ECOLOGY

Definition: It is the scientific study of the interactions that determine the distribution and abundance of organisms within a particular environment.

DEFINITION OF TERMS IN ECOLOGY

Species: A group of organisms that can successfully interbreed.
Population: The members of the same species living in one habitat at the same time. E.g. tilapia fish in a pond, mahogany trees in a forest, people in a country, termites in one anthill, etc
Community: All the organisms of different populations living in a well-defined area e.g. all organisms within a pond
Habitat: Specific locality where an organism normally lives within the environment e.g. leaf litter for earthworms, intestines of man for tapeworms, ponds for frogs, beside the water storage tanks for toads, kitchen for cockroaches, etc.
Ecological niche: The role an organism plays in the habitat, and its interactions with other organisms. i.e. the sum of all environmental factors that influence the growth, survival and reproduction of a species. A niche is like the "profession" of an organism
Biomass: It is the dry weight of all organic matter contained in organisms per unit area of ground or volume of water.
Dry weight is the wait after all the water has been removed by heating in an oven or sunshine.
Ecosystem: it is natural unit composed of living (biotic) organisms and non-living (abiotic) things whose interactions lead to a self-sustaining system.
(i) Water (aquatic) ecosystems may be fresh water bodies (e.g. lakes, ponds, rivers) or marine water bodies (e.g. sea, ocean). Organisms in water may be of large size (nektons) e.g. fish, whales, turtles or very tiny (planktons) e.g. phytoplanktons and zooplanktons.
(ii) Land (terrestrial) ecosystems include forests, deserts, savanna, etc

THE MAJOR COMPONENTS OF AN ECOSYSTEM

a) Abiotic / nonliving things: these are physical and chemical factors that influence living organisms on land (terrestrial) ecosystems and in water (aquatic). ***Examples of abiotic components:*** Temperature, Light, Wind, Humidity, soil (edaphic) factors e.g. Soil PH, Soil air, Inorganic particles.
b) Biotic / living components: these are the plants, animals and decomposers.

THE MAJOR BIOTIC / LIVING COMPONENTS OF ECOSYSTEMS

1. Producer: An organism that produces food from carbon dioxide and water using photosynthesis e.g. plant, algae, plankton or bacteria.
2. Consumer: An animal that eats other organisms
(i) **Herbivore:** A consumer that eats plants (= primary consumer).
(ii) **Carnivore:** A consumer that eats other animals (= secondary consumer).
(iii) **Top carnivore**: A consumer at the top of a food chain with no predators.
(iv) **Omnivore**: A consumer that eats both plants and animals.
3. Decomposer: An organism that consumes detritus (= detrivores + saprophytes)
(i) **Detrivore**: An animal that eats detritus.
(ii) **Saprophyte**: A microbe (bacterium or fungus) that lives on detritus.
Important of decomposition:
(1) It enables dead bodies to be disposed off which, if left would accumulate everywhere.
(2) Recycles nutrients to be used by other organisms e.g. Mineral salts are released from dead bodies into soil for plant growth.

OTHER TERMS ASSOCIATED WITH FEEDING

Autotroph: An organism that manufactures its own food (= producer)
Heterotroph: An organism that obtains its energy and mass from other organisms (=consumers + decomposers)
Plankton: Microscopic marine organisms.
Phytoplankton: "Plant plankton" i.e. microscopic marine producers.
Zooplankton: "Animal plankton" i.e. microscopic marine consumers.
Predator: An animal that hunts and kills animals for food.
Prey: An animal that is hunted and killed for food.
Scavenger: An animal that eats dead animals, but doesn't kill them
Detritus (Carrion): Dead and waste matter that is not eaten by consumers
Symbiosis: Organisms living together in a close relationship (= parasitism, mutualism, pathogen).
Mutualism: Two organisms living together for mutual benefit.
Commensalism: Relationship in which only one organism benefits
Parasite: An organism that feeds on a larger living host organism, harming it
Pathogen: A microbe that causes a disease.

ENERGY FLOW THROUGH AN ECOSYSTEM

- The sun is the primary source of energy in the ecosystem.
- Light energy is converted into chemical energy by green plants (primary producers) during photosynthesis.
- Herbivores (primary consumers) get only about 10% of the energy when they feed on green plants, the rest (90%) of the energy is lost as heat and some remains locked up in indigestible parts of the plant like cellulose.
- Carnivores (secondary consumers) get about 10% of the energy when they feed on herbivores, the 90% is lost as heat or it remains in indigestible parts like bones, hooves, hair, skin etc, and the trend is maintained even as tertiary consumers feed on secondary consumers.
- Decomposers get about 1% of the energy from dead bodies.
- The number of organisms decreases at each successive feeding level because of the great energy losses, so the energy left in organisms is little to support large numbers of top consumers.

1. FOOD CHAIN*:*

A linear sequence of energy flow from photosynthetic organisms (green plants) to animals with repeated eating and being eaten.

Examples of food chains

Microscopic Algae → mosquito larvae → small fish → large fish

Grass → grasshopper → lizard → eagle

(Producer) (Primary consumer) (Secondary consumer) (Tertiary consumer)

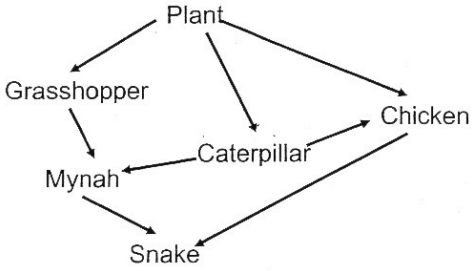
EXERCISE:

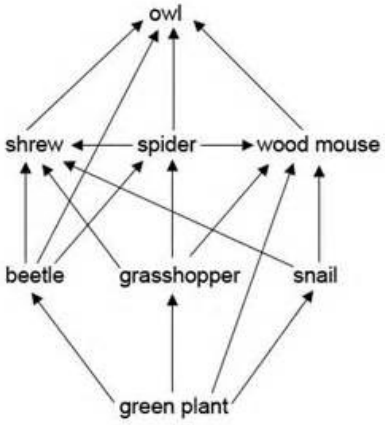
Construct four food chains, each consisting of four feeding levels (not less than four organisms)

2. FOOD WEB:

This is a complex energy transfer relationship where plants are eaten by animals, that are also eaten by other animals whereby most animals have alternative sources of food.

Examples of food webs in a grassland





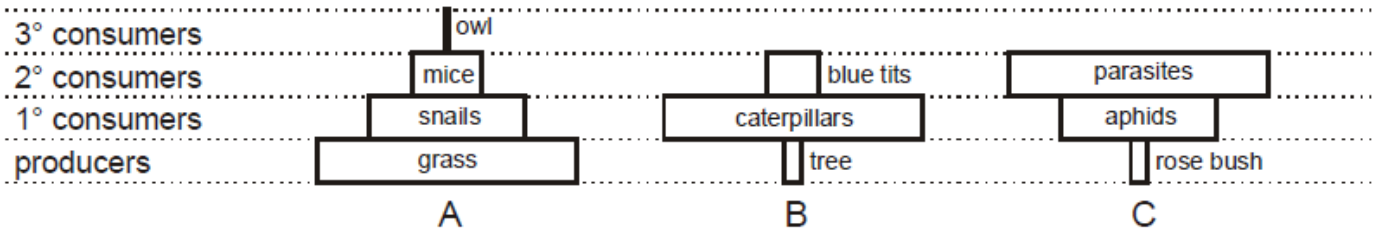
EXERCISE

Construct a food web using the following organisms: phytoplanktons, mosquito larvae, small fish, large fish, and crocodiles.

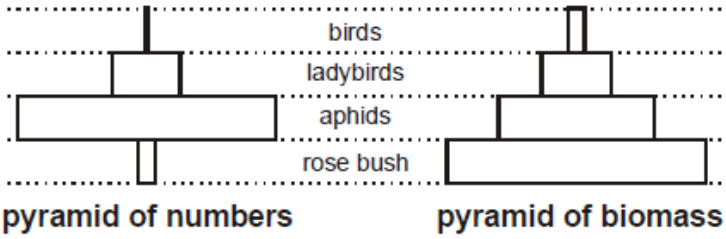
ECOLOGICAL PYRAMIDS

These are histograms that provide information about feeding (trophic) levels in ecosystems.

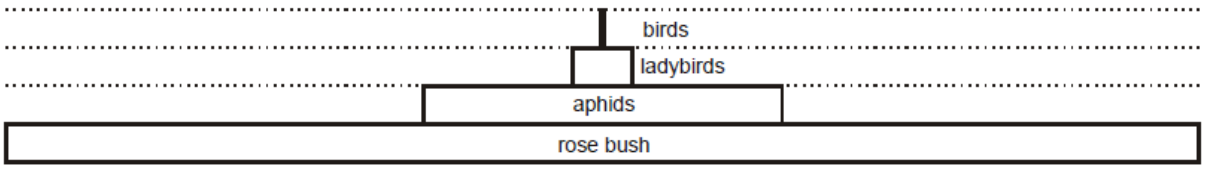
Pyramid of numbers: It is a histogram representing the numbers of different organisms at each trophic level in an ecosystem at any one time



Pyramid of biomass: it is a histogram showing the total dry mass of organisms present at each feeding level.



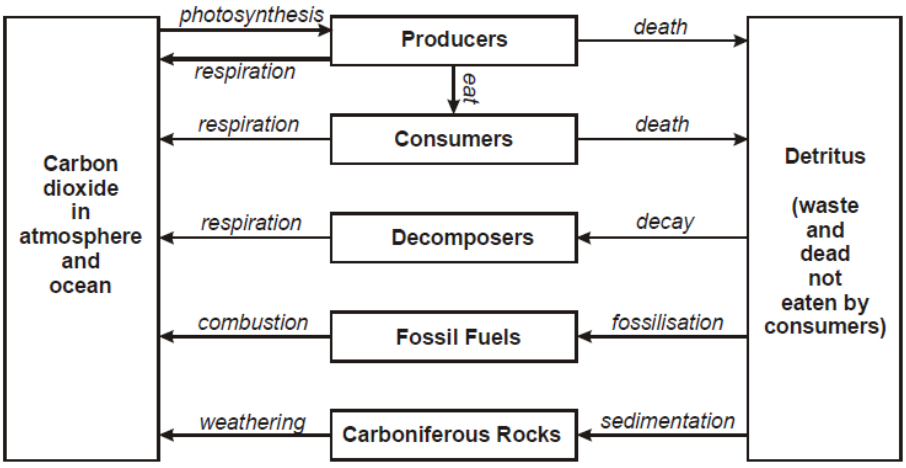
Pyramid of energy flow: it is a histogram showing the total amount of energy present at each feeding level.
Construct a pyramid of numbers from this information: producer numbers – 10,000,000, primary consumers – 100,000, secondary consumers – 1,000, tertiary consumers – 10.



Note:
i) The number of organisms at any trophic level is represented by the length (or area) of a rectangle.
ii) Generally, as the pyramid is ascended, the number of organisms decreases, but the size of each individual increases.

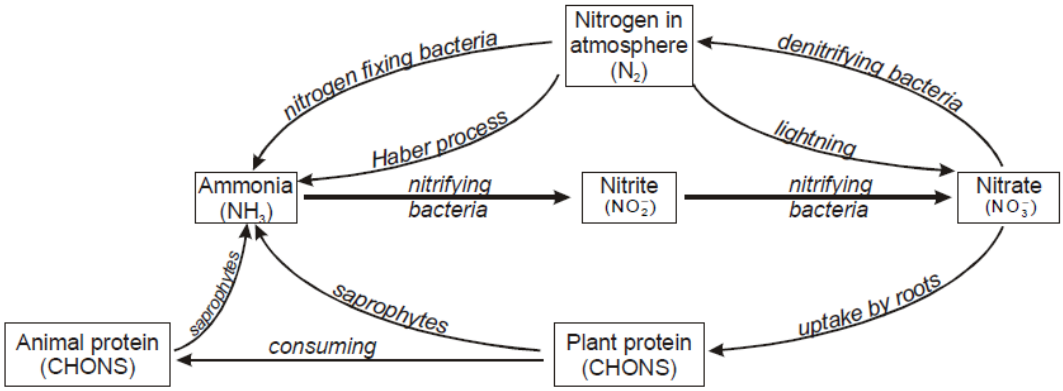
MATERIAL CYCLING (NUTRIENT CYCLING)
This the process by which chemical compounds of a particular element that constitutes living matter are transferred between living organisms (biotic phase) and non-living environment (abiotic phase).

CARBON CYCLE



How human activities affect the carbon cycle
i) Cutting trees and other plants that absorb CO_2 through photosynthesis increases carbon dioxide in the atmosphere.
ii) Burning of fossil fuels like coal, petroleum oil etc and wood adds large amounts of CO_2 into the troposphere.

NITROGEN CYCLE



How human activities affect the nitrogen cycle

1. Burning of fuels forms nitric oxide, which reacts with atmospheric oxygen to form nitrogen dioxide gas that reacts with water vapour to form acid rain containing nitric acid. Nitric acid together with other air pollutants (i) damages trees (ii) corrodes metals (iii) upsets aquatic ecosystems.
2. The inorganic fertilizers applied to soil are acted upon by anaerobic bacteria to release nitrous oxide into the stratosphere, where it (i) contributes to ozone depletion (ii) contributes to green house effect.
3. Nitrogen is removed from top soil when we (i) harvest nitrogen-rich crops (ii) irrigate crops (iii) burn or clear grasslands and forests before planting crops
4. Adding nitrogen compounds to aquatic ecosystems e.g. sewage algal blooming, which upon death, their decomposition causes oxygen shortage resulting into death of aerobic organisms e.g. some fish.
5. The accelerated deposition of acidic nitrogen containing compounds e.g. NO_2 and HNO_3 onto terrestrial ecosystems stimulates growth of weeds, which outcompete other plants that cannot take up nitrogen as efficiently.

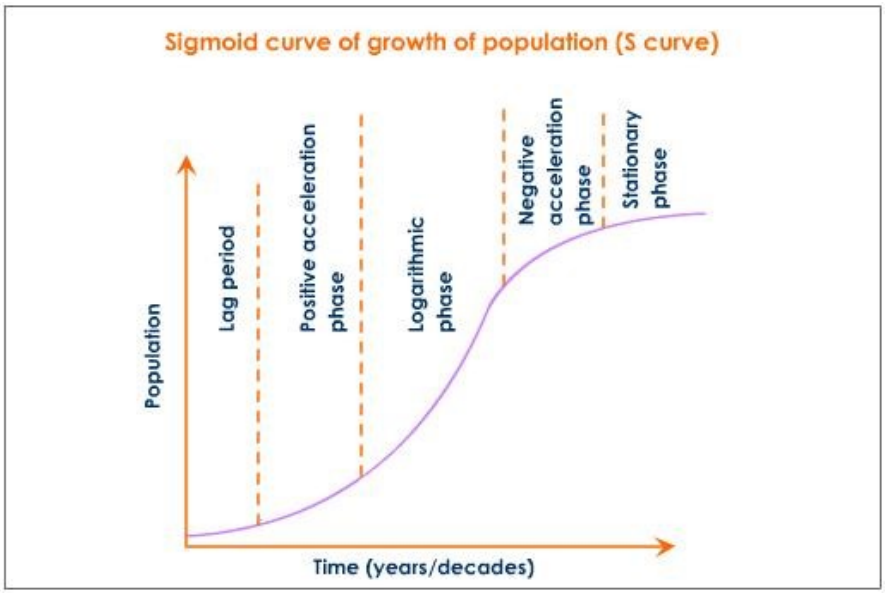
POPULATION AND COMMUNITIES

Definitions of some terms

Immigration: Movement of individuals into a population from neighboring populations.
Emigration: Departure of individuals from a population.
Rare species: Species with small populations either restricted geographically with localized habitats or with widely scattered individuals.
Endangered species: Species with low population numbers that are in considerable danger of becoming extinct.
Extinct species: Species, which cannot be found in areas they previously inhabited nor in other likely habitats.

POPULATION GROWTH

These are the changes in numbers of a species.
Population growth may form a curve which is either (i) J-shaped (ii) Sigmoid shaped (S-shaped)



The actual factors responsible for the shape of each phase depend on the ecosystem, and this can be illustrated by considering two contrasting examples: yeast in a flask (reproducing asexually), and rabbits in a field (reproducing sexually).

PHASES	YEAST IN A FLASK	RABBITS IN GRASSLAND
Lag phase	Little growth while yeast starts synthesizing appropriate enzymes for new conditions.	Little growth due to small population. Individuals may rarely meet, so few matings. Long gestation so few births.
Acceleration phase	Slow growth because cells are getting used to conditions in the environment	Slow growth because of few reproducing individuals
Log phase (Logarithmic phase)	Rapid exponential growth. No limiting factors since relatively low density.	Rapid growth. Few limiting factors since relatively low density.
Deceleration phase (Negative acceleration phase)	Slow growth due to accumulation of toxic waste products (e.g. ethanol) or lack of sugar.	Slow growth due to intraspecific competition for food/territory, predation, etc.
Stationary phase	Population is stable (fluctuates slightly above and below the carrying capacity). Cell death is equivalent to cells formed.	Population is stable (fluctuates slightly above and below the carrying capacity). Death rate is equivalent to the birth rate

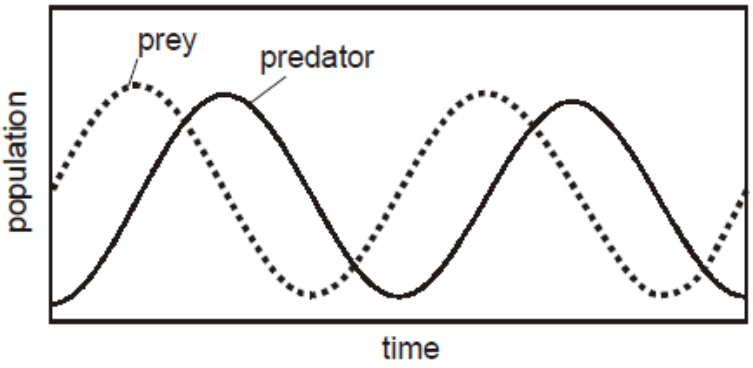
Note: At the stationary phase, the population is called the **carrying capacity** of the environment **(K),** and is the maximum population supported by a particular ecosystem.

HOW BIOTIC FACTORS AFFECT POPULATION SIZE

a) Predation:

This is a relationship whereby members of one species (the predator) feed on all or part of a living organism of another species (the prey). Therefore, predators are only found where there is prey e.g. herbivores are found where there is suitable plant material. A predator is an animal that feeds on another live organism. A prey is the live organism that is fed on by the predator.

PREDATOR-PREY INTERACTIONS IN ECOSYSTEMS



Description of the changes in population numbers:

Initially, the population of the prey is higher that the population of the predator.
Within a short time, both populations of prey and predator increase rapidly.
The population of the prey reaches a maximum earlier than the predator.
As the prey population decreases rapidly, the predator population continues to increase gradually for a short time to a maximum then also decreases rapidly.
As the predator population continues to decrease, the prey population starts to increase rapidly, followed by a rapid increase in predator population. The cycle is repeated.

Explanation for the observed changes in populations:

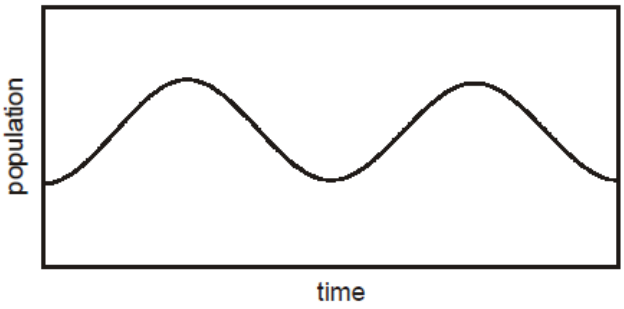
At the beginning there are more prey than predator to provide food to the predators.
When the predator population is low, they get enough food and few preys are eaten so they both increase rapidly.
The large number of preys provides food to predators, so they reproduce fast and increase in numbers.
The increased predator population eats many preys and the prey population crashes.
The decrease in prey numbers causes the predators to starve and even their reproduction reduces, so the predator numbers crash.
Finally, the very low number of predators allows the prey population to recover, causing the cycle to start again.

b) Competition:

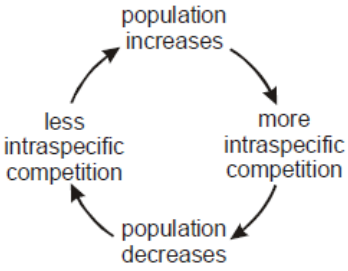
This is a relationship whereby two individuals of the same species or different species struggle to obtain resources which are in limited supply.

(i) Intraspecific competition is the competition between members of the same species for the same resources.

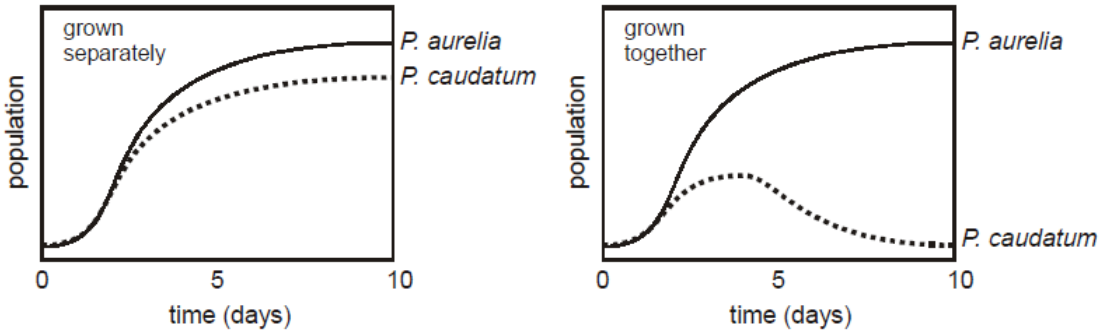
Intraspecific competition tends to have a stabilising influence on population size. If the population gets too big, intraspecific population increases, so the population falls again. If the population gets too small, intraspecific population decreases, so the population increases again.



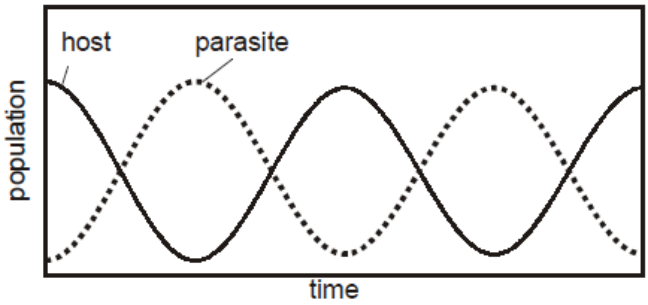
Explanation:



(ii) Interspecific competition is the competition between members of two or more different species for food, space, good hiding place, water, sunlight, nesting sites or any other limited resource.
When interspecific competition is very intense one of the competing species must
(i) migrate to another area if possible
(ii) shift its feeding habits or behaviour through natural selection and evolution
(iii) suffer a sharp population decline or
(iv) become extinct in that area, otherwise two species can never occupy exactly the same ecological niche.



(*c*) ***Parasitism***
An organism called **parasite** obtains nutrients from the body of another organism of different species called **host.**
The parasite is usually smaller than its host in size.
Parasites do not usually kill their hosts, but the host suffers harm.



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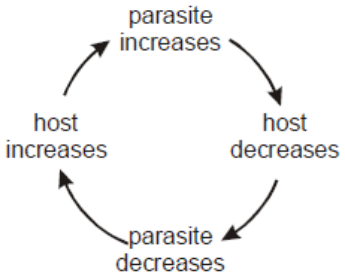
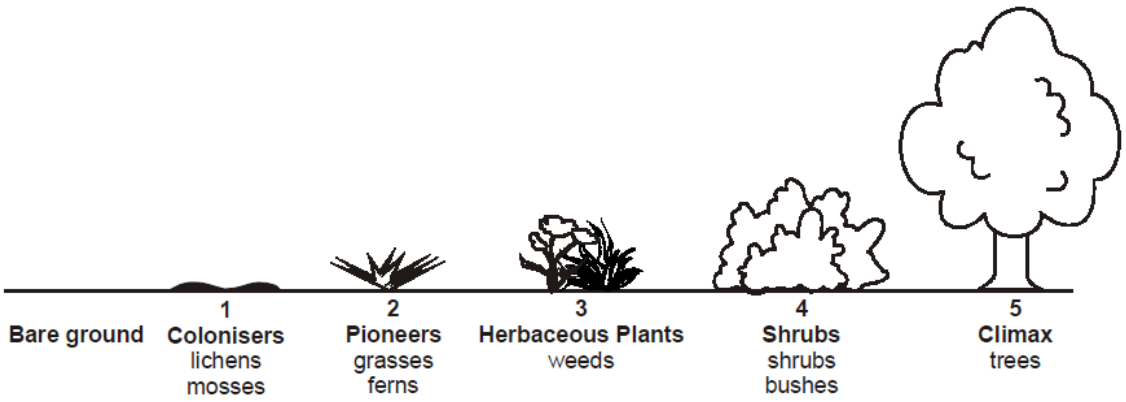


ECOLOGICAL SUCCESSION:
This is a long-term directional change in the composition of a community brought about by the actions of the organisms themselves.
Types of succession:
a) Primary succession: This is the gradual change in species composition of an area that has never had any vegetation growing on it. It occurs on bare rocks exposed by erosion, newly cooled larva, abandoned highway or parking yard, newly created shallow pond, Sand dunes.

An example of primary succession on land



Description of primary succession on land

Lichens and mosses attach to bare rocks and start forming soil by producing tiny bits of organic matter. As patches of soil build up, eventually the pioneer species are replaced by small grasses whose seeds germinate after arriving by wind. Death and decay of small grasses increases nutrients in soil. With time herbs, low shrubs and small trees appear. Later a complex forest of trees appears and remains, unless natural or human processes disturb the area. In this case the forest is termed as **climax community** (final community at the end of succession, which a particular environment can sustain).

b) Secondary succession: This is the gradual change in species composition of an area where the natural community of organisms has been disturbed, removed or destroyed but some soil or bottom sediment remains. It occurs on abandoned farmlands, burnt or cut forests, heavily polluted streams, flooded land

Climax community: final community at the end of succession, which a particular environment can sustain.

TERMS USED IN POPULATION STUDIES:

Population size: Number of individuals in a population.

Population density: Total number of organisms of a species per unit area (land) or per unit volume (water)

Population growth: A change in the number of individuals (increase-positive or decrease-negative)

Birth rate (natality): Number of new individuals produced by one organism per unit time (Humans: per year).

Death rate (mortality): Number of individuals dying per unit of time per unit of population (humans: number of deaths per 1000 per year e.g. 20 deaths per 1000 people per year)

Environmental resistance: All the environmental factors acting jointly to limit the growth of a population.

Carrying capacity: Maximum number of individuals of a given species that can be sustained indefinitely in a given area of land or volume of water.

DETERMINATION OF POPULATION SIZE OF ORGANISMS

Importance of estimating population size

(i) It enables monitoring of population growth.
ii) It enables determination of habitat requirements of a species.
iii) It enables determination of carrying capacity of the area i.e. to determine whether existing populations are likely to be sustainable
iv) It enables determination of age structure and sometimes sex ratio of the population.

METHODS OF DETERMINING POPULATION SIZE OF ORGANISMS

Total count: This is the physical counting of every individual of a population in a specified area of ground. Examples:
(i) Census of people after every ten years
(ii) aerial counting from a low flying aircraft of large, sessile, slow moving animals and mobile but large animals e.g. giraffes, elephants, lions, etc.

Quadrat sampling: A metallic, plastic or wooden frame of known area e.g. $1m^2$ or $0.5m^2$ is randomly thrown several times in the area under investigation and all individuals within the quadrat are counted each time.
Population density is expressed as an average figure per metre squared. Total population is got by multiplying the average with the total area under investigation. Quadrat is suitable for grasses and very slow moving animals.

Capture-recapture: (Lincoln index method)
This method is used on highly mobile animals like fish, small mammals e.g. rats, birds, arthropods e.g. insects like butterflies and grasshoppers.
It involves capturing and counting the organisms (N_1), marking them in a way that causes no harm, and returning them to the natural environment.
After allowing sufficient time for the population to mix thoroughly, a second catch (N_2) is made and the number of marked individuals recaptured is recorded as N_3
Estimated total population (P) = $\frac{N_1 \times N_2}{N_3}$

Worked example:
In estimating the number of fish in a small lake, 625 fish were caught, marked and released. After one week, 920 fish were caught and of these, 150 bore marks. What was the estimated size of fish population?
$P = \frac{N_1 \times N_2}{N_3}$ **Where: N_1** = number of fish in 1st catch, **N_2** = 2nd catch, **N_3** = recaptured fish

$P = \frac{625 \times 920}{150} = 3833$

Assumptions which are made when using the capture-release-recapture method:
-That organisms mix randomly within the population.
-That the time allowed for random mixing is enough.
-That changes in population size due to immigration, emigration, death and birth are negligible.
-That the movement of organisms is restricted geographically.
-That there is even dispersing of organisms within the study area.
-That the mark does not hinder the movement of the organisms or make them conspicuous to predators.

Disadvantages / Limitations:
-It is only reliable when the organisms' range of movement is relatively restricted and defined.
-Animals often move in groups whose members recognise one another and avoid mixing with those of other groups.
-Many animals have particular localities (home ranges) where they confine, so the marked animals may not spread widely.
-Loss of marked individuals reduces those recaptured and this causes inaccuracy.

NATURAL RESOURCES
A natural resource is anything not made by man obtained from the environment to meet human needs and wants.
Classification of natural resources
Perpetual resources: Resources that are replaced (renewed) continuously on human time scale e.g. solar energy, wind.
Renewable resources: Resources that are replenished (replaced) fairly rapidly (hours to decades) through natural processes as long as the usage is not faster than the replacement e.g. Fresh water, fresh air, fertile soil, animals and plants (Forests, grasslands)
Nonrenewable resources: Resources that exist in a fixed quantity or stock in the earth's crust. On the shorter human time scale, they depleted much faster than they are formed. E.g. Fossil fuels (e.g. coal, oil, natural gas), metallic minerals (e.g. copper, iron, aluminium), non-metallic minerals (e.g. salt, clay, sand, phosphates)
Environmental degradation: The process when the resource's natural replacement rate is exceeded resulting into a decline in its availability.
Recycling of resources: This is the reprocessing of a resource into new products. Old aluminium saucepans and copper items can be recycled.
Re-using of resources: Using of resources over and over in the same form. E.g. Glass bottles of alcoholic and soft drinks can be collected, washed and refilled many times.
WILDLIFE
This includes plants and animals that occur in their natural environment.

POLLUTION
It is the release of substances or energy into the external environment in amounts and duration that cause harm to living organisms or their environment.
Pollutants include noise, heat and radiation as different forms of energy, many chemical compounds and elements, plastics and excretory products.
Categorisation of pollutants basing on their persistence in the environment
Degradable (non-persistent) pollutants: Are the pollutants that are broken down completely or reduced to acceptable levels by natural physical, chemical and biological processes.
Biodegradation: is the breakdown of complex chemical pollutants into simpler chemicals by living organisms (usually specialised bacteria) e.g. sewage is a biodegradable pollutant.
Slowly degradable (persistent pollutants): Are those that take a longer time to degrade e.g. DDT - an insecticide, and **plastics e.g. plastic bags.**
c) ***Non-degradable pollutants:*** these cannot be broken down by natural processes e.g. the toxic elements lead, mercury, arsenic, selenium

Air pollutants

1. Carbonmonoxide **(**CO)

Sources *(where it comes from)*

i) Motor vehicle exhausts
ii) Incomplete combustion of fossil fuels
iii) Tobacco smocking

Effects/consequences:

i) Prevents oxygen usage by blood by forming carboxy-haemoglobin, which may cause death.
ii) Small concentrations cause dizziness and headache.

Control:

i) Efficient combustion of fuels in industry an homes
ii) Avoid smocking.
iii) Vehicle exhausts gas control e.g. in USA.

2. Sulphurdioxide (SO_2)

Sources

Combustion of Sulphur-containing fuels, oil, coal gas

Effects/consequences:

i) Causes lung diseases, irritation of eye surface, and asthma resulting into death if in high concentrations.
ii) Forms acid rain which increases soil PH.
iii) Reduces growth of plants and kills lichens. Lichens are indicator species for SO2 pollution. The presence of many lichen species indicates low level of SO2 pollution in that area.

Control:

i) Use of Sulphur free fuel e.g. natural gas.
ii) Installation of SO2 extraction units in industrial flues and chimneys.

3. Carbondioxide (CO_2)

Sources:

i) Motor vehicle exhausts
ii) Combustion of fossil fuels

Effect/consequences: increased carbondioxide causes Green house effect – warming up of the earth's atmosphere as a result of the blanket of carbondioxide, preventing escape of solar radiation higher into space.

Control: Planting more green plants, reduction in combustion of fossil fuels by relying on alternative sources of energy e.g. solar energy.

4. Chlorofluorocarbons (CFCs)

Sources:

Aerosol propellants, refrigerator and air conditioner coolants, expanded plastics. E.g. bubbles in plastic foam used for insulation and packaging

Effect /consequences:

They react with ozone in the atmosphere hence reducing the ozone layer and permitting greater penetration of heat from the sun hence causing global warming.

Control: Ban should be put on the use of CFCs

5. Noise

Sources: Discos, road traffic, engines, machines, aeroplanes, firearms

Effects/consequences: Hearing impairment, total deafness, and nervous disorders.

Control: Effect laws against excessive noise, put on ear muffs and plugs while in industry.

Clearly distinguish between green house effect and global warming

Green house effect:

This is the condition when carbondioxide in the atmosphere forms a blanket that allows the sun's radiation to pass and heat the earth but prevents the heat from the earth's surface to escape far into the atmosphere.

Global warming:

This is the observed temperature rise on the earth as a result of the green house effect.

Possible effects of global warming

(1) Rise in sea level due to melting of polar ice and thermal expansion of seas **(2)** Altered temperature gradients cause cyclones and heavy rains as water evaporates quicker **(3)** Species migrations which are likely to cause pests/diseases to extend their ranges. **(4)** Reduced crop yields due to drier weather **(5)** Flooding of low-lying islands and coastal cities **(6)** Extinction of some animal and plant species **(7)** Increased death of the human population due starvation and diseases **(8)** Greatly increased wild fires in areas where the climate becomes drier.

How plastics (including polythene bags) cause degradation of soil

When dropped in soil, plastics can't be decomposed by micro-organisms and they are impermeable to water. Therefore, they prevent water from penetrating into soil. Plant roots and other soil living organisms may fail to get water and hence may die.

Biological pest control

This is the eating or weakening of a pest species by its natural predator or parasite. E.g. using cats to eat rats, using beetles to feed on the water hyacinth on Lake Victoria, placing fish in ponds to eat mosquito larvae,

Problems of using insecticides:

i) Accidental misuse of toxic chemicals results in death of humans and domestic animals.
ii) Many are non-specific, killing non-target species, particularly natural predators of the pest species.
iii) Pest resistance occurs i.e. genetic variation enables a few individuals in the pest population to survive and may quickly reproduce.
iv) There is pest replacement i.e. since most crops are susceptible to attack by more than one pest.

EFFECTS OF DISCHARGING SEWAGE IN RIVERS

At the point of sewage outfall:
(i) Light reduces under water hence no photosynthesis because sewage contains solids which float at the surface.
(ii) Dissolved oxygen reduces greatly in water because of much decomposition of organic matter in sewage by bacteria.
(iii) Ammonium ions increase greatly in water because the decomposition of proteins in faeces releases ammonium ions.
(iv) Downstream, ammonium ions reduce while nitrate ions increase because ammonium ions are converted to nitrate ions.
(v) As nitrate ions increase downstream, algae growth increases because algae absorb nitrates.
(vi) Most fish die at the point of sewage discharge due to suffocation / lack of oxygen.
(vii) Downstream, the water clears because much of organic matter in sewage is fully decomposed.

TYPICAL EXAMINATION QUESTIONS

1. The following table shows the estimated number of organisms recorded in a dam.

Organisms	Numbers
Small fish	3500
Microscopic algae	120000
Crocodiles	95
Large fish	950
Mosquito larvae	8900

a) Construct:
(i) A food chain consisting of three organisms
(ii) A food web for the dam.
b) State which organism(s) is/are:
(i) Producer (ii) primary consumer (iii) secondary consumer
(c) Which organism would be depleted first in this ecosystem? Give a reason for the answer.
(d) What would be the **immediate** consequences of:
(i) Decreasing the number of large fish?
(ii) Increasing the number of mosquito larvae?

2. (a) name the major living components of ecosystems.
(b) By means of a diagram, illustrate the flow of energy through an ecosystem.
(c) Write a chemical equation for the process by which energy enters an ecosystem.
(d) Name three air pollutants and state one effect of each to the environment.

3. In an ecological study, a group of students estimated and recorded the number of organisms in a small bush.

Organism	Number
Termites	3 900
Grass tussocks	130 000
Lizards	12
Praying mantis	128
Herbivorous beetles	3002

a) Construct a possible food web for the organisms found in the bush.
b) With reasons, state what would happen if all the lizards were removed from the bush.