Lesson 23 Biodiversity

Aims

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

- know that biodiversity can be assessed:
  - within a habitat at the species level using a formula to calculate an index of diversity
  $$D = \frac{N(N-1)}{\Sigma n(n-1)}$$
  - within a species at the genetic level by looking at the variety of alleles in the gene pool of a population
- understand the ethical reasons and economic reasons (ecosystem services) for the maintenance of biodiversity
- understand the principles of *ex situ* conservation (zoos and seed banks) and *in situ* conservation (protected habitats), and the issues surrounding each method.

Context

This lesson covers section 3.3 of the Edexcel AS and A-level Biology specifications.

Edexcel A Level Biology 1, pages 173 – 180.

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Introduction

Biodiversity is short for “biological diversity”, and refers to the *variety* of living organisms that are found in a habitat, an ecosystem, or globally. It takes two important forms:

1. the variety of *species* that are found in one of these locations: biodiversity at the **species level**, and

2. the variety of *alleles* found in the gene pool of a population of a single species: biodiversity at the **genetic level**.

We first look at how biodiversity is measured, and then at why and how it should be maintained.

Some technical terms used in what follows include:

- **population**: the members of a single species that are actually able to breed together, because they are not separated by any barrier which would prevent them doing so. So we could talk about the population of robins in the mainland of the British Isles, which is different from the population in mainland Europe.

- **alleles**: alternative forms of the same gene, for example the tall and dwarf alleles for the height gene in pea plants. Different alleles arise within the same gene by mutation.

- **gene pool**: the sum total of all the genes, and their alleles, in a population (or, more strictly, in the *gametes* of the population).

Measuring biodiversity

Biodiversity within a habitat at the species level is more complicated than a simple head count of the number of different species found there. That simple head count is known as the **species richness**.

For example, imagine three habitats:

- the first has 96 organisms of species A, 2 organisms of species B and 2 organisms of species C, while

- the second has 40 of A, 35 of B and 25 of C.

The species richness is the same in the two habitats: it is 3. But the first habitat has less biodiversity. It is far more “monochrome” in what is living there. On the other hand, a third habitat with 90 of A and two each of B, C, D, E and F also has more biodiversity than the first. So biodiversity really depends upon two things:

- the number of different species present: greater species richness means greater diversity, and
- how evenly-balanced the numbers of the different species are: greater balance also means greater diversity.

A mathematical formula is used to capture both of these aspects of diversity. Known as the Simpson Diversity Index after its inventor, it is:

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

where D = diversity
N = the total number of organisms present (i.e. the population sizes of all the species present added up)
n = the number of individuals of each species

The **Σ** sign (the Greek capital letter "sigma") means the "sum of". So to get the bottom line you take the population size of species A, multiply it by itself minus 1, repeat for all the species present individually, and then add all of these numbers together.

Activity 1	Use the Simpson Diversity Index to calculate the species diversity of each of the three habitats described above.

Activity 2	**Practical work**.
	Select two areas of grassland to which you have access, one a garden or park lawn, and one a wild, untended area. Mark out a square metre of one of the areas. Count the species richness: you do not need to be able to identify the different species, just call them A, B, C and so on. Then count the number of each of the separate species present. Use your data to calculate the biodiversity of plant species present using the Simpson Diversity Index. Repeat for the second area, and compare the diversity figures.

Maintaining biodiversity

Biodiversity is under threat from human activity. Many natural habitats are being destroyed to make way for buildings and other structures, for agriculture, and for a variety of other purposes such as mines and golf courses. And once their habitats are destroyed, the organisms that live there are also lost.

These losses are more serious in some parts of the world than in others, because global biodiversity is not evenly spread. In general:

- hostile environments (such as the arctic tundra and hot deserts) have low biodiversity
- more temperate environments (such as in most of the UK) have higher biodiversity.

The most biodiverse areas of all are the **tropical rainforests**, where there is enough water and suitable temperatures for growth all year round. These forests make up less than 2% of the Earth's land surface, but contain about 50% of all its living species.

The area of the tropical rainforests is rapidly shrinking because of human exploitation. There are now only three sizeable areas remaining – the Amazon Basin in South America, the Congo Basin in Africa, and the islands of Indonesia in the Far East – and these are shrinking at a rate of about 10,000 m^2 per *second* due to logging for timber and clearing of the land for agriculture. The mass extinction of species going on because of this is comparable to the great extinctions during geological history caused by catastrophic climate change.

Activity 3

(a) Biodiversity hotspots are regions within significant levels of biodiversity that are under threat from human activity. Enter "biodiversity hotspots" into the Wikipedia search box to view a list and map of these.

(b) Enter "tropical rainforests" into the Wikipedia search box to view details of this key ecosystem, with clickable links to the regions in which it is found.

At the genetic level

Biodiversity at the *genetic* level is reduced when surviving populations become too small. In this situation, many of the members of a species are related, forming an **inbreeding** group. In inbreeding groups, a large number of genes are found with two identical alleles in organisms, a condition called **homozygosity**. This is usually unhealthy. Deleterious mutations may be masked when paired with a normal allele (heterozygosity), but cause loss of vigour or worse in the homozygous condition.

Pages 173 – 175 of the textbook describe a case study involving orang-utans in Borneo which illustrates the importance and difficulty of maintaining genetic diversity in populations.

Reasons for biodiversity differences

The environment of a particular species in a particular ecosystem has two aspects:

- **abiotic factors**: these are aspects not directly connected with the other organisms present, such as temperature, humidity, pH and so on.

- **biotic factors**: these are the direct impacts of the other organisms present, including:

  - **competition** for scarce resources
  - **predation** by other species
  - abundance of other species as a **food supply**

In hostile environments, like the arctic tundra and hot deserts, the *abiotic* factors are the main determinant of which species can live there. Only those well-adapted to the cold and dryness respectively can survive. Few species are well-enough adapted for this, so species diversity is low.

In equable environments like the tropical rain forest, no special adaptations are required to survive the abiotic conditions. Many species are able to survive there, so biodiversity is high. In this situation, biotic factors are more important than abiotic ones in determining survival.

We study the effects of abiotic and biotic factors in more depth in the second year of the A-level course.

Why loss of biodiversity matters

There are two different sorts of reason why loss of biodiversity is a bad thing: ethical and economic.

Ethical reasons

Ethical reasons are to do with matters of right and wrong.

Most extremely, it can be argued that we as a species have no more right to life and happiness than any of the other species that we share the planet with, especially intelligent life forms such as the other mammals. If this is true, then what we are currently doing to the rest of life is little better than mass genocide. If we saw a species doing this to its fellow life forms on another planet we would condemn it, and we need to apply the same ethical standards to ourselves.

Less extremely, it can be argued that:

- although we are the dominant *culture* on the planet, primitive human cultures have as much right to live unmolested in their ecosystems (principally the tropical rain forest) as we do in the rest of the planet

- as the dominant *species* on the planet, have a responsibility of “stewardship”. We should care for life and the environment rather than wilfully destroying it.

However, much of this cuts little ice with most people and governments. They generally feel that, and act as if, nature exists simply for our benefit in one way or another.

Economic reasons

“Human benefit” includes both straight economic exploitation and other less tangible things that we gain from our environment. Both of these are covered by the term **ecosystem services**. These may be classified in various ways. For example Table 8.5 on page 176 of the textbook subdivides them into ecological, economic and aesthetic reasons.

First, a biodiverse environment may be viewed as an **aesthetic resource** (“aesthetic” is to do with “beauty”) for relaxation and uplift. We get joy from seeing beautiful animals and plants in natural ecosystems, something that stretches of tarmac and fields of crops do not deliver. Such emotions are an important part of the good quality of life that most people seek.

Second, a biodiverse environment also delivers more straightforwardly economic benefits. For example:

- a larger reserve supply of genes / alleles to use to enhance crop yields, for example by conferring disease resistance.

- a larger source of new medicines. Many modern medicines were originally derived from plants or other organisms.

There may be many more examples of such uses waiting to be discovered, in known or unknown species, that will be lost if biodiversity is not maintained.

Third, biodiverse ecosystems are also more stable, so less susceptible to catastrophic change, than simpler ones. So the maintenance of biodiversity helps to keep the natural environment intact for all the other services it provides for us.

Activity 4	Enter "ecosystem services" into the Wikipedia search box to view a wider list of services that ecosystems provide for us. List these below.

Methods used

Given that the maintenance of biodiversity is a good thing, there are two different approaches that are used to achieve it. The first seeks to preserve the natural habitats in which it is found, while the second seeks to preserve it by artificial methods even when these habitats are lost. The first approach is an ***in situ*** ("in place") approach, and the second an ***ex situ*** ("out of place") approach. Table 8.7 on page 180 of the textbook details many of the advantages and disadvantages of each approach.

Ex situ methods

Even when natural habitats are lost, the animal and plant species within them can be saved from extinction by zoos, botanical gardens and seed banks:

- **zoos**, for example London Zoo at Regents Park in London, are well-known. Originally simply a way of showing exotic foreign animals to a curious public, they now have a crucial role in the preservation of rare animals through **captive breeding programmes**. Some of the animals produced by these programmes may be released to reintroduce species into areas from which they have been lost. It is important that the captive population of a species does not fall too low, or inbreeding will affect the health of offspring produced by homozygosity (see above). Inter-zoo loans for breeding purposes help to keep the effective population high.

- **botanical gardens**, for example Kew Gardens in west London, serve a similar function for threatened flowering plant species.

- **seed banks**, for example the Millenium Seed Bank in West Sussex (see Figure 8.15 on page 179 of the textbook). Growing threatened plant species in a botanical garden takes a lot of land area, is labour intensive, and requires large glasshouses for plants from warmer climates. Species may also be preserved more cheaply, and using less land area, in the form of their seeds. These are carefully dried, and maintained at a suitable temperature (about minus 18^{0}C) and humidity (less than 7% water in the seeds). Every few years, the number depending upon the species, some of the seeds are grown, and the seeds harvested and restored, to maintain the viability of the stock.

In situ methods

The preservation of natural habitats is achieved by a number of methods, some of which overlap:

- **Nature reserves** are areas dedicated exclusively to the preservation of natural habitats and the species that they contain. An example is Wicken Fen, a wetland nature reserve in Cambridgeshire. The size, shape and relationship to other reserves is crucial to a reserve's effectiveness: see Figure 8.14 on page 178 for an illustration of this. The most effective reserves are:

    - big
    - with a low perimeter to area ratio
    - proximity to other reserves, preferably linked to them by corridors along which animals can move.

- **SSSIs** (Sites of Special Scientific Interest), for example Arlington Reservoir in East Sussex. These are areas which contain rare habitats and/or species. They are partially protected by law from destruction. Some are within nature reserves; others are within the property of normal landowners, for example farmers, whose use of them is restricted.

- **National Parks**, for example the English Lake District. These usually contain some nature reserves and SSSIs, but the rest of the land area is privately owned and is used for dwellings (including in villages and small towns) farming and forestry. The use of land is restricted by law to minimise the loss of habitats and species, and to maintain its aesthetic qualities for human recreation.

Such approaches are straightforward in the relatively affluent UK, but in the developing world they often conflict with the needs of the local, impoverished, human population.

Activity 5	Read examination questions 3 - 5, 6c and 8 on pages 181 - 182 of the textbook. Guidance on answering them is given at the end of the lesson.

Read *Edexcel Biology for AS,* pages 173 – 180.

Answer the "Test yourself" questions on pages 180, and check your responses.

Keywords

alleles
biodiversity
biotic factor, abiotic factor
botanical garden
captive breeding programme
ecosystem services
gene pool
homozygosity
inbreeding
in situ, *ex situ*
national park
nature reserve
population
seed bank
species level, genetic level
species richness
SSSI
tropical rainforest

Summary

Lesson 23: Biodiversity

Introduction: species level and genetic level

Measuring biodiversity: Simpson diversity index

Maintaining biodiversity
- at the genetic level
- reasons for biodiversity differences
- why loss of biodiversity matters
  - ethical reasons
  - economic reasons
- methods used
  - *ex situ* methods
  - *in situ* methods

What you need to know

- the meanings of the terms listed in Keywords above
- the importance of biodiversity for human flourishing
- possible ethical reasons for maintaining biodiversity
- the different approaches that may be used to maintain biodiversity, with an example of each

What you might be asked to do

- calculate biodiversity using the Simpson Diversity Index (which will be given to you)
- explain why biodiversity is different in different ecosystems
- evaluate the different possible methods for maintaining biodiversity

Suggested Answers to Activities

Activity 1

(a) First habitat: $D = \frac{100(99)}{96(95)+2(1)+2(1)} = \frac{9900}{9120+2+2} = 1.09$

Second habitat: $D = \frac{100(99)}{40(39)+35(34)+25(24)} = \frac{9900}{1560+1190+600} = 2.96$

Third habitat: $D = \frac{100(99)}{90(89)+2+2+2+2+2} = \frac{9900}{8020} = 1.23$

Activity 5

Q3: See "Ex situ methods" in general, and "seed banks" in particular above.

Q4: (a) $D = \frac{95(94)}{45(44)+40(39)+10(9)} = \frac{8930}{1980+1560+90} = 2.46$

(b) See "Measuring biodiversity" above.

Q5: (a) Of the 11,000 left in 2003, half are outside the protected areas and subjected to forest destruction and direct killing by humans. The remaining areas of protected forest containing the orang-utans are small and scattered (see Figure 8.13 on page 174 of the textbook). Orang-utans do not move far to mate; in particular they do not cross rivers or non-forested areas. Thus the groups left are inbreeding. This leads to homozygosity and weakening of the stock. The establishment of forest corridors to link their areas to outbreed is too expensive for the local economy to support.

(b) The reasons will need to be mainly ethical and aesthetic (see "Why loss of biodiversity matters", and page 176 of the textbook), because there are few strictly economic or ecological reasons connected with orang-utans, and these are outweighed in practice by the economic needs of the relatively poor local human populations.

(c) This is really a hybrid between an *in situ* and *ex situ* method: part zoo, part nature reserve. As all known animals have been collected, and they are all on one small island so able to meet and breed, it keeps genetic diversity as high as possible. Lack of predators also gives them a chance. It depends upon whether the island can support a big enough population for genetic diversity to remain high.

Q8: Consider the points in "*In situ* methods: National Parks" above. Then research some specific examples, as recommended in the "Tip" box on page 182 of the textbook, by entering "conflicts of interests in national parks" into the Google search box.