3.1 An introduction to biodiversity

Opposite: Sumatran tigers are critically endangered. This magnificent animal epitomizes the crisis facing many species on Earth, and the need to conserve biodiversity for future generations.

Significant ideas

Biodiversity can be identified in a variety of forms, including species diversity, habitat diversity, and genetic diversity.

The ability to both understand and quantify biodiversity is important to conservation efforts.

Big questions

As you read this section, consider the following big question:

- How are the issues addressed in this topic of relevance to sustainability or sustainable development?

Knowledge and understanding

- Biodiversity is a broad concept encompassing total diversity which includes diversity of species, habitat diversity, and genetic diversity.
- Species diversity in communities is a product of two variables, the number of species (richness) and their relative proportions (evenness).
- Communities can be described and compared by the use of diversity indices. When comparing communities that are similar, low diversity could be evidence of pollution, eutrophication, or recent colonization of a site. The number of species present in an area is often used to indicate general patterns of biodiversity.
- Habitat diversity refers to the range of different habitats in an ecosystem or biome.
- Genetic diversity refers to the range of genetic material present in a population of a species.
- Quantification of biodiversity is important to conservation efforts so that areas of high biodiversity may be identified, explored, and appropriate conservation put in place where possible.
- The ability to assess changes to biodiversity in a given community over time is important in assessing the impact of human activity in the community.

Biodiversity is a broad concept encompassing total diversity, including species diversity, habitat diversity, and genetic diversity.

What is biodiversity?

The word **biodiversity** is a conflation of 'biological diversity' and was first made popular by ecologist EO Wilson in the 1980s. It is now widely used to represent the variety of life on Earth. *Bio* makes it clear we are interested in the living parts of an ecosystem, and *diversity* is a measure of both the number of species in an area and their relative abundance (Chapter 2, pages 138–140). The term can be used to evaluate both the complexity of an area and its health. Biodiversity can be measured in three different ways: species diversity, habitat diversity, and genetic diversity.

Biodiversity refers to the variety of life on Earth. The word was first used by conservation biologists to highlight the threat to species and ecosystems, and is now widely used in international agreements concerning the sustainable use and protection of natural resources.

Rainforests have high diversity. They are rich in resources (e.g. food, space) with many different niches available, so many species can co-exist.

A species is a group of organisms sharing common characteristics that interbreed and produce fertile offspring.

Species diversity

Species diversity refers to the variety of **species** per unit area; it includes both the number of species present and their relative abundance. The higher the species diversity of a community or ecosystem, the greater the complexity. Areas of high species diversity are also more likely to be undisturbed (e.g. primary rainforest). Species diversity within a community is a component of the broader description of the biodiversity of an entire ecosystem.

Species diversity in communities is a product of two variables, the number of species (richness) and their relative proportions (evenness).

Richness and evenness

As we saw in Chapter 2 (pages 138–140), richness and evenness are components of biodiversity. *Richness* is a term that refers to the number of a species in an area, and *evenness* refers to the relative abundance of each species (Figure 3.1). A community with high evenness is one that has a similar abundance of all species – this implies a complex ecosystem where there are lots of different niches that support a wide range of different species. In contrast, low evenness refers to a community where one or a few species dominate – this suggests lower complexity and a smaller number of potential niches, where a few species can dominate.

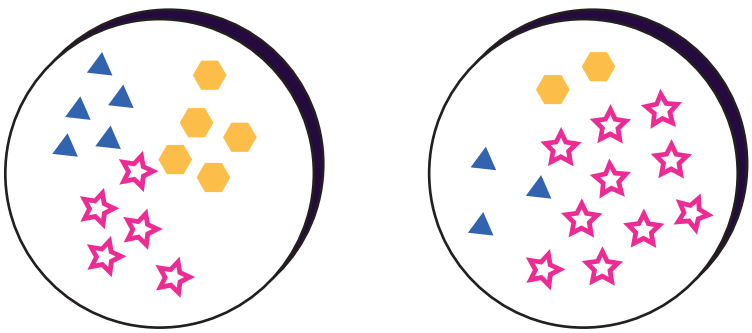

Figure 3.1 Richness and evenness in two different communities. Both communities have the same number of species (species richness) with three species each, but community 1 has greater evenness (all species are equally abundant) than community 2, where one species dominates. Community 1 shows greater species diversity than community 2.

A community is a group of populations living and interacting with each other in a common habitat.

Communities can be described and compared by the use of diversity indices, for example using the Simpson's index (Chapter 2, pages 139–140). When comparing communities that are similar, low diversity could be evidence of pollution, eutrophication or recent colonization of a site. Number of species is often used to assess biodiversity in an area, although measurement of species richness alone can be a misleading measure of disturbance to ecosystems; species diversity measures give more meaningful data (pages 153–154).

The Simpson index (*D*) is a method for measuring diversity (Chapter 2, page 139). Areas with a high *D* value suggest a stable and mature site. A low value of *D* could suggest pollution, recent colonization, or agricultural management.

Measurements of species richness depend on sample size, especially when dealing with small organisms such as insects. Figure 3.2 shows the accumulated species richness of dung beetles (a large group of scarab beetles

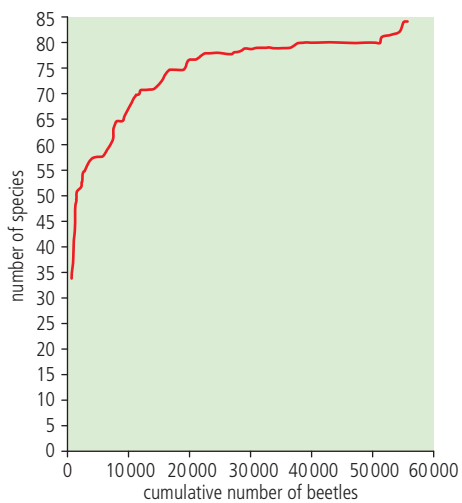

Figure 3.2 Species accumulation graph of beetles collected by pitfall trap in the Bornean lowland rainforest

that feed on faeces, carrion (dead animals), decomposing plant material, as well as other food sources) in a rainforest ecosystem in Borneo. Accurate measurement of species richness was only possible after a large number of beetles had been collected. Clearly, for accurate measures of species richness and, by implication, accurate calculation of diversity indices, appropriate sample sizes are required.

Does it matter that there are no absolute measurements for diversity indices? Numbers can be used for comparison but on their own mean little. Are there other examples in science of similar relative rather than absolute measurement systems?

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You need to be able to comment on the relative values of biodiversity data (e.g. why the value of *D* in one area is higher than that in another). Interpreting diversity is complex, low diversity can be present in natural, ancient and unpolluted sites (e.g. Arctic ecosystems).

Habitat diversity

Habitat diversity is often associated with the variety of ecological niches. For example, a woodland may contain many different habitats (e.g. river, soil, trees) and so have a high habitat diversity, whereas a desert has few (e.g. sand, occasional vegetation) and so has a low habitat diversity.

A habitat is the environment in which a species normally lives.

Habitat diversity refers to the range of different habitats in an ecosystem or biome.

Death Valley desert. Ecosystems such as deserts have low biodiversity as there are fewer opportunities for species to coexist.

Genetic diversity

The term *genetic* refers to **genes**, which are sections of DNA found in the nucleus of all cells. They are essentially the instructions from which a species is produced. **Gene pool** refers to all the different types of gene found within every individual of a species. A large gene pool leads to high **genetic diversity** and a small gene pool to low genetic diversity. Although the term normally refers to the diversity within one species, it can also be used to refer to the diversity of genes in all species within an area.

Genetic diversity refers to the range of genetic material present in a population of a species.

Early definitions of diversity have become limited as scientific knowledge has increased. Species diversity depends on the correct identification of different organisms and their distribution around the Earth. In the past, this was based on physical characteristics, which we now know can prove unreliable (e.g. two species may look similar but be completely unrelated). Genetic diversity allows for a more accurate way to describe species, although variation within the gene pool of individual species may cause problems (i.e. all species show physical variation in size, colour, and so on – it may be difficult to decide whether individuals are from different species or simply indicate variation within one species).

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Genetic diversity in cheetahs is low

Species with low genetic diversity, such as cheetahs, are more prone to extinction. This is because if the environment changes, such a species is less likely to have the genes to help it to survive.

Overview of biodiversity

The term *biodiversity* is often used as a way of referring to the heterogeneity (variability) of a community, ecosystem or biome, at the species, habitat, or genetic level. The scientific meaning of diversity can become clear from the context in which it is used and may refer to any of the meanings explained above. For the meaning to be obvious, the level should be spelled out by using the correct term (i.e. species diversity, habitat diversity, or genetic diversity).

Conservation of habitat diversity usually leads to the conservation of species and genetic diversity.

CONCEPTS: Biodiversity

Biodiversity is a broad concept encompassing the total diversity of living systems, which includes the diversity of species, habitat diversity, and genetic diversity.

You need to be able to distinguish between biodiversity, diversity of species, habitat diversity, and genetic diversity.

Of the three types of diversity, the increase of habitat diversity is most likely to lead to an increase in the other two. This is because different habitats tend to have different species, and so more habitats will generally have a greater variety of species. Similarly, different species tend to have different genes and so more species will generally include a greater variety of genes. The conservation of habitat diversity will therefore usually lead to the conservation of species and genetic diversity.

Quantification of biodiversity is important to conservation efforts so that areas of high biodiversity may be identified, explored, and appropriate conservation put in place where possible.

Conservation of biodiversity

Conservation means 'keeping what we have'. Conservation aims to protect habitats and ecosystems, and hence species from human-made disturbances, such as deforestation and pollution. Conservation activities aim to slow the rate of extinction caused by the knock-on effects of unsustainable exploitation of natural resources and to maintain biotic interactions between species.

CONCEPTS: Sustainability

Diversity indices can be used to assess whether the impact of human development on ecosystems is sustainable or not.

Ecosystems can be immensely complex systems, as you learned in Chapter 2. How can the effects of human activities be assessed given such complexity? In Chapter 2 you considered ways in which the effects of human disturbance can be measured (pages 142–144). Disturbance, or perturbation, takes ecosystems away from steady-state equilibrium and can lead to new stable states after certain tipping points are reached (Chapter 1, page 33). In Chapter 2, you explored the differences between fundamental and realized niche (page 63): perturbation can simplify ecosystems, or change them so that opportunities for the existence for many species are removed (i.e. ecosystems change so that the realized niche of species no longer exists in the area). Such changes may, for other species, provide an expansion of their usual range because their realized niche spreads into the disturbed area. For example, species found in the canopy and along river banks in a rainforest (rather than the forest interior) may spread into forest that has been logged where new conditions are now found.

Bulldozer making a logging road in rainforest in Sabah, Malaysia. Change in the ecosystem leads to change in the species found there.

CONCEPTS: Equilibrium

Disturbance takes ecosystems away from steady-state equilibrium and can lead to new stable states if certain tipping points are reached.

A key tool used by conservation biologists to assess the effect of disturbance is use of diversity indices, such as the Simpson's index. Quantification of biodiversity in this way is important to conservation efforts so that areas of high biodiversity are identified, explored, and appropriate conservation put in place where possible. Areas that are high in biodiversity are known as hotspots. They contain large numbers of **endemic** species (species not found anywhere else), and so measures of biodiversity are essential in identifying areas that should be protected against damaging human activities. An example of a biological hotspot is Tumbes-Chocó-Magdalena, an area that includes the forests of the South American Pacific coast (from Panama to Peru) and the Galápagos Islands.

Measurements of species richness, on their own, are not sufficient to establish the impacts of human activities. Assessment of species richness varies according to sampling technique. Certain species may be sampled by a given technique but not others; light traps, for example, sample insects drawn to a light bulb, but not the ones that are not. Sample size also affects the assessment of species richness – the bigger the sample, the more species collected. The relative abundance of species in a community must also be taken into account, as you have seen. Care must be taken in giving reasons for differences in species diversity, as measured by the Simpson's index (page 139). For comparisons to be made between different areas using a diversity index, the same sampling method must be used and a similar type of habitat investigated (e.g. forest ecosystems in the same region). Diversity indices also work best when similar groups of organisms are compared (e.g. dung beetle communities

The ability to assess changes to biodiversity in a given community over time is important in assessing the impact of human activity in the community.

You need to be able to discuss the usefulness of providing numerical values of species diversity to understanding the nature of biological communities and the conservation of biodiversity.

from undisturbed and perturbed forest sites – Case study, see below) rather than broader groups (i.e. all animal species in an area).

Values of *D* are relative to each other and not absolute, unlike measures of, for example, temperature which are on a fixed scale. This means that two different areas can be compared to each other using the index, but a value on its own is not useful. Individual values of *D* give an indication of the composition of the community being investigated (i.e. low values of *D* indicate low evenness, meaning one species may dominate the community) but do not, on their own, help in identifying areas of biodiversity that should be conserved.

CONCEPTS: Biodiversity

Species diversity is a measure of the number of species in an area and their relative abundance.

Case study

Species richness and diversity of beetle communities following logging

A flight intercept trap in logged forest. Insects fly into the net and fall into aluminium trays where they are collected.

A study was carried out in the tropical rainforests of Borneo to investigate the effects on dung beetle communities of logging and conversion to plantation. The aim of the investigation was to understand the nature of biological communities in these forest ecosystems and to see the effect of human activities, and to establish the conservation value of these areas. Beetles were collected using a flight interception trap (page 132).

The results are shown in Table 3.1.

Table 3.1 Results of an experiment to investigate the effect of human activity on beetles in the Borneo rainforest

Trap location	Measurements of species richness and diversity		
	Species richness	Diversity	Evenness
primary forest	36	2.96	0.83
logged forest	42	2.24	0.60
plantation	14	2.05	0.78

Species richness is the number of species, diversity is measured using a diversity index, and evenness is a measure of how evenly (equally) abundance is distributed between species (an evenness value of 1 would indicate that all species are equally abundant). Primary forest is forest that is pristine and has not been affected by human activities.

Species richness is highest in logged forest: this is because disturbed forest contains a mixture of species which are usually separated along environmental gradients and not found in one location in primary forest (e.g. riverine species and those found in the canopy move into logged areas). The species diversity in logged forest is lower than primary forest, indicating a simplified ecosystem where certain species dominate. This is indicated by a low evenness measure. Plantation forest has the lowest species richness and diversity, indicating a loss of primary forest species and a much simpler ecosystem compared to primary rainforest. This study indicates the dangers of only using species richness information to compare different areas: species diversity is a much more robust and accurate method of indicating the health, and therefore conservation value, of ecosystems.