gave a total of 30 million tropical forest arthropods! Obviously there are many assumptions in this estimate and it was subsequently criticised, particularly for the assumption that all tropical tree species support such a large number of specialist insects. Subsequent estimates have been significantly lower, some based on more conservative scaling-up procedures and others based on the rate at which new species are being discovered in a range of taxonomic groups. There is now less variability in overall estimates and a general consensus is being reached that there are between 10 and 15 million species currently on Earth.

All of these estimates assume that there are no more surprises in terms of hidden diversity. This assessment may have to be revised if, for example, we find higher than expected numbers of species in the deep oceans. There is also a problem with the species concept in taxonomic groups such as the viruses and bacteria. Since there is no agreement on whether the species concept is applicable to these groups it is difficult to compare their diversity or richness with other groups. Genetic diversity may be a more appropriate measure in this case. I wonder how many genes there are on Earth?

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If we cannot accurately count how many species occur in a given area then, clearly, measuring its biodiversity is also going to be an estimate. Different methods of estimating biodiversity will be considered in Chapter 8, but it is important to note here that the majority of the information gathered to date on the geographical distribution of biodiversity is based solely on the number of species (usually within one of the better recorded taxonomic groups) recorded in a given area. Thus the unit of measurement is the species and relative biodiversity is expressed in terms of **species richness** of selected taxonomic groups. Even though these measures are crude, they do suggest some inequalities in distribution that are of significance for conservation.

How is biodiversity distributed among taxonomic groups?

Species are not distributed evenly among higher taxonomic groups and most belong to those taxa that are least appreciated and understood. To anyone cataloguing species on earth it quickly becomes apparent that in terms of species number, the world is dominated by the Class Insecta and its close relatives (other Arthropods such as spiders) (Fig. 1.2). Of the species currently described, more than half are insects. Some of the best known taxonomic groups such as the mammals and birds, in which most species are already described, actually make up a small proportion of the total species. But what would the proportions look like if all species, known and unknown, were included? Based on the current estimates described in Box 1.2, species richness is likely to be dominated by the insects to an even greater extent than estimates currently based on named species. Other poorly recorded taxa, such as the algae, fungi and perhaps deep-ocean invertebrates, will probably rise as a proportion of the total as our knowledge of them advances.

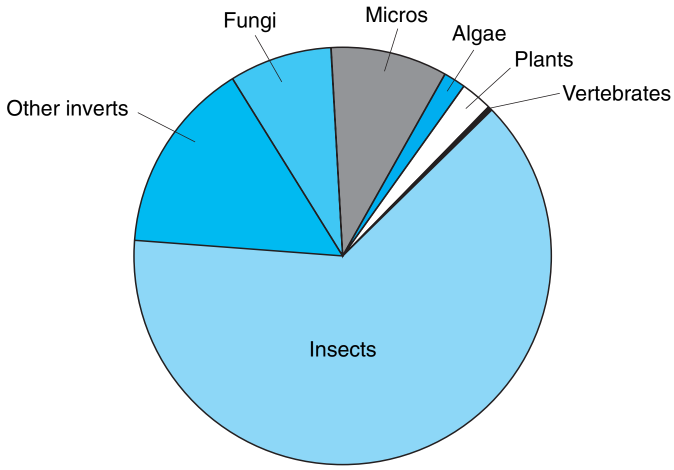

Fig. 1.2 Proportion of all species currently recorded belonging to each major taxonomic group. Note the vertebrates (on which most conservation effort is expended) constitute an almost vanishingly small slice of the pie. Data from Groombridge (1992).

What do we know about global patterns of diversity?

Across a whole range of taxonomic groups there is a tendency for species richness to decrease from the tropics to the poles (Fig. 1.3). A decrease in species richness of American land birds from the tropics of Central America to the Arctic tundra of northern Canada is shown in Fig. 1.4.

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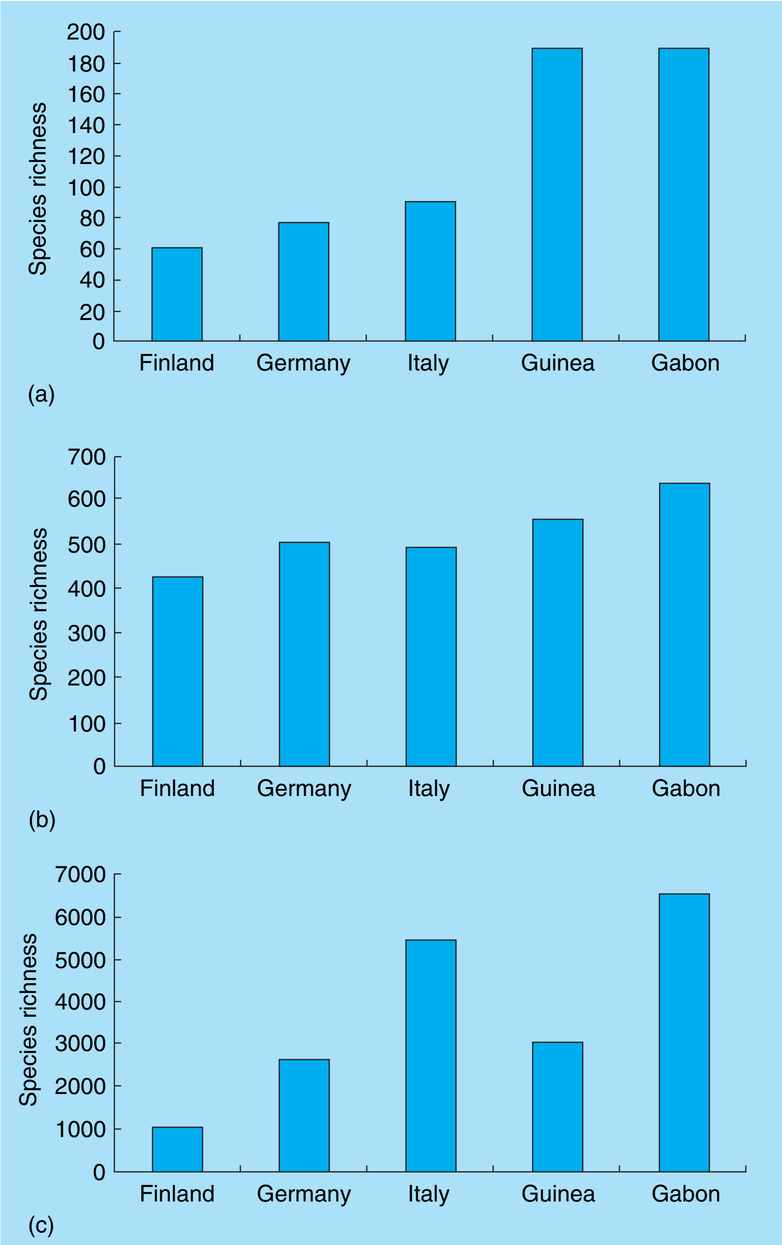

Fig. 1.3 Variation in species richness in (a) mammals, (b) birds and (c) flowering plants, among countries of similar size, but from different latitudes. All show a progressive increase from high to low latitudes.

This pattern is mirrored for many taxonomic groups, but is often complicated by physiographic and climatic factors such as mountain ranges and rainfall patterns. This is shown in the pattern for American land mammals and for tree species (Fig. 1.5). In both, the general trend is for a decrease from the tropics to the poles, but in mammals, species richness increases in the Rocky Mountain ranges, whilst trees reach a high species richness in the moister climate of the southeastern USA. Across all species, there is also a trend for decreasing species richness from low to high altitudes. The reason for these global trends has been the subject of much debate. The reason may at first seem obvious in that polar and

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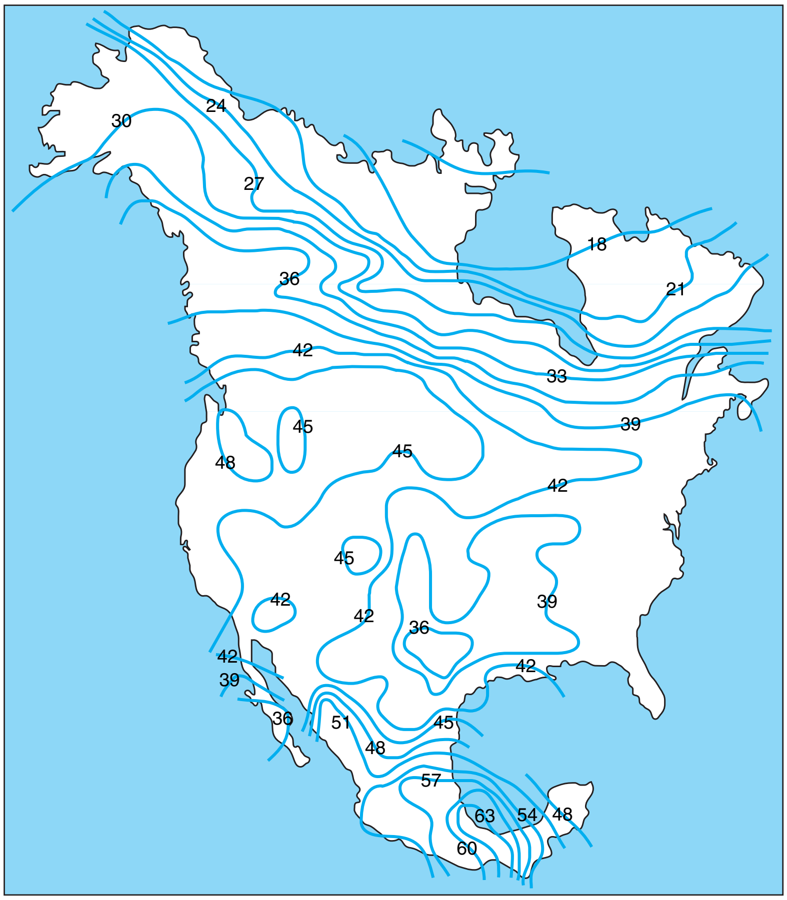

Fig. 1.4 Density of families of breeding birds in North America showing general decrease from the tropics to North Pole. Redrawn from Cook (1969) with kind permission of the Society for Systematic Zoology.

high-altitude environments are 'harsh' or 'extreme' and therefore present significant challenges for survival, but this a rather anthropomorphic view and these environments are clearly not harsh to those species that survive there and nowhere else. Many explanations have been put forward to explain the latitudinal gradient in diversity; none is completely satisfactory but they are not mutually exclusive and some can be effectively combined.

The *catastrophe hypothesis* argues that all stable environments encourage diversification in time and since the tropics have been stable for longer than temperate regions, which have suffered catastrophic changes in climate in the form of ice ages (Box 1.3), one would expect greater diversity in lower latitudes. Regions that have suffered other sorts of catastrophes such as volcanic activity have lower diversity and therefore provide good supporting evidence. However, coral reefs are prone to catastrophic changes in sea level but have very high diversity, thus undermining this hypothesis. The related *evolutionary speed hypothesis* similarly argues that because conditions are more favourable in the tropics, organisms develop faster and go through more generations per unit time. Biotas in warmer climates will evolve at more rapid rates than those in cold climates because of the more constant favourable

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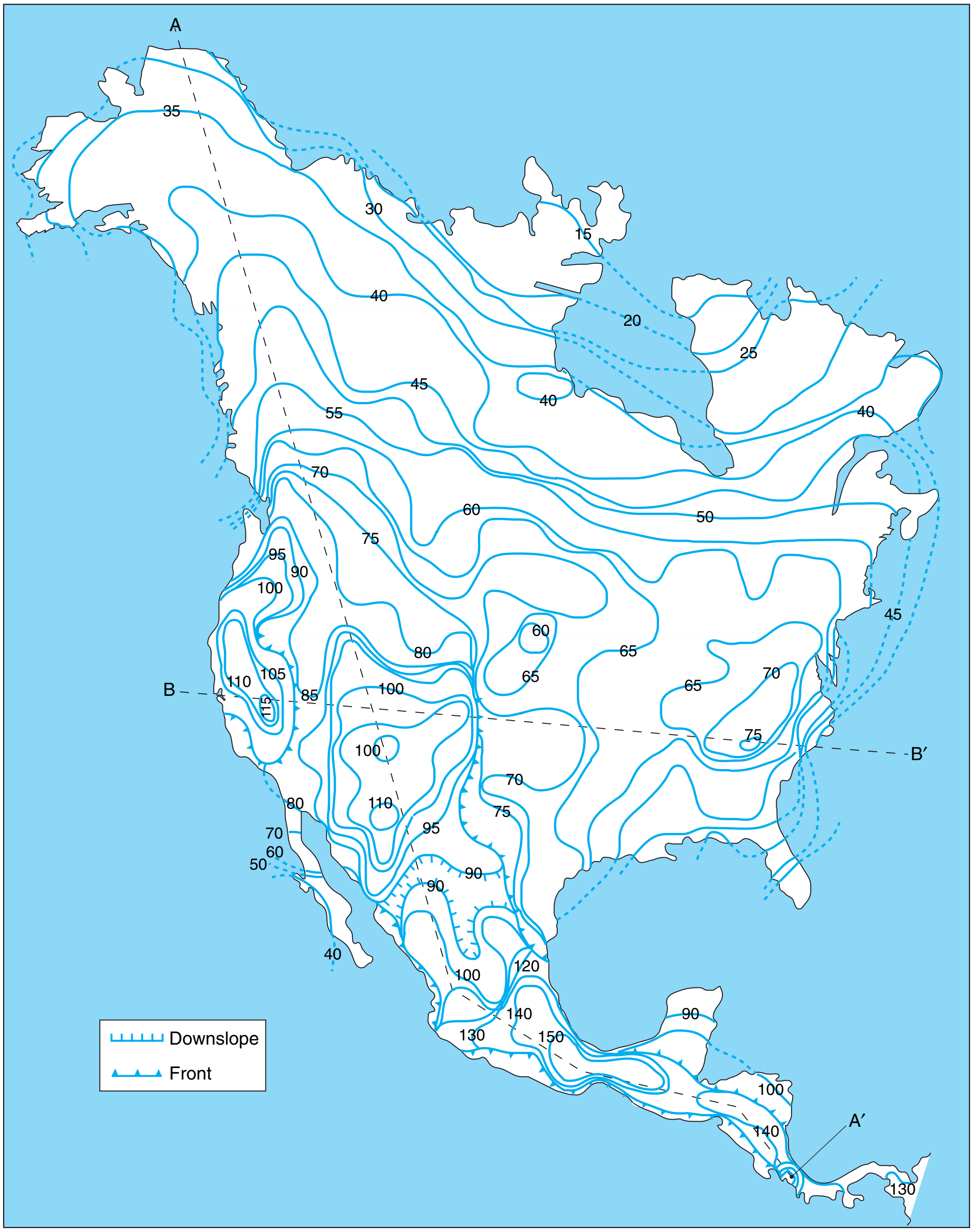

Fig. 1.5 (a) Species richness of terrestrial mammals in North America showing general decrease from tropics to pole, but also variance due to habitat heterogeneity. Redrawn from Simpson (1964) with kind permission of the Society for Systematic Zoology.