

HL IB Environmental Systems & Societies (ESS)



3.1 Biodiversity & Evolution

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Biodiversity & Resilience



Your notes

Understanding Biodiversity

Why is biodiversity important?

- Biodiversity can be thought of as a study of all the **variation** that exists within and between all forms of life
- Biodiversity looks at the range and variety of **habitats**, **species** and **genes** within a particular region
- It can be assessed at three different levels:
 - The number and range of different ecosystems and habitats
 - The number of species and their relative abundance
 - The genetic variation within each species
- Biodiversity is very important for the **resilience** of ecosystems
 - This is because biodiversity allows them to resist changes in the environment and avoid ecological tipping points

Habitat diversity

- This is the range of different habitats within a particular ecosystem or biome
- If there is a large number of **different habitats** within an area, then that area has high biodiversity
 - A good example of this is a coral reef
 - They are very complex with lots of microhabitats and niches to be exploited
- If there is only one or two different habitats then an area has low biodiversity
 - Large sandy deserts typically have very low biodiversity
 - The conditions are basically the same throughout the whole area



Your notes



A coral reef is an example of an ecosystem with high biodiversity due to high habitat diversity (Photo by Francesco Ungaro on Unsplash)

Species diversity

- An ecosystem such as a tropical rainforest that has a very high number of different species would be described as species-rich
 - Species richness is the number of species within an ecosystem
- Species diversity looks at the number of **different species** in an ecosystem, and also the evenness of abundance across the different species present
 - The greater the number of species in an ecosystem and the more evenly distributed the number of organisms are among each species, then the greater the species diversity
- Ecosystems with high species diversity are usually more **stable** than those with lower species diversity as they are more resilient to environmental changes
 - For example in the pine forests of Florida, the ecosystem is dominated by one or two tree species

- If a pathogen comes along that targets one of the two dominant species of trees, then the whole population could be wiped out and the ecosystem it is a part of could **collapse**



The lack of species diversity in the pine forests of Florida makes them vulnerable to collapse when pathogens enter the ecosystem (Photo by Worm Funeral on Unsplash)



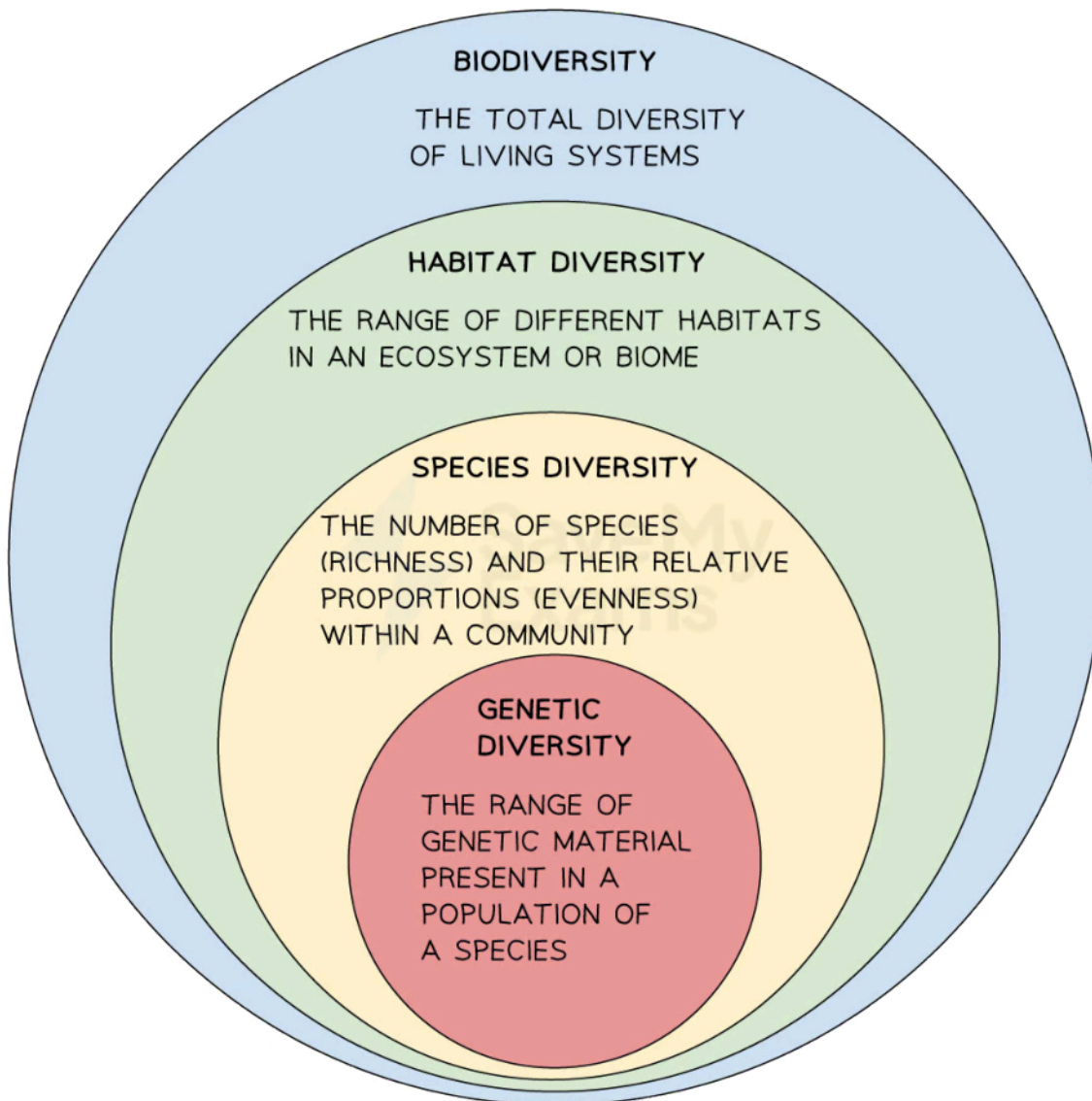
Your notes

Genetic diversity

- Genetic diversity is the diversity of **genes** found within different individuals of a species
- Although individuals of the same species will have the **same set of genes**, these genes can take a variety of **different forms**
- This makes it possible for genetic diversity to occur **between populations** of the same species
- Genetic diversity **within a single population** also occurs
 - This diversity is important as it can help the population **adapt to**, and survive, **changes in the environment**
 - This could include changes in biotic factors such as new predators, pathogens and competition with other species
 - Or the changes could be abiotic factors like temperature, humidity and rainfall



Your notes



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



Your notes

Evolutionary Processes

Evolutionary Processes

- Biodiversity arises from evolutionary processes
 - Evolution is the cumulative change (i.e. the overall change over time) in the heritable characteristics of a population or species
 - Natural selection is the name of the mechanism that drives this evolutionary change
 - Natural selection occurs continuously and can take place over billions of years
 - The result of this process of natural selection is the biodiversity of life on Earth we see today

Natural Selection

- In any environment, the individuals that have the best adaptive features are the ones most likely to **survive** and **reproduce**
- This results in natural selection:
 - Individuals in a species show a range of variation caused by **differences in genes** (genetic diversity)
 - When organisms reproduce, they produce more offspring than the environment is able to support
 - This leads to **competition** for food and other resources, which results in a "struggle for **survival**"
 - Individuals with **characteristics** most **suited** to the environment have a higher chance of survival and more chances to **reproduce**
 - Therefore, the genes resulting in these characteristics are **passed on to offspring** at a higher rate than those with characteristics less suited to survival
 - This means that in the next generation, there will be a greater number of individuals with the better adapted variations in characteristics
- This theory of natural selection was put forward by Charles Darwin and became known as "survival of the fittest"

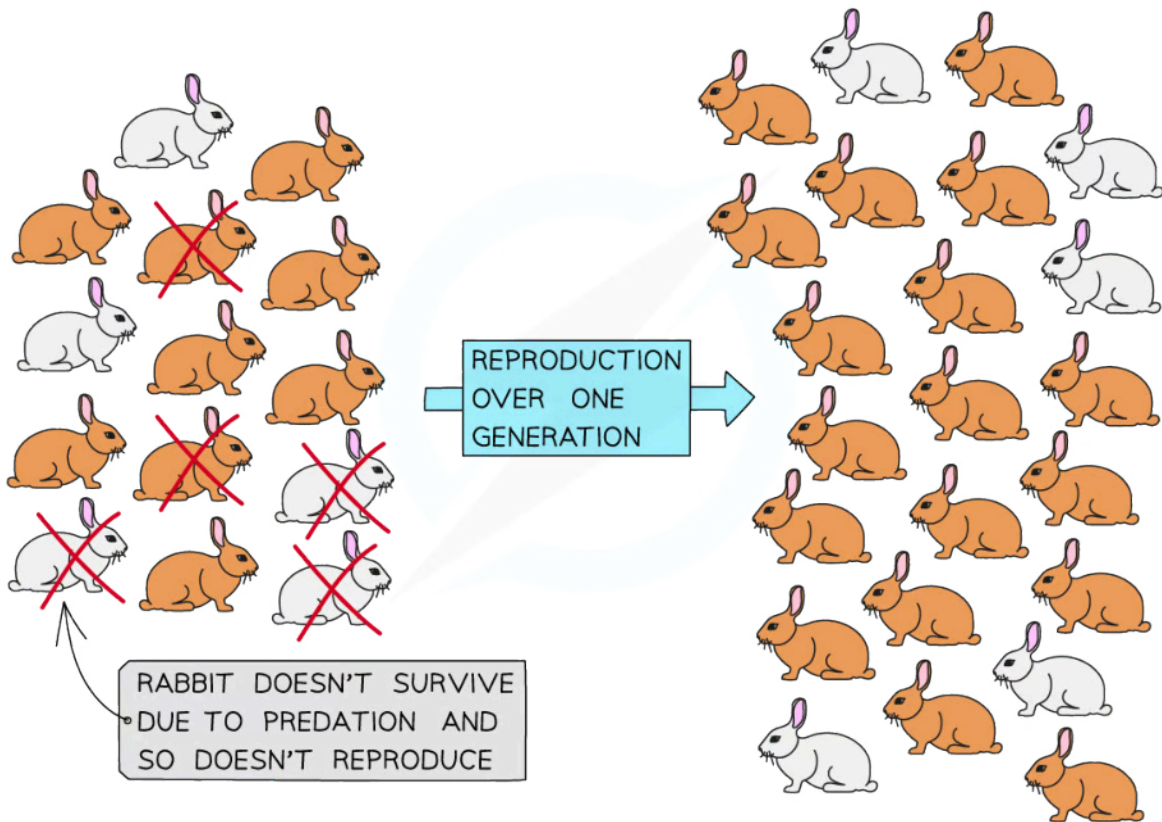
Example of natural selection

- Imagine a population of rabbits shows variation in fur colour
- The rabbits have natural predators like foxes
 - This acts as a selection pressure



Your notes

- Rabbits with a white coat do not camouflage as well as rabbits with brown fur
 - This means predators are more likely to see white rabbits when hunting
- As a result, rabbits with white fur are less likely to survive than rabbits with brown fur
- The rabbits with brown fur therefore have a selection advantage
 - This means they are more likely to survive to reproductive age and be able to pass on their genes to their offspring
- Over many generations, the frequency of the gene for brown fur will increase and the frequency of the gene for white fur will decrease



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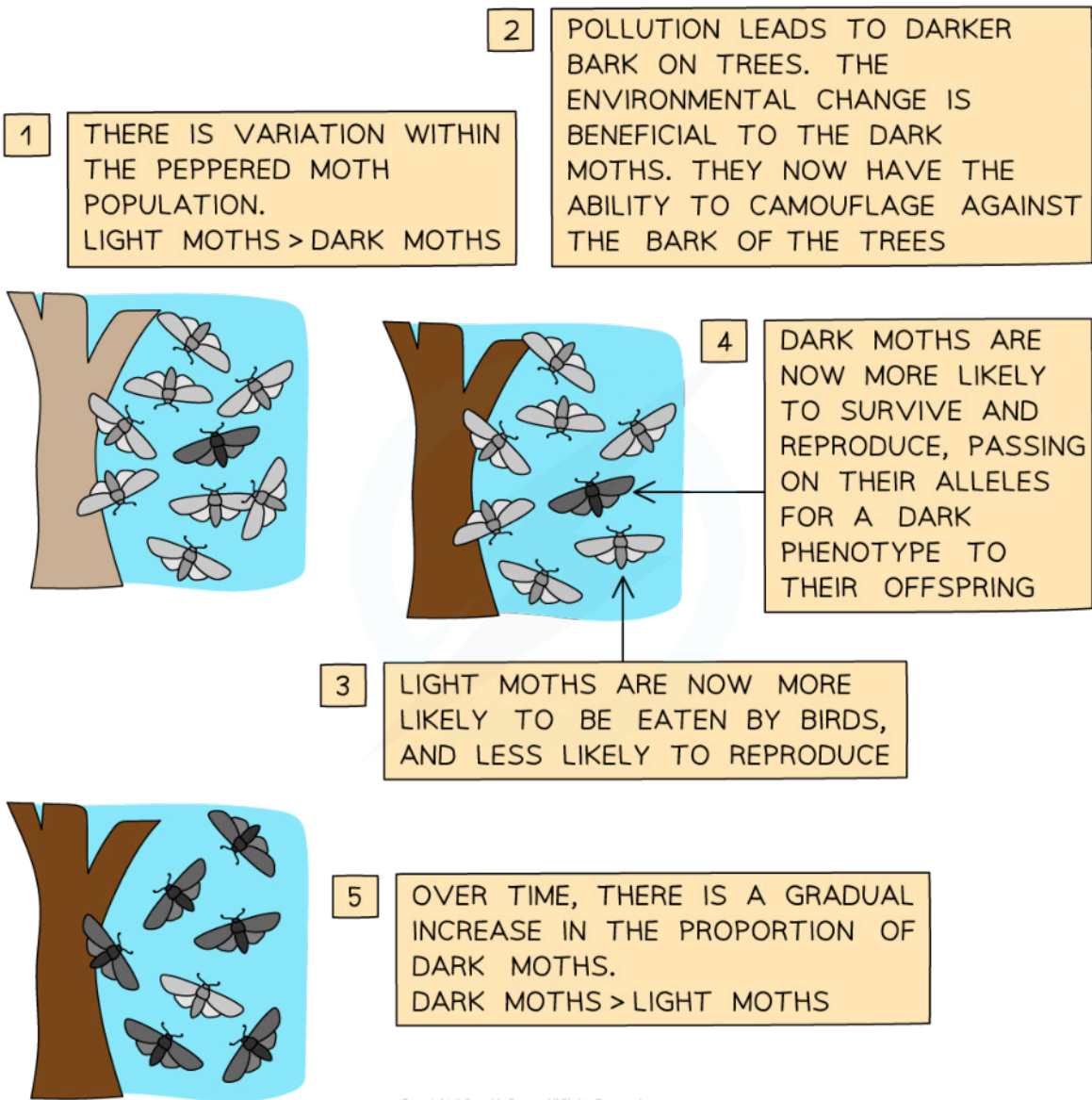
Selective pressures acting on a rabbit population for one generation—predation by foxes causes the frequency of rabbits with brown fur to increase and the frequency of rabbits with white fur to decrease

- Remember that organisms better suited to their environments are more likely to survive
 - However, this does not mean their survival is guaranteed
- Organisms that are less suited to an environment are still able to survive and potentially reproduce within it



Your notes

- However, their chance of survival and reproduction is lower than the individuals that are better-adapted
- Also, it is important to be aware that an environment, and the selection pressures it exerts on an organism, can change over time
 - When a change occurs then a different characteristic may become more advantageous
- Finally, remember that all organisms (not just animals) experience selection pressures as a result of the environment they are in



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Another good example of natural selection is the evolution of the peppered moth

Speciation

- Speciation is the generation of **new species** through evolution
- It occurs when populations of a species become **isolated** and adapt to their environments in different ways
- Over time, these populations become so different that they can **no longer interbreed** with each other to produce **fertile offspring**
- When they cannot interbreed in this way, they are considered **separate species**

EXAM TIP



There are many examples of natural selection and you cannot possibly be familiar with all of them, however, they ALL follow the same sequence:

Based on the idea that within a species there is always variation due to chance mutations, some individuals will develop a characteristic that gives them a survival advantage that allow them to live longer, breed more, and be more likely to pass their genes on. Repeated over generations, the advantageous characteristic will become the norm within a population.



Your notes

Assessing Biodiversity



Your notes

Species Diversity

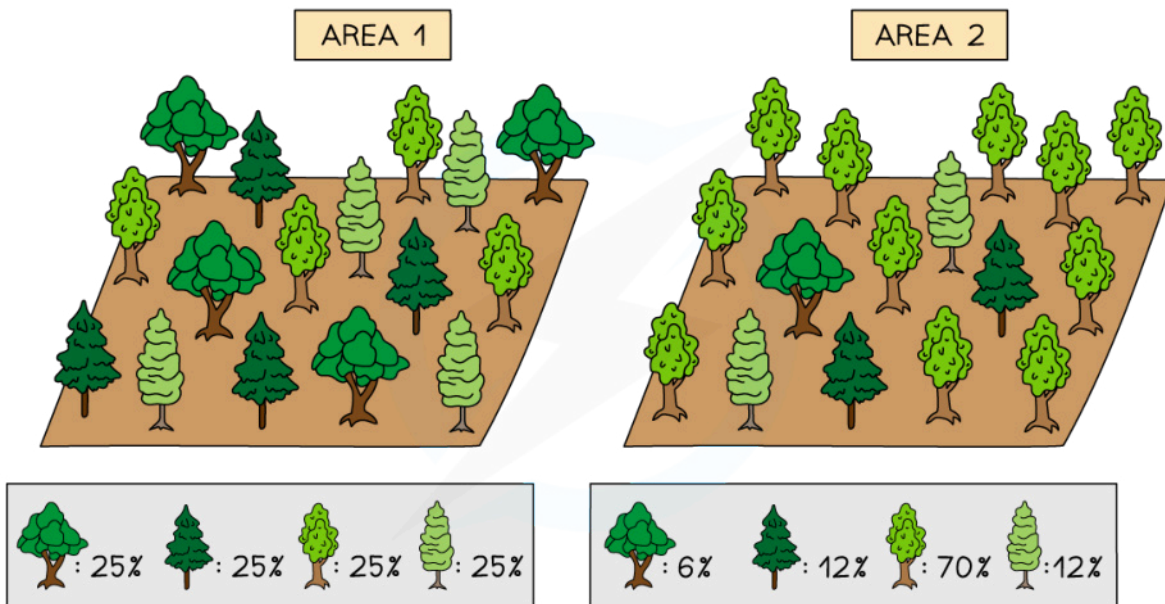
- Species **richness** is the **number of species** in a community or defined area
 - In some cases, it can be a useful measure to compare the biodiversity of different areas
- However, in other cases, species richness can be a **misleading indicator** of diversity
 - This is because it does not take into account the **number of individuals of each species**
- Once the abundance of each species in an area has been recorded, the results can be used to calculate the **species diversity** for that area
 - Species diversity looks at the number of different species in an area but also the **species evenness**
 - Species evenness is the **evenness of abundance** across the different species (i.e. their **relative abundances**)

Species richness vs species diversity

- Species diversity is a much more **informative** measurement than species richness and conservationists often favour the use of species diversity as it takes into account both species richness and evenness
- For example:
 - Area 1 and Area 2 both contain four tree species
 - However, Area 2 is actually dominated by one species and in fact, one of the species is very rare (only one individual)
 - Although the two areas have exactly the same species richness, Area 1 has a higher species evenness (and therefore a higher overall species diversity) than Area 2
 - This example illustrates the limitations of using just species richness on its own



Your notes



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Area 1 and Area 2 have the same species richness but different species evenness. As it has a higher species evenness, the overall species diversity of Area 1 is higher than that of Area 2, as species diversity takes both richness and evenness into account

Simpson's Diversity Index

- Biological communities can be described and compared through the use of **diversity indices**
 - These are mathematical tools used to quantify the diversity of species within a community
- These indices provide a measure of the variety of species present, as well as their relative abundances
 - They can be used to **compare different communities** or to **track changes** in diversity **over time**
- A commonly used diversity index is **Simpson's index**

Calculating Simpson's diversity index

WORKED EXAMPLE



- A group of students used the kick sampling technique to collect, identify and count the invertebrates inhabiting a river
- Samples were obtained from different sites along the course of the river
- The data was used to calculate the Simpson's diversity index at two different river sites



Your notes

- This index of diversity is useful when comparing two similar habitats, or the same habitat over time
- The formula for calculating Simpson's Diversity Index, D , is:

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

- Where:
 - D = Simpson's diversity index
 - N = total number of individuals sampled
 - n = number of individuals of each species

Data Collection Table

Species	Mean number of organisms per m ² of river bed	
	Site A	Site B
Mite	14	0
Snail	9	0
Leech	3	26
Worm	0	6
Flat worm	132	9
Mayfly nymph	43	0
Olive mayfly nymph	154	0
Midge Larva	0	10
Blackfly larva	77	0
Caddis larva	15	1
Fish	1	0
Freshwater shrimp	211	6
Water hog louse	0	40

Site A

Species	Number (n)	n (n-1)
Mite	14	182



Your notes

Snail	9	72
Leech	3	6
Worm	0	0
Flat worm	132	17 292
Mayfly nymph	43	1 806
Olive mayfly nymph	154	23 562
Midge Larva	0	0
Blackfly larva	77	5 852
Caddis larva	15	210
Fish	1	0
Freshwater shrimp	211	44 310
Water hog louse	0	0
Total	$N = \sum n = 659$	$\sum n(n-1) = 93\,292$

$$D = \frac{N(N-1)}{\sum n(n-1)} = \frac{659(658)}{93292} = 4.65$$

Site B

Species	Number (n)	n (n-1)
Mite	0	0
Snail	0	0
Leech	6	30
Worm	26	650
Flat worm	9	72
Mayfly nymph	0	0
Olive mayfly nymph	0	0
Midge Larva	10	90



Your notes

Blackfly larva	0	0
Caddis larva	1	0
Fish	0	0
Freshwater shrimp	6	30
Water hog louse	40	1560
Total	$N = \sum n = 98$	$\sum n(n-1) = 2432$

$$D = \frac{N(N-1)}{\sum n(n-1)} = \frac{98(97)}{2432} = 3.91$$

- By comparing the diversity indices for Site A and Site B, we can see that Site B has a lower species diversity
 - The value of D will be higher where there is greater richness (number of species) and evenness (similar abundance)
 - The lowest possible value for D is 1

EXAM TIP



Remember, this index of diversity is only useful when comparing two similar habitats, or the same habitat over time.

You will be provided with the formula for Simpson's Index in the exam but you need to know how to use it to calculate Simpson's Diversity Index for example sets of data.



Your notes

Biodiversity Management

Biodiversity Management

Importance of biodiversity management

- Biodiversity refers to the variety of life on Earth, including ecosystems, habitats, species and genetic diversity
- Managing biodiversity is crucial for many reasons, including:
 - **Ecosystem stability**—biodiversity maintains ecosystem resilience to environmental changes
 - **Medicine and pharmaceuticals**—many medicines are derived from biodiversity, offering potential treatments for various diseases
 - **Cultural and spiritual significance**—biodiversity holds cultural and spiritual importance, preserving traditional knowledge
 - **Economic benefits**—biodiversity contributes to tourism and livelihoods, supporting local economies
 - **Climate regulation**—ecosystems help mitigate climate change by sequestering carbon dioxide
 - **Pollination and food security**—biodiversity, especially pollinators, is essential for crop pollination and food production.

Gathering Knowledge of Biodiversity

- Effective biodiversity management requires comprehensive knowledge at both global and regional levels

Global biodiversity data collection

- **International organisations:**
 - Organisations like the IUCN (International Union for Conservation of Nature) and WWF (World Wildlife Fund) gather data globally
 - For example, the IUCN Red List categorises species based on their extinction risk

Regional biodiversity data collection

- **National and local agencies:**
 - Government-funded agencies, such as Natural England in the UK, collect data on local species and habitats



Your notes

- For example, Natural England conducts surveys on bird populations to monitor their status
- **Citizen science:**
 - Involves public participation in scientific research
 - Volunteers collect data on local wildlife, which is then used by scientists
 - For example, the Big Butterfly Count in the UK engages the public in counting butterfly species
- **Voluntary organisations:**
 - NGOs like The Wildlife Trusts (UK) work on local biodiversity projects
 - For example, the Wildlife Trusts have a long-term hedgehog monitoring programme

Training for data collection

- **Indigenous people:**
 - Indigenous communities often possess detailed traditional knowledge of local ecosystems
 - Training helps integrate their knowledge with scientific methods
 - For example, indigenous rangers in Australia are trained to monitor and protect native species
- **Parabiologists:**
 - These are local people trained to assist in biological research
 - They bridge the gap between local communities and scientific researchers
 - They may be used to gather information for use in conservation management

Biodiversity management strategies

- There are many different biodiversity management strategies but the main categories are:
 - The creation of protected areas
 - The restoration of existing but damaged habitat
 - The implementation of sustainable management strategies
- **Protected areas:**
 - Creating parks, reserves and conservation areas
 - For example, the establishment of marine protected areas to safeguard coral reefs
- **Habitat restoration:**
 - Restoring degraded ecosystems to their natural state

- For example, rewilding projects involve the restoration of ecosystems by reintroducing native species to their original habitats
- **Sustainable practices:**
 - Encouraging sustainable agriculture, forestry and fishing
 - For example, certification schemes like Fair Trade promote sustainable farming practices



Your notes