DP IB Environmental Systems & Societies (ESS): SL

3.1 Biodiversity & Evolution

Contents

Biodiversity & Resilience

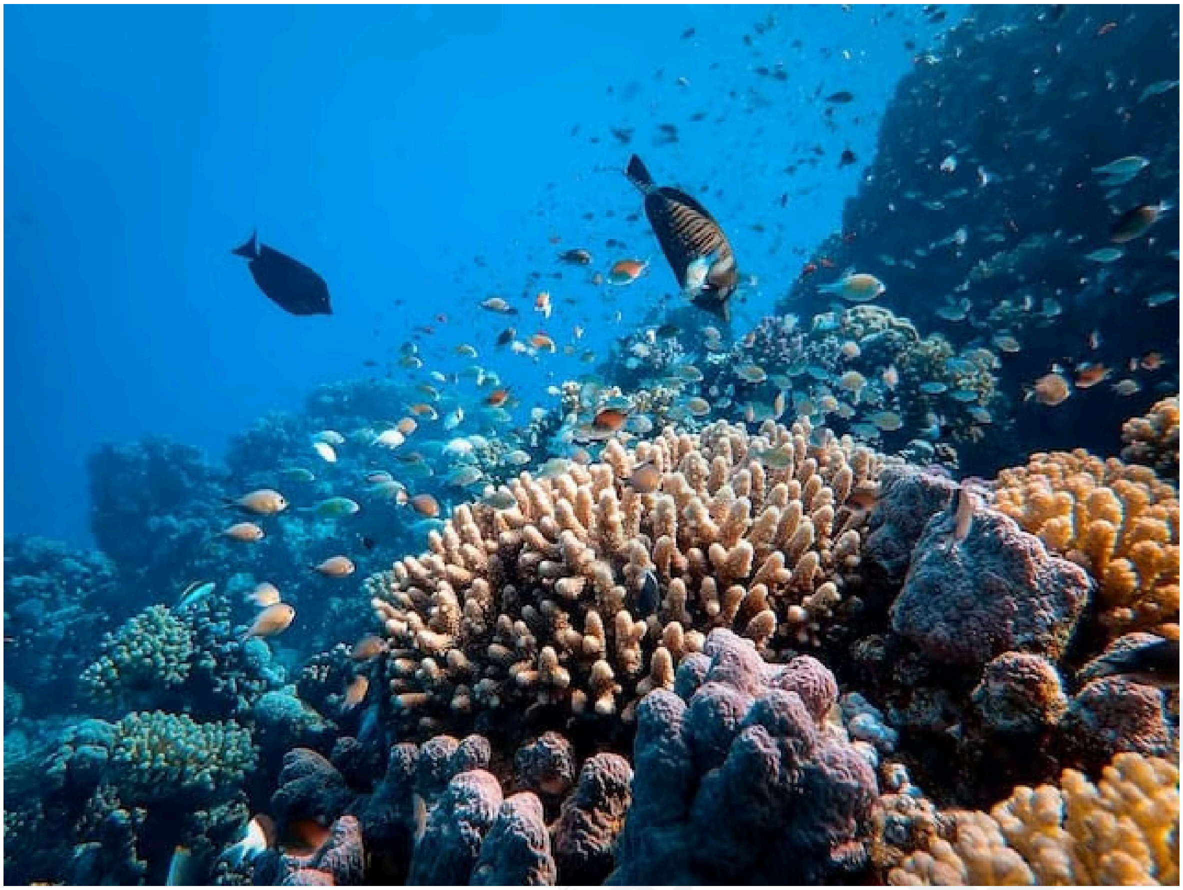
Understanding Biodiversity

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



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)

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

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

- 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

- 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
    - 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

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**

Assessing Biodiversity

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

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

- 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:

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

- 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

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= ∑n= 659	∑n(n-1)= 93 292

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

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

Blackfly larva	0	0
Caddis larva	1	0
Fish	0	0
Freshwater shrimp	6	30
Water hog louse	40	1 560
Total	N= ∑n= 98	∑n(n-1)= 2 432

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

- 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

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

        - 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