WJEC (England) Biology GCSE

Topic 6: Ecosystems

Notes

('Higher Tier only' in **bold**)

6.1 Levels of organisation within an ecosystem

Key terms

- Ecosystem - an ecosystem is made up from all the living organisms and abiotic components (such as soil, rocks and water) in a community. These interact with each other to function as one unit.
- Producer - an organism that converts light energy to chemical energy in order to produce its own nutrients. Photosynthetic organisms are the main producers of biomass.
- Consumer - an organism which gets biomass from feeding on other animals or plants.
- Herbivore - organisms which feed on plants.
- Carnivore - organisms which feed on animals.
- Decomposer - organisms which break down decaying organic material (detritus).
- Population - A group of organisms of the same species living together in one habitat.
- Community - Populations of many different species living together in one ecosystem make up a community.
- Food chain - a diagram which shows the order of biomass transfer through feeding in an ecosystem.
- Food web - a diagram showing how different food chains interact with each other.
- Biomass - the total mass of living material. This is passed through food chains during feeding.
- Trophic level - the trophic level of an organism refers to its position in the food chain, food web or pyramid of biomass.
- Pyramid of biomass - shows the total mass of organisms in each trophic level of a food chain.

Abiotic factors which affect a community

Abiotic factors are non-living factors which have an impact on the living organisms in an area. The climate and soil conditions will determine which species of plant grow in an ecosystem. Different species of plants attract different types of wildlife, thus abiotic factors can have a big impact on which organisms live in an area. The main abiotic factors which affect communities are:

- pH - soil pH affects what plants grow in the soil; some plants, such as ferns, grow in alkaline soil, whereas other plants, such as blueberries, prefer acidic soil.

- Light - plants depend on light to grow, therefore the amount of light can affect how many plants grow in a community. For example, tall trees can block light from reaching the forest floor, meaning that plants cannot grow at ground level. If there is only a small amount of plants, fewer herbivores, and therefore fewer carnivores, will live in an area as there is limited food.

- Temperature - different plants and animals are suited for different climates. Consequently, the temperature will affect what kinds of organisms live in a community. Temperature fluctuations can also have an impact on what animals live in a community as many animals

migrate over winter if the temperature drops.

- Salinity - plants must be specially adapted to live in marine environments, as these plants often grow in salty water and can be submerged, limiting oxygen intake. Most plants found on land would die if grown in salt water due to the salt disrupting metabolic reactions.

Biotic factors which affect a community

Biotic factors are dependent on living organisms:

- Predation - organisms which have lots of predators will have a slower rate of population growth as more will be killed.
- Disease - disease can reduce the population by killing organisms. In densely populated areas, disease can spread quickly, thus a large proportion of the population may be wiped out.
- Food availability - if there is a large amount of food, organisms can breed more successfully. If there is a food shortage, there is a higher death rate which results in a slow or negative population growth.

Competition

There is competition within communities for resources such as food, mates, shelter and space. This can be between organisms of the same species, or between organisms of different species. Competition is important as it promotes natural selection and evolution as the stronger, better adapted organisms will be able to compete more successfully and thus reproduce to pass on their beneficial traits.

Interdependence

Organisms of different species in a community depend on each other. For example, plants rely on insects and animals to spread their seeds, whereas animals rely on plants for shelter. All organisms depend on others for food: predators and herbivores eat other organisms, whereas plants get their nutrients from animal excrement and decomposers.

Trophic levels and biomass transfer

Energy is introduced into biological systems as light energy which is absorbed by photosynthetic organisms. This energy is then transferred to chemical energy (biomass) and can pass to other organisms through feeding. When these animals die, they are broken down by decomposers which return their nutrients to the soil.

A food chain shows the order of biomass transfer between organisms. Food chains start with producers, which are plants which convert light energy from the Sun to chemical energy. Organisms which feed on plants or other animals are known as consumers. Plants are eaten by herbivores, which gain biomass from the plants that is used for growth. This consumer is then eaten by another animal which gains the biomass from the first. Each of these organisms has its own trophic level. Consumers are classed as primary, secondary, tertiary or quaternary, depending on their position in the food chain.

Loss of biomass

Biomass transfer is inefficient, and biomass is lost between each stage of the food chain due to a number of reasons:

- Not all animal and plant material can be digested to gain energy from, e.g. fur and bones.
- Biomass is lost through excretion and decay.
- Biomass is used in other processes, e.g. movement and keeping warm.

This means that organisms later on in the food chain gain less energy from their food than organisms earlier on, as energy is lost at each level. Consequently, organisms later in the food chain must eat a larger amount to gain enough energy for survival. For this reason, there are usually not more than five trophic levels as too much energy would be lost to sustain another. This is also why it is more efficient for humans to eat plants rather than animals, as there are more stages in the food chain if animals are present.

Pyramids of numbers and biomass

A pyramid of numbers can be used to show the number of organisms in each trophic level. This is similar to a pyramid of biomass, which measures the total biomass of all the organisms at each level. A pyramid of biomass tends to have a true pyramid shape as biomass is lost in each level.

6.2 The principle of material cycling

Different materials cycle through abiotic and biotic components of an ecosystem. Materials such as carbon, water and nitrogen occur naturally in the air and soil. They are taken up by plants and then pass along the food chain during feeding. These materials are returned to the air or soil during excretion and decomposition, where they can be taken up again. In stable communities, the amount of materials taken up is equal to the amount returned.

The carbon cycle

Carbon is an essential element which makes up the majority of molecules in living organisms. The carbon cycle is used to show how carbon atoms move between the atmosphere and living organisms:

1. Carbon is present in the atmosphere in the form of carbon dioxide, which makes up about 0.04% of the air.
2. Carbon dioxide is taken in by plants during photosynthesis. Here, the carbon is transferred from carbon dioxide to other molecules such as proteins and carbohydrates.
3. These molecules are passed through the food chain when feeding occurs, hence carbon is also passed between the trophic levels.
4. Carbon is returned to the atmosphere during respiration, which releases carbon dioxide, and during decomposition.

Carbon can be trapped in dead organisms when decomposition does not occur. These organisms become fossilised over thousands of years to form fossil fuel. When this fossil fuel is burned, large amounts of carbon dioxide is released back into the atmosphere. This, along with the effect of deforestation, leads to the amount of carbon dioxide in the atmosphere increasing, which causes global warming.

The water cycle

Water is another important molecule in ecosystems. Water has a range of roles in cells: it acts as a solvent in which reactions occur, it is used in metabolic reactions, and also helps maintain a constant temperature by acting as a temperature buffer.

The water cycle:

1. Water evaporates from bodies of water such as lakes and rivers to form water vapour (gas). It also is released from plants during transpiration.
2. This water vapour rises upwards and begins to cool. When it cools, condensation occurs, turning the vapour back into liquid water which forms clouds.
3. When the cloud becomes too heavy, water falls from the cloud as precipitation (rain, snow, hail etc).
4. This water is then taken up by plants and animals where it passes through the food chain, or returns to a body of water, so that the cycle can continue.

Decomposition

When organisms die, they are broken down by decomposers which return their nutrients to the soil. Dead organic material is known as detritus. Decomposers are small organisms in the soil such as

bacteria and fungi which use extracellular digestion to break down detritus, a process catalysed by enzymes. During extracellular digestion, bacteria and fungi secrete enzymes from their cells into the soil to break down organic material, before reabsorbing the products back into their cells. It is called “extracellular” as it occurs outside of the cell.

Factors affecting the rate of decomposition:

- Temperature - decomposers rely on enzymes to break down and digest their food. Warm temperatures that are close to the enzyme’s optimum will speed up the rate of decomposition. At low temperatures, the rate of decomposition is low as enzymes are inactive.
- Presence of oxygen - with oxygen, decomposers can work aerobically and release carbon dioxide. In oxygen deficient areas of decomposition, for example landfills and marshes, decomposers break down detritus anaerobically. Anaerobic respiration is slower and releases methane, another greenhouse gas.
- Presence of water - in dry soils, decomposition can be slow since decomposers are living organisms that need water to survive. In water logged soils, however, water fills the air spaces which leads to anaerobic decomposition.

6.3 Biodiversity

Measuring biodiversity

Biodiversity refers to the number of organisms and the variety of different species within an area, as well as the diversity in the genes of these organisms. Biodiversity is important as it promotes evolution and provides resources such as food and wood. A wide variety of organisms also increases the chance that some can be used in new medicines.

Biodiversity in a community can be measured by taking random samples of organisms in an area. The more samples taken, the more accurate the results. Once the results are collected, various statistical tests can be carried out to analyse the data. Biodiversity can be measured using different equipment and techniques, including:

- Quadrat sampling - quadrats are square grids, usually $1m^2$ in size and made up of 100 small squares. They are placed randomly in an area and the percentage cover of a chosen species can be measured by counting how many squares in the grid contain the species. This is often done in two different areas to compare their biodiversity, for example sampling could be done on mown and unmown grassland to compare the effect of mowing on biodiversity.
- Transect sampling - transects are used to measure changes in the abundance and distribution of species between two places. This involves placing a straight line through an area and, at regular intervals, using a quadrat to measure the abundance of the chosen species. An example of this would be measuring the change in biodiversity when moving up a seashore.
- Capture recapture method - this method is used to estimate the population size of an animal species in an area. Animals of a chosen species are captured and marked, and then are released back into the ecosystem. Later, animals are recaptured and the number caught with the mark is compared to the number caught without the mark. This is used to estimate a total population size. This method assumes that there are no significant numbers of births or deaths, and no animals enter or leave the area in the time between taking the two samples. Researchers must also make sure that the mark left does not affect the chances of survival of the organism, which would make the results inaccurate.

To calculate population size:

$$population\ size = \frac{[total\ number\ caught\ in\ first\ sample]\ x\ [total\ number\ caught\ in\ second\ sample]}{[number\ caught\ in\ second\ sample\ with\ mark]}$$

Indicator species

An indicator species is one that is used as an indicator to show the condition of an ecosystem. They are usually common species that are sensitive to environmental changes, and which respond predictably to those changes. By measuring the species behaviour and population size, the health of the ecosystem can be seen. Using indicator species removes the need for scientific equipment and testing, although it may be difficult to find the exact cause of any changes in behaviour. An example of an indicator species is coral, which is used to measure the health of underwater reefs. Corals are extremely sensitive to their environment; if the temperature becomes too high or low, or

corals are exposed to other stresses, they will lose their pigments and become bleached. Thus, reef health can be measured by looking at how much coral bleaching is occurring.

Human interactions with ecosystems

Human activities can a huge negative impact on biodiversity:

- The use of chemicals, such as those in pesticides, can decrease the number of species in an environment by killing pest species, reducing biodiversity. Rain can also cause these chemicals, as well as those in fertilisers, to wash into water sources, killing organisms and causing eutrophication. This can have a knock-on effect, as it will reduce the amount of prey for other species, which could also die.

- Urbanisation and industrialisation have resulted in habitat destruction, as well as vastly increasing the amount of pollution. Pollution can lead to acid rain, which damages tree leaves and leads to the destruction of forest habitats, and a rise in the temperature of some areas, meaning species which cannot adapt will die out. In addition, some factories pollute water sources, leading to the death of organisms. An example of this is pollution from factories in China killing pink river dolphins, which are now critically endangered.

To combat these issues, there is an effort to conserve biodiversity, both locally and globally. Nature reserves and national parks can help to maintain biodiversity as well as protect endangered species. Farming can also be carried out in a more sustainable way, by reducing the use of chemicals and by managing fishing and logging levels to help preserve habitats.

At an international level, treaties such as the Kyoto protocol help to reduce pollution and manage climate change. This has varying levels of success, however, depending on the level to which individual countries abide by these treaties.

Endangered species

When the number of surviving organisms in a species becomes very low, the species is classed as endangered. This is harmful to a species as it greatly reduces the gene pool by decreasing the number of alleles available. This makes the species more susceptible to disease and less able to adapt to changes. Species can become endangered for a variety of reasons, such as habitat destruction, climate change, hunting, pollution, and competition from introduced species.

If an endangered species is not protected, it can become extinct. There are many measures that can be used to protect a species from extinction:

- Monitoring - endangered animals can be monitored. This allows the number of organisms left to be tracked over time and can also highlight their preferred habitats and migration patterns, allowing important habitats to be protected.
- Education - this allows people to understand why a species is becoming extinct so that protective measures can be implemented.
- Captive breeding programmes - endangered animals can be bred in captivity where their chance of survival is greater. They can later be reintroduced to habitats in the wild.

- Seed banks - seeds from endangered plant species can be preserved so that the plants may be grown in the future.

Biological control agents

Humans can introduce alien species to an area to act as a biological control agent. These species prey on existing species and reduce the biodiversity of an area. They are usually introduced to decrease the number of pests which destroy crops. An example of this is the introduction of Cane toads to Australia. Cane toads were first introduced in 1937 to reduce the beetle population, which were damaging sugarcane crops. These toads, however, multiplied exponentially and preyed on many native species, as well as secreting poisonous toxins. Since their introduction, many other species have declined, including native lizards, snakes and crocodiles.

6.4 Some of the biological challenges of increasing food yields using fewer resources

Balancing development with biodiversity

It is important to balance the need for resources such as food and industrial materials with the need to preserve the biodiversity of ecosystems. This is essential to protect ecosystems and endangered species, whilst still maintaining quality of life for humans. These needs can be balanced by taking resources sustainably and recycling waste materials. Pollution can also be managed to reduce global warming and damage to ecosystems.

The Environmental Agency is a government agency that aims to protect the environment by regulating air, water and land quality in the UK. They also monitor fishing and marine areas. They do this by observing the condition of the environment and how it changes over time. Collecting detailed and reliable information about the environment is crucial to maintain and improve the condition of ecosystems.

Food security and population growth

As the human population increases, food production must also increase. This is a problem as more land is required to grow crops and animals, meaning that there is more deforestation and an increasing amount of greenhouse gases emitted from animal production. Unsustainable farming practices can also lead to long-term problems which decrease soil fertility. For example, overuse of chemicals can lead to soil contamination, and over-farming can lead to soil erosion and desertification, meaning that crops cannot grow.

Food security refers to the sustainability and accessibility of a food source. Different factors can put strains on a food source, including:

- Increasing population - the increasing birth rate and decreasing death rate, due to the development of better medicines, results in more people who require food. In addition, more homes and urban areas are needed, which reduces the amount of farmland available to grow crops and farm animals for food.
- Changing diets - developed countries typically consume a larger amount of meat. As countries such as China become more developed, the demand for meat increases. This is not sustainable.
- New pests and pathogens - these can damage crop production and infect animals, leading to food shortages.
- Environmental change - global warming leads to an increase in extreme weather conditions. These include droughts, tropical storms and flash flooding, which can all destroy crops and kill livestock.

To maintain food security, it is important to conserve the biodiversity and sustainability of food production. There are also methods to increase the yield from farming: plants and animals can be genetically modified to be more resilient to harsh conditions, for example some strawberries have been genetically modified to be frost resistant, which prevents plant death in cold conditions. They can also be selectively bred to increase the yield per plant or animal by selecting desirable

characteristics. To improve this further, they are grown in optimum conditions, e.g. in a greenhouse, so that all their energy is put into growing rather than other activities like keeping warm or searching for food.