Zoogeography

Lesson 9

- # Has the diversity an influence on the stability of an ecosystem?

- -Charles Elton who first proposed (in the 1950s) that a more complex and rich ecosystem should also be more stable, meaning that it was less prone to violent fluctuations such as those caused by epidemic disease or pest outbreaks
- the development of mathematical modelling as an approach to the understanding of populations did not provide the expected results
- a species in a diverse ecosystem is no less subject to fluctuations caused by unfortunate events, such as drought or disease, than is a species in a simple ecosystem.
- On the conservation side, the loss of global biodiversity that we are currently experiencing may well be affecting the functioning of the entire biosphere: i.e. In the field of agriculture, the use of multicropping systems rather than single-species stands can provide advantages in terms of both productivity and stability of the system, which is a particular concern in marginal areas, such as arid regions.

- Some confusion can arise m *diversity* is used.
- often, it is simply used as ıt within an ecosystem: **species richness**

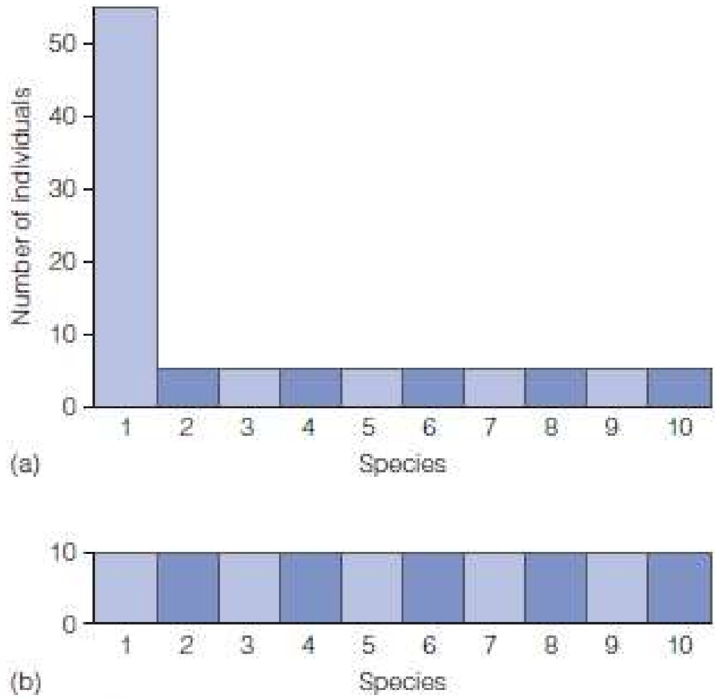


Figure 3.5 Hypothetical community of 10 species and 100 individuals. In (a), one species dominates; and in (b), all species have equal representation. It can be argued that (b) represents the more diverse of the two communities despite their having identical species richness.

- what precisely do we mean by **stability**?
- Is a stable ecosystem one which is difficult to deflect from its current composition or function?
- Stability can be explained in terms of **inertia**, or **resistance** to change
- Alternatively, a stable ecosystem could be defined as one which rapidly returns to its original state following disturbance → this uses the concept of **resilience** as a basis for defining stability.
- A **stable ecosystem** should behave in a **predictable manner** no matter what fate may cast in its path, and biodiversity does appear to render an ecosystem predictable by providing a kind of '**biological insurance**' against the failure of certain sensitive species when exposed to particular stresses.

Responses of an ecosystem to disturbance

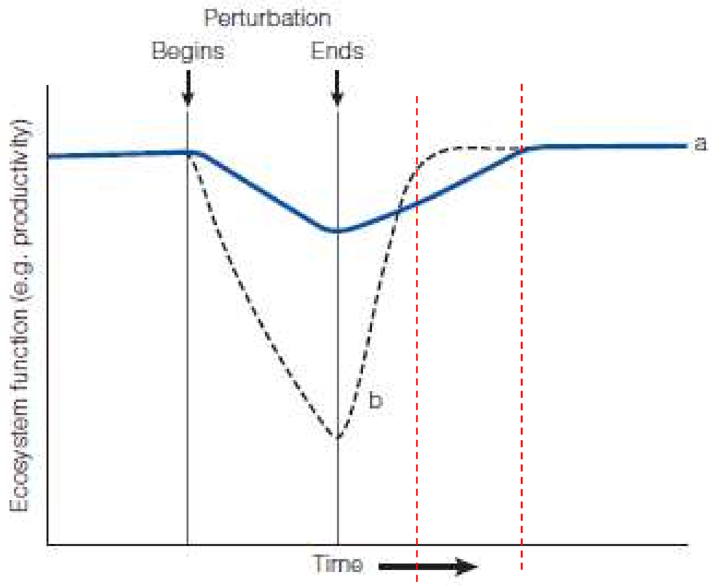
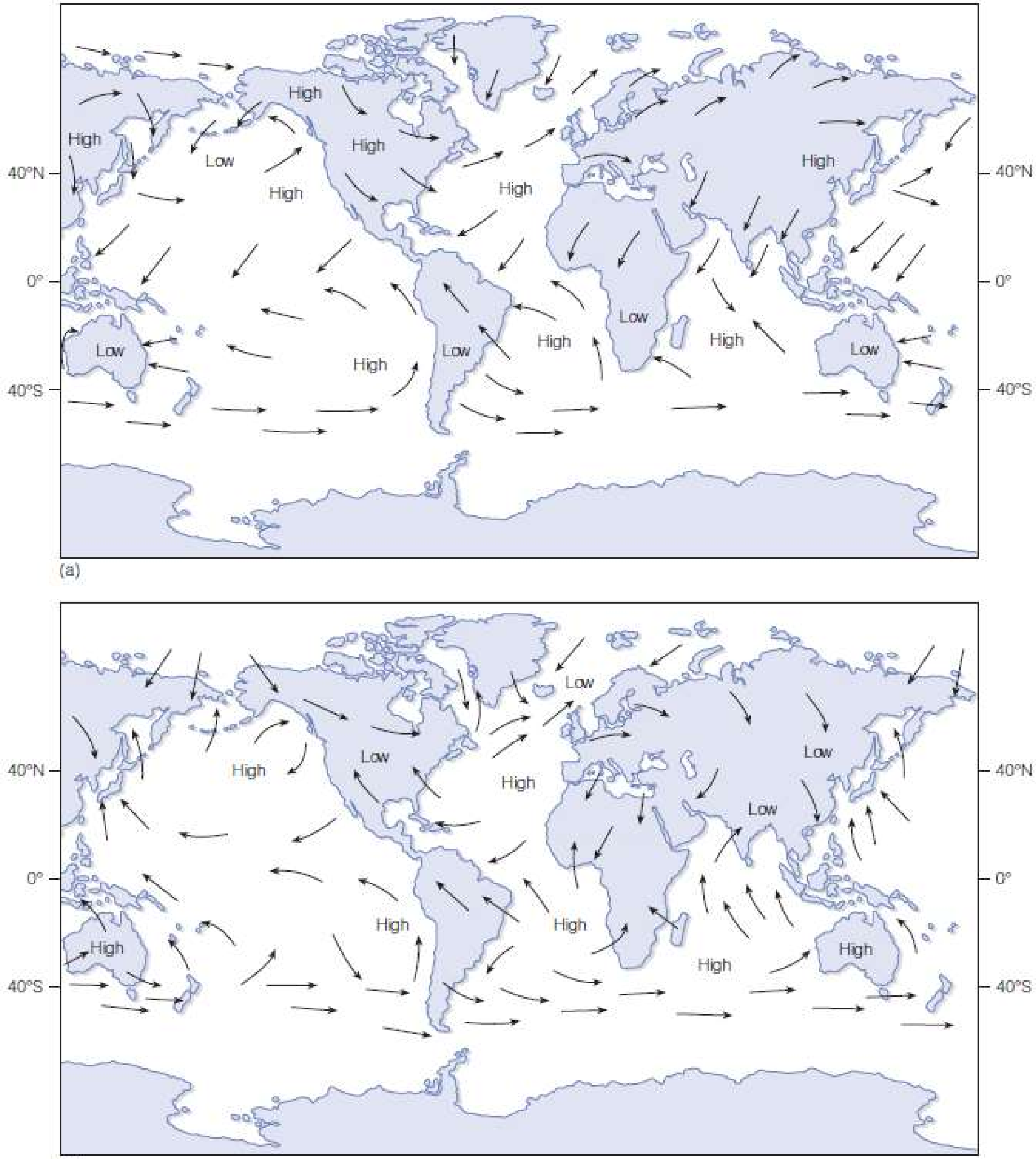


Figure 3.6 Two possible responses of an ecosystem to disturbance. Line a (solid) represents an ecosystem that is resistant to perturbation. Its response to disturbance is slower and less severe, but its return to its original state is slow. Line b (dashed) shows a resilient ecosystem that is more severely affected by the disturbance, but rapidly returns to its original state. Either could be regarded as an illustration of ecosystem stability. Adapted from Leps [16].

Global F

- The **climate** of a ced within that area, including tempe sons of the year.



(a)

(b)

The angle of incidence of the sun's rays approaches 90°

riations in climate also result m the pattern of movement air masses

Thermohaline oceanic circulation or oceanic conveyor belt

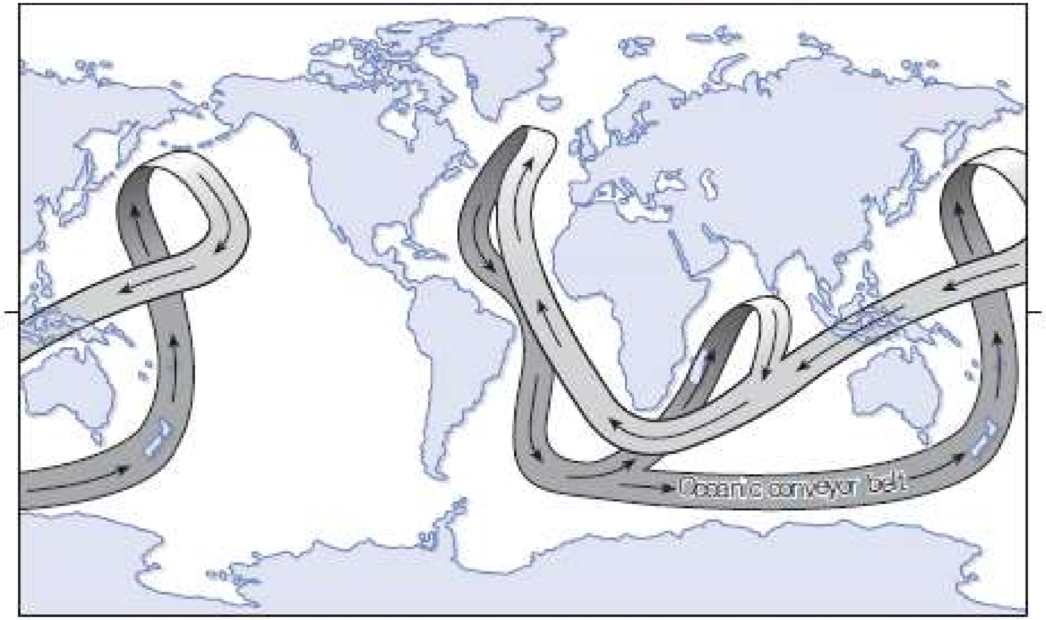
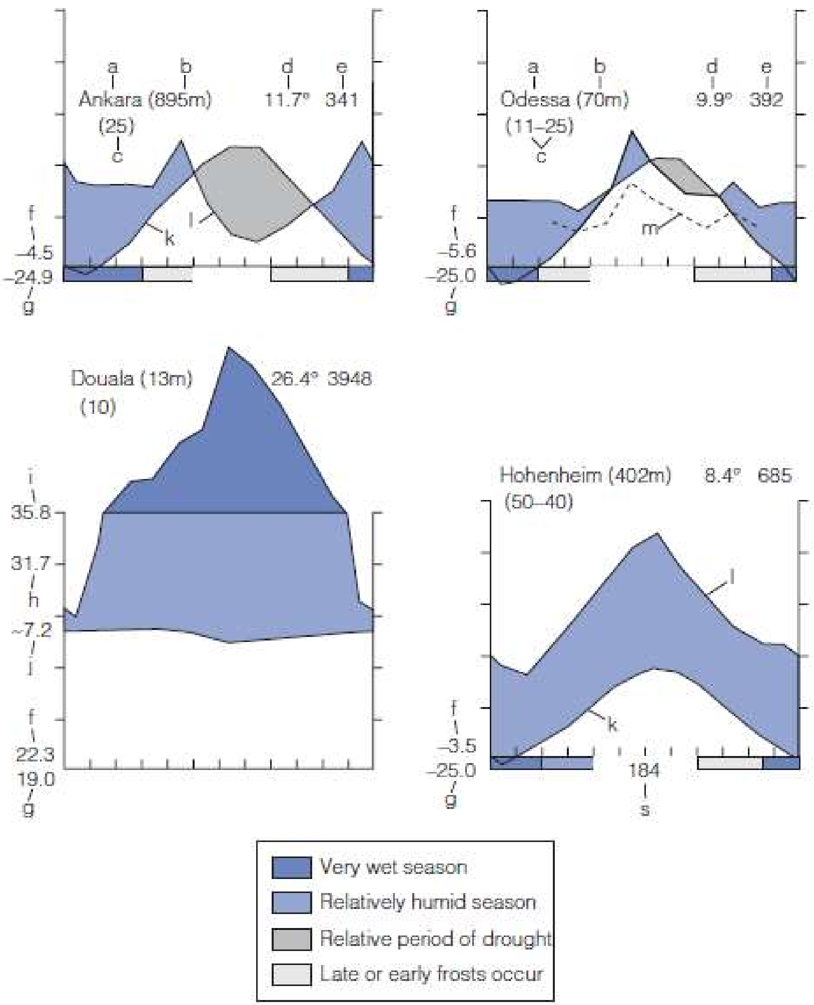


Figure 3.15 The oceanic conveyor belt carrying warm, low-salinity surface waters northwards into the North Atlantic and deep, higher salinity cold waters from west to east into the Indian Ocean and the Pacific. From here, water receives a renewal of its heat content, rises to the surface and returns westward into the Atlantic.

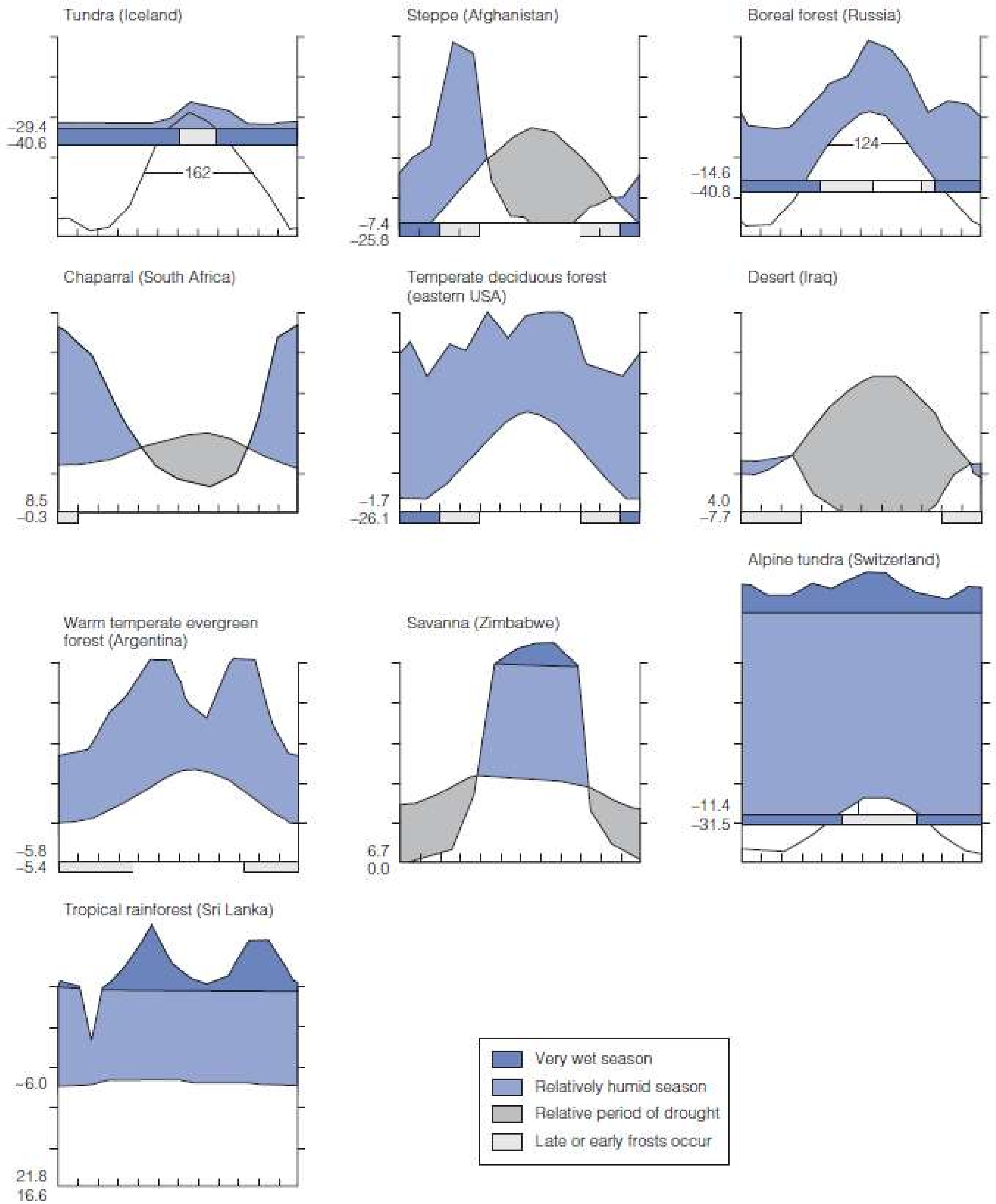
Climate Diagrams

- Biogeographers have long sought a means of **portraying climates in a simple**, **condensed form** that would give at a glance an indication of the main features that might be of critical importance to the survival of organisms in the area.

- Heinrich Walter, of the University of Hohenheim in Germany, devised a form of climate diagram that is now widely used by biogeographers



- abscissa: months (Northern Hemisphere, January– December; Southern Hemisphere, July–June);
- ordinate: one division = 10°C or 20 mm rainfall.
- (a) Station;
- (b) height above sea level;
- (c) duration of observations in years (if there are two figures, the first indicates temperature and the second precipitation);
- (d) mean annual temperature in °C;
- (e) mean annual precipitation in millimetres;
- (f) mean daily minimum temperature of the coldest month;
- (g) lowest temperature recorded;
- (h) mean daily maximum temperature of the warmest month;
- (i) highest temperature recorded;
- (j) mean daily temperature variations;
- (k) curve of mean monthly temperature;
- (l) curve of mean monthly precipitation; (m) reduced supplementary precipitation curve (10°C = 30 mm precipitation);
- (s) mean duration of frost-free period in days.



Tundra (Iceland)
–29.4
–40.6
162
Steppe (Afghanistan)
–7.4
–25.8
Boreal forest (Russia)
124
–14.6
–40.8
Chaparral (South Africa)
8.5
–0.3
Temperate deciduous forest (eastern USA)
–1.7
–26.1
Desert (Iraq)
4.0
–7.7
Alpine tundra (Switzerland)
–11.4
–31.5
Warm temperate evergreen forest (Argentina)
–5.8
–5.4
Savanna (Zimbabwe)
6.7
0.0
Tropical rainforest (Sri Lanka)
–6.0
21.8
16.6
Very wet season
Relatively humid season
Relative period of drought
Late or early frosts occur

Modelling Biomes and Climate

- effort has been expended in improving the definitions of biological units, the biomes, and fitting them to specific climatic envelopes.
- We now have much more detailed information about the physiology of different plant and animals, including their tolerance of cold or heat and their ability to cope with drought or flooding.

https://vimeo.com/143850932

https://vimeo.com/164607091

Summary

1 The idea of 'communities' of organisms that occur in discrete units, which are predictable in terms of species composition, is attractive and useful to biogeographers, but nature often exhibits a gradual and continuous change in species assemblages depending on the individual requirements of species.

2 In a landscape consisting of a fragmented mosaic of different habitats, communities are more likely to have distinct boundaries and therefore to be recognizable in nature.

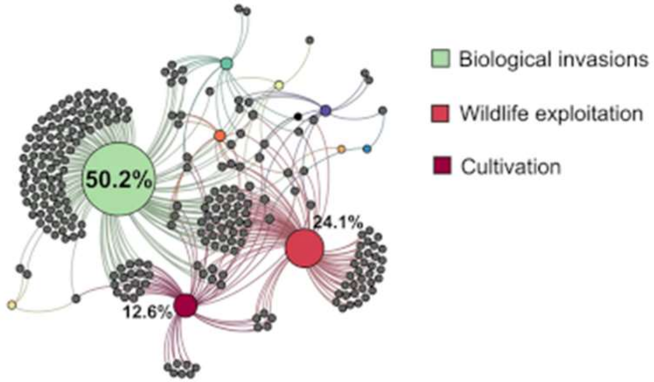
3 The ecosystem is a useful way of considering biotic (animal, plant, and microbial) assemblages in relation to the non-living world. It is a concept based on the ideas of energy flow through a series of feeding (trophic) levels and the circulation of elements between living organisms and the non-living world.

4 The use of the ecosystem concept and the notion of functional types of organisms (producers, decomposers, nitrogen-fixers etc.) within the community provides a way of investigating the implications of biodiversity for natural systems. It allows us to ask the question: are all species really necessary for the maintenance of the stability of an ecosystem, or are some redundant? Current research suggests that some species can be lost without necessarily destabilizing an ecosystem. More critical is the maintenance of a balance of functional types.

5 Global ecosystems, often called biomes, are best defined in terms of vegetation physiognomy or of functional types, either morphological or physiological. Models relating biome distribution to climate can then be developed.

6 Climate-biome models provide a means of predicting the outcome of climate change on the Earth's biogeography and will have implications in both conservation and agriculture. But predictions of biome shifts are only as good as the climatic predictions that underlie them.

Biodiversity is Dynamic



- Genetic change resulting from mutation and recombination
- Evolution resulting from natural selection and genetic drift
- Interaction among biota
- Effects of a variable environment
- Effect of biota on the environment
- Relative rates of speciation and extinction

How many species are there?

- biologists have made range between 3 and 500 million species!

- What they all agree upon is that only a **very small proportion** of the total is currently known to science and has been adequately described.

- Some parts of the world have been little studied
- Many very abundant species are extremely small, so they may have gone unnoticed in the past

Counting species

Concept Box 4.1

A conservative estimate for the possible number of species on Earth is 12.5 million [5], but the tropical ecologist Terry L. Erwin [6] has proposed that the total is far greater than this, perhaps as high as 30 million for tropical insects alone. He came to this conclusion as a result of a study of beetles on a single tree species, *Luehea seemannii* (a tropical tree related to the lime tree of temperate regions) in Panama, which he sampled by 'fogging'. This is an efficient technique for stunning the insects in a canopy by smoking them with an insecticide. The dazed insects fall from the tree and are collected in trays placed beneath the canopy. Erwin examined just 19 individual trees of *L. seemannii* in the Panamanian forests and managed to obtain 1200 species of beetles alone from this analysis. This large number is not entirely surprising, since beetles are extraordinarily successful insects and may comprise as much as 25% of the total number of species of living organisms. But this study does illustrate the remarkable richness of beetles in the tropical forest.

From these data, Erwin made a number of assumptions about the numbers of beetle found specifically on particular tree species, the numbers of tree species found and the proportions of different organisms in the forest in relation to one another. He extrapolated from the information gathered and came to the conclusion that, if this number of beetles is truly representative of the forest richness, then one might predict a total of 30 million species of insect on Earth. The uncertainty of many of his assumptions, however, should make us very cautious in accepting this figure uncritically. Other entomologists, such as Nigel Stork and Kevin Gaston [7], have checked Erwin's estimates using data from studies in the tropical forests of Borneo. Stork has generated estimates ranging from 10 million to 80 million for the arthropods (a group of invertebrate animals including the insects). Another independent estimate [8] supports the lower end of this scale, placing tropical arthropods at 6 to 9 million. The range of error in all estimates is still so wide that there is bound to be a great deal of discrepancy in the figures arrived at, but the world's wealth of species is likely to exceed 10 million.

Table 4.1 The numbers of described species in selected groups of organisms, together with the likely total numbers on Earth, and the percentage of the group that is currently known. Data from Groombridge [15].

Group	Number of described species	Likely total	%
Insects	950 000	8 000 000	12
Fungi	70 000	1 000 000	7
Arachnids	75 000	750 000	10
Viruses	5000	500 000	5
Nematodes	15 000	500 000	3
Bacteria	4000	400 000	1
Vascular plants	250 000	300 000	83
Protozoans	40 000	200 000	20
Algae	40 000	200 000	20
Molluscs	70 000	200 000	35
Crustaceans	40 000	150 000	27
Vertebrates	45 000	50 000	90

Counting the Biodiversity

- The process of **listing all the species** present at a site
- An alternative approach is **to assess the richness of certain groups** of well-known organisms that are easily observed and identified (such as higher plants, mammals, birds or butterflies) and **to assume that they have a consistent proportional relationship to the less easily observed** and identified groups.
- Considering the **body size.** There are fewer large organisms than small ones (body-size–abundance relationship).

Body-size–abundance relationship

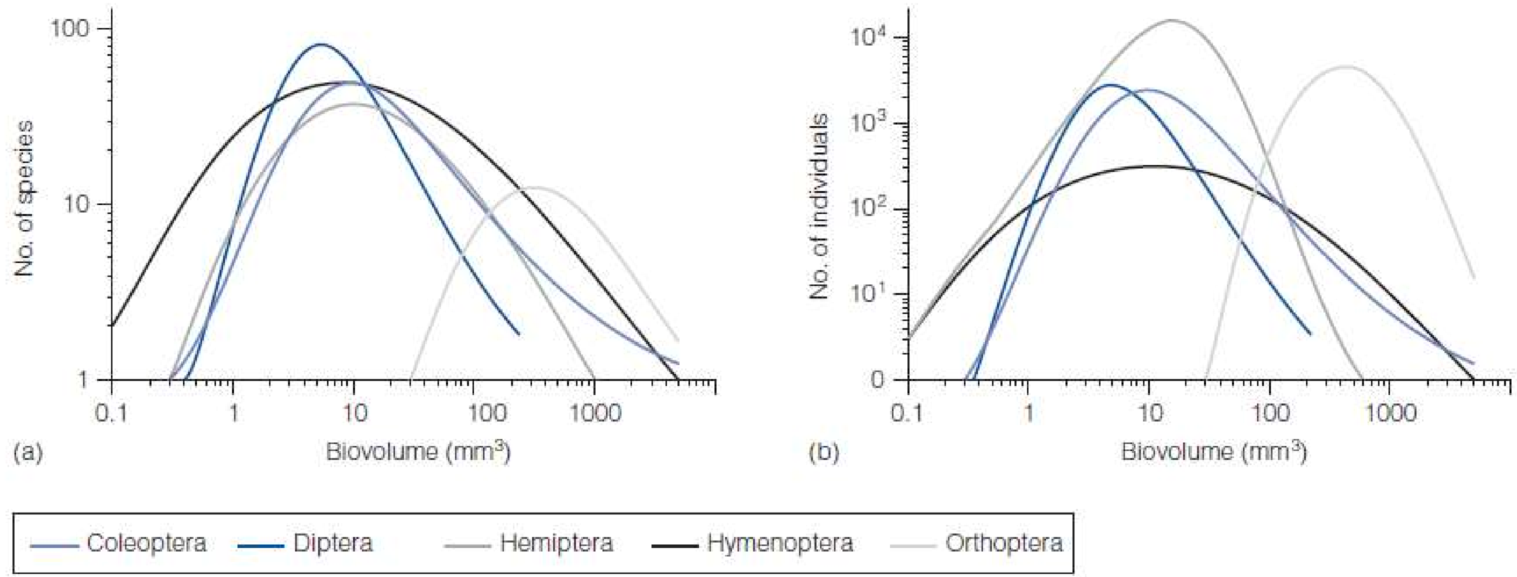


Figure 4.2 The numbers of species and individuals of various insect groups in relation to their body size in grassland in Minnesota. The groups shown are Orthoptera (grasshoppers), Hymenoptera (wasps and bees), Hemiptera (bugs), Coleoptera (beetles) and Diptera (flies). Adapted Siemann *et al.* [21].

Latitudinal Gradients of Diversity

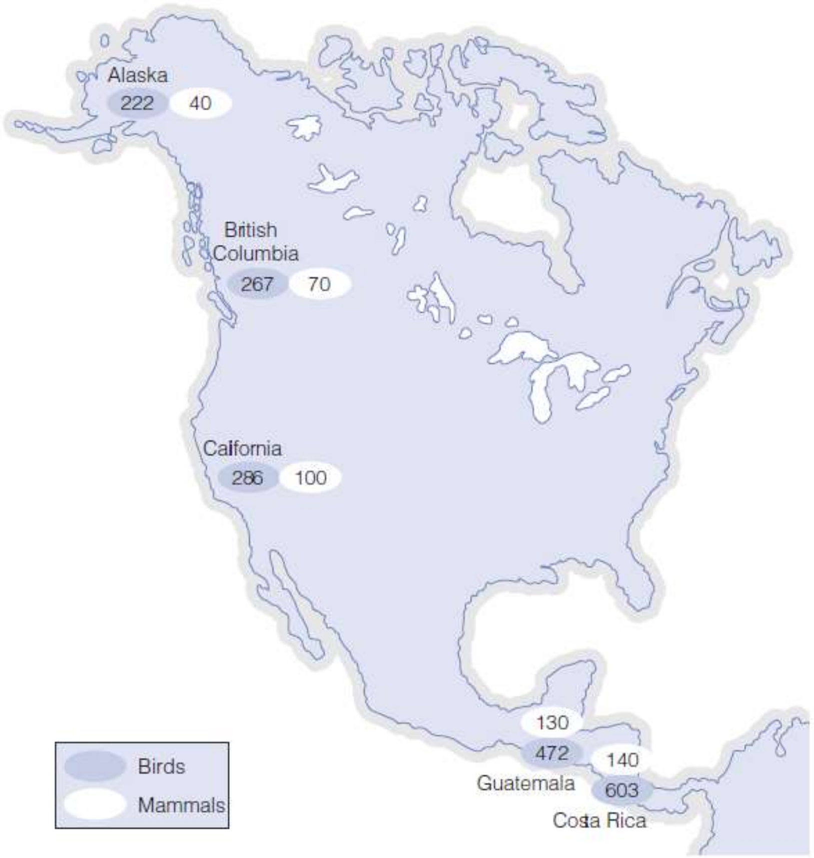


Figure 4.3 Numbers of breeding birds and mammal species in different parts of Central and North America.

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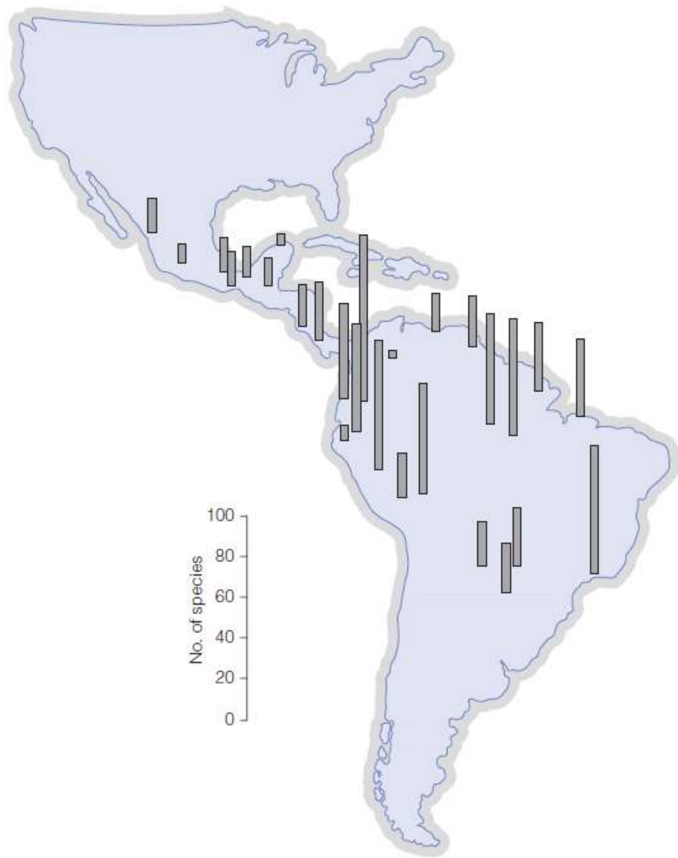

Figure 4.4 Numbers of species of frog in different parts of Central and South America. Data from Groombridge [27].

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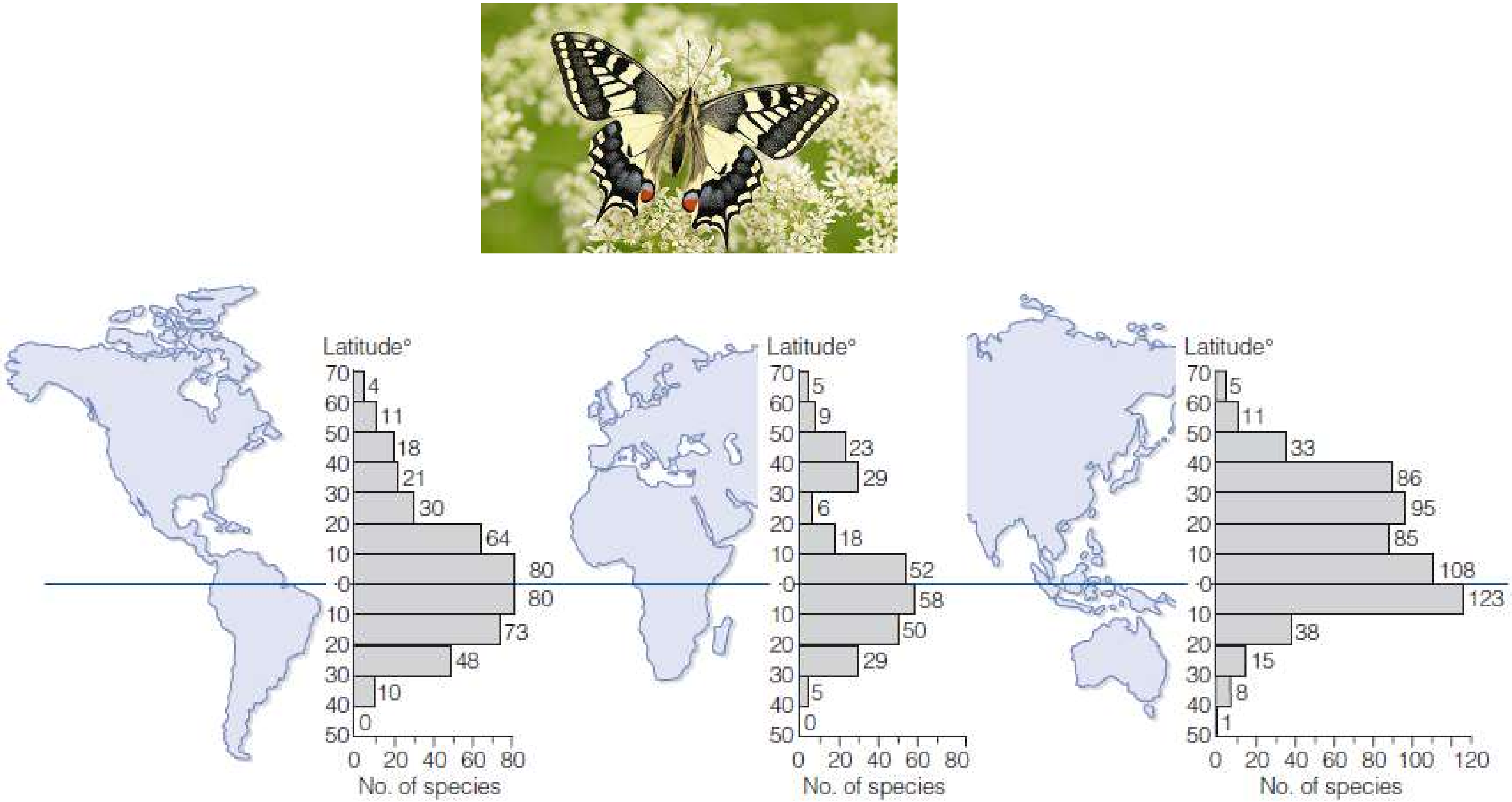


Figure 4.5 Latitudinal gradients of species richness for swallowtail butterflies in three different parts of the world. Data from Collins and Morris [28].

Importance of the structure of an environment

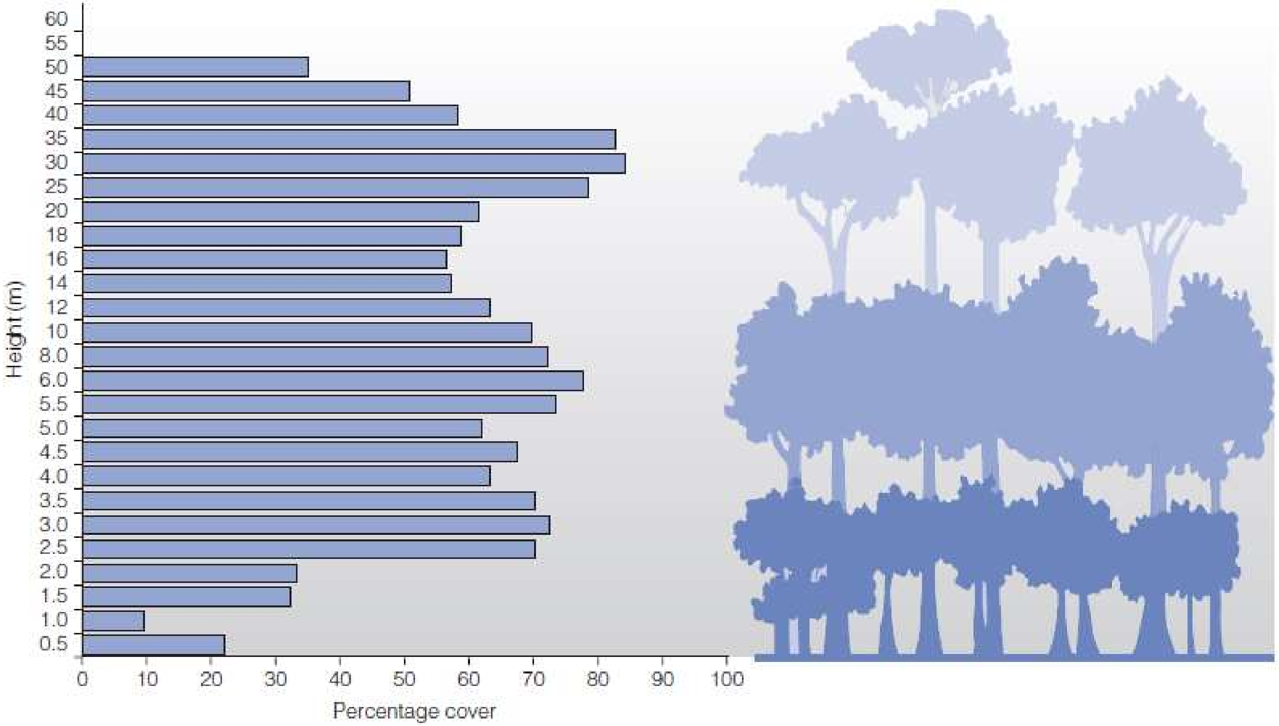


Figure 4.10 Profile of a tropical rainforest with the percentage leaf canopy cover recorded at different heights above the ground. Note the stratification of the leaf cover into distinct layers. From Terborgh and Petren [34].

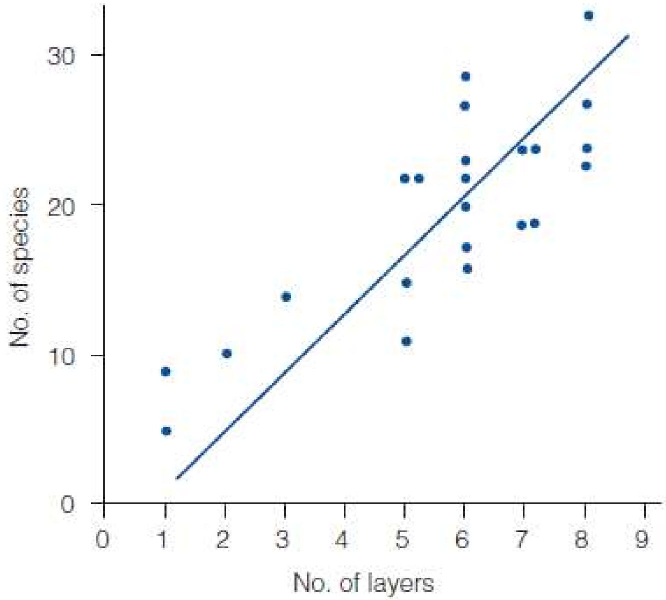


Figure 4.12 Graph showing the relationship between the number of bird species and the number of layers in the vegetation stratification. Data from Blondell [35].

Is Evolution faster in the Tropics?

- **Metabolic theory**. In an environment where energy is abundant and temperature is consistently high, such as the tropics, metabolic rates in organisms tend to be faster.
- Fecundity is greater, and generation times may be shorter.
- Consequently, genetic modification by mutation (see Chapter 6) is faster. Ultraviolet radiation is generally greater in
- the tropics, and this can increase mutation rates.
- so that species are constantly generating new variations.

- At the same time, there is a positive feedback in that the new varieties are in competition with one another, leading to an intense degree of selection for the most fit.

Biodiversity Hotspots

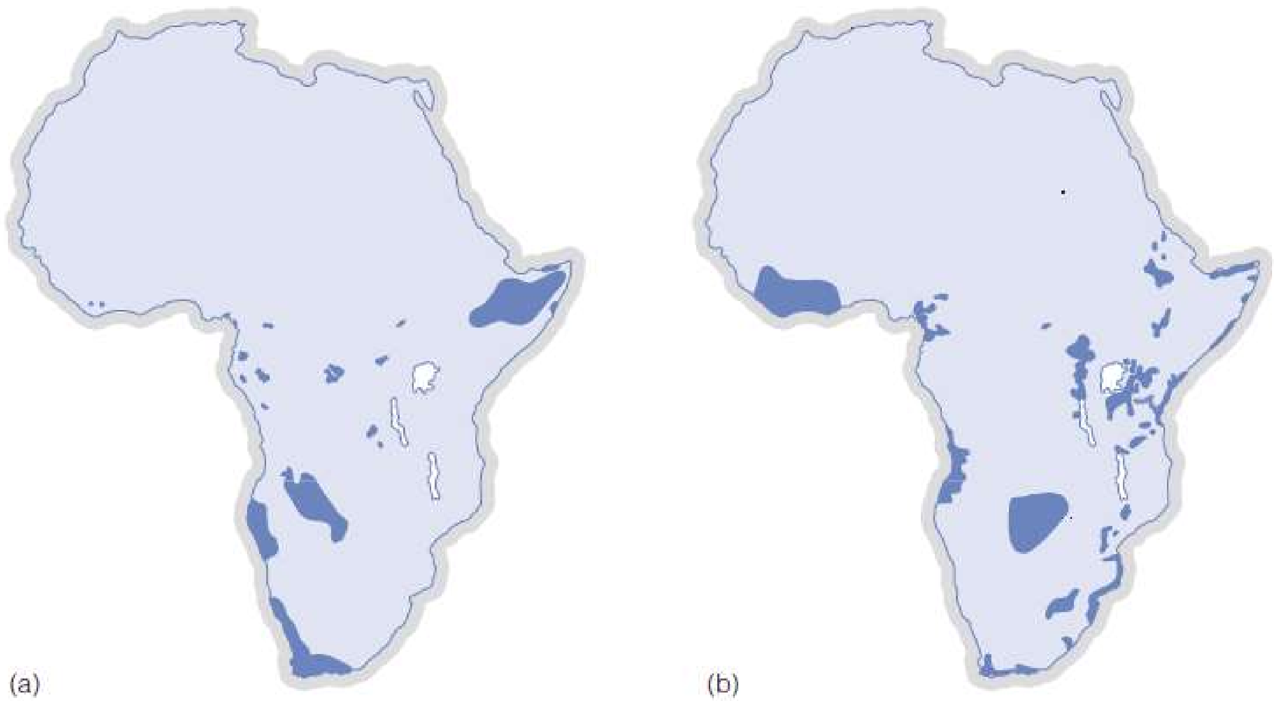
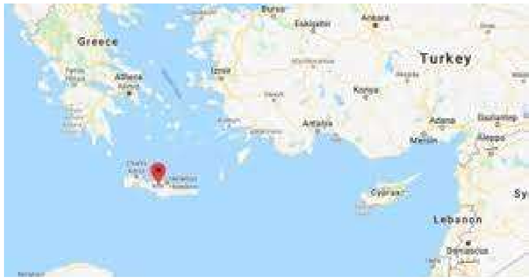


Figure 4.15 The areas of Africa that are particularly rich in (a) plant species, compared with those areas that are rich in (b) endemic birds. As can be seen, the two do not always correspond.

Mediterranean region; high biodiversity accompanied by a very long history of human activity

- The island of Crete is only 245 km long by 50 km wide and has been isolated as an island for about 5.5 million years.
- It has supported human populations since at least the arrival of Neolithic peoples about 8000 years ago.
- Since then, climatic changes have resulted in the development of very dry conditions in summer, and additional disturbance by earthquake and volcano activity has been experienced.
- The increase in human populations, their need for agricultural land and their intensive pastoralism have resulted in the stripping of much of the original vegetation.
- despite all this, Crete has 1650 species of plant, 10% of which are endemic to the island

It is possible that moderate human pressures can increase biodiversity as a result of diversifying habitats



Hotspots as center of endemisms

- using data from amphibians, reptiles, birds and mammals showed some degree of correlation between diversity and endemicity.
- the establishment of protection for those areas where endemic vertebrates are abundant also provides a safeguard for a wide range of other species and is good overall policy for biodiversity conservation.
- Work on marine fish diversity in the South Pacific also suggests that fish biodiversity hotspots coincide with centres of evolution and that diversity in surrounding areas is related to distance from such hotspots