

ECOLOGY

Ecology is the **scientific** study of interactions among organisms and their environment, such as the interactions **organisms** have with each other and with their abiotic **environment**

Ramdeo Misra is revered as Father of Ecology in India.

Ecology is basically concerned with **four levels of biological organisation** – organisms, populations, communities and biomes.

Ecology at the organismic level is essentially physiological ecology which tries to understand how different organisms are adapted to their environments in terms of not only survival but also reproduction.

The rotation of our planet around the Sun and the tilt of its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons. These variations together with annual variation in precipitation account for the formation of major biomes such as desert, rain forest and tundra.

Regional and local variations within each biome lead to the formation of a wide variety of habitats.

Major biomes of India are

- (a) Tropical rain forest;
- (b) Deciduous forest;
- (c) Desert;
- (d) Sea coast.

Even our intestine is a unique habitat for hundreds of species of microbes.

The key elements that led to such variation are temperature, water, light and soil.

MAJOR ABIOTIC FACTORS

Temperature is the most ecologically relevant environmental factor.

You are aware that the average temperature on land varies seasonally, decreases progressively from the equator towards the poles and from plains to the mountain tops.

It ranges from subzero levels in polar areas and high altitudes to $>500^{\circ}\text{C}$ in tropical deserts in summer.

There are, however, unique habitats such as thermal springs and deep-sea hydrothermal vents where average temperatures exceed 1000°C .

It is general knowledge that mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forests and tuna fish are rarely caught beyond tropical latitudes in the ocean.

A few organisms can tolerate and thrive in a wide range of temperatures (they are called **euthermal**), but, a vast majority of them are restricted to a narrow range of temperatures (such organisms are called **stenoethermal**).

WATER For aquatic organisms the quality (chemical composition, pH) of water becomes important.

The salt concentration (measured as salinity in parts per thousand), is less than 5 in inland waters, 30-35 in the sea and > 100 in some hypersaline lagoons.

Some organisms are tolerant of a wide range of salinities (**eutonaline**) but others are restricted to a narrow range (**stenothaline**).

Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems, they would face.

LIGHT

Many species of small plants (herbs and shrubs) growing in forests are adapted to photosynthesise optimally under very low light conditions because they are constantly overshadowed by tall, canopied trees.

Many plants are also dependent on sunlight to meet their photoperiodic requirement for flowering. For many animals too, light is important in that they use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, reproductive and migratory activities.

The availability of light on land is closely linked with that of temperature since the sun is the source for both. But, deep (>500m) in the oceans, the environment is perpetually dark and its inhabitants are not aware of the existence of a celestial source of energy called Sun

SOIL

The nature and properties of soil in different places is dependent on the climate, the weathering process, whether soil is transported or sedimentary and how soil development occurred.

Various characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils.

These characteristics along with parameters such as pH, mineral composition and topography determine to a large extent the vegetation in any area.

Responses to Abiotic Factors

(i) Regulate:

Some organisms are able to maintain homeostasis by physiological (sometimes behavioural also) means which ensures constant body temperature, constant osmotic concentration, etc. All birds and mammals, and a very few lower vertebrate and invertebrate species are indeed capable of such regulation

(thermoregulation and osmoregulation). Evolutionary biologists believe that the 'success' of mammals is largely due to their ability to maintain a constant body temperature and thrive whether they live in Antarctica or in the Sahara desert.

The mechanisms used by most mammals to regulate their body temperature are similar to the ones that we humans use.

(ii) *Conform*:

An overwhelming majority (99 per cent) of animals and nearly all plants cannot maintain a constant internal environment. Their body temperature changes with the ambient temperature. In aquatic animals, the osmotic concentration of the body fluids change with that of the ambient water osmotic concentration. These animals and plants are simply conformers. Heat loss or heat gain is a function of surface area. Since small animals have a larger surface area relative to their volume, they tend to lose body heat very fast when it is cold outside; then they have to expend much energy to generate body heat through metabolism. This is the main reason why very small animals are rarely found in polar regions

(iii) *Migrate*:

The organism can move away temporarily from the stressful habitat to a more hospitable area and return when stressful period is over. Every winter the famous Keoladeo National Park (Bharatpur) in Rajasthan host thousands of migratory birds coming from Siberia and other extremely cold northern regions.

iv) *Suspend*:

In bacteria, fungi and lower plants, various kinds of thick-walled spores are formed which help them to survive unfavourable conditions – these germinate on availability of suitable environment. In higher plants, seeds and some other vegetative reproductive structures serve as means to tide over periods of stress besides helping in dispersal – they germinate to form new plants under favourable moisture and temperature conditions. They do so by reducing their metabolic activity and going into a state of ‘dormancy’. In animals, the organism, if unable to migrate, might avoid the stress by escaping in time. The familiar case of bears going into **hibernation** during winter is an example of escape in time. Some snails and fish go into **aestivation** to avoid summer-related problems-heat and dessication. Under unfavorable conditions many zooplankton species in lakes and ponds are known to enter **diapause**, a stage of suspended development

ADAPTATIONS:

It is any attribute of the organism (morphological, physiological, behavioral) that enables the organism to survive and reproduce in its habitat.

Examples - the kangaroo rat in North American deserts is capable of meeting all its water requirements through its internal fat oxidation (in which water is a by product). It also has the ability to concentrate its urine so that minimal volume of water is used to remove excretory products. Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits to minimise water loss through transpiration. They also have a special photosynthetic pathway (CAM) that enables their stomata to remain closed during day time. Some desert plants like *Opuntia*, have no leaves – they are reduced to spines – and the

photosynthetic function is taken over by the flattened stems. Mammals from colder climates generally have shorter ears and limbs to minimise heat loss. (This is called the **Allen's Rule**) In the polar seas aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces loss of body heat.

Some organisms possess adaptations that are **physiological** which allow them to respond quickly to a stressful situation. If you had ever been to any high altitude place (>3,500m Rohtang Pass near Manali and Mansarovar, in China occupied Tibet) you must have

experienced what is called *altitude sickness*. Its symptoms include nausea, fatigue and heart palpitations. This is because in the low atmospheric pressure of high altitudes, the body does not get enough oxygen. But, gradually you get acclimatised and stop experiencing altitude sickness. *How did your body solve this problem?* The body compensates low oxygen availability by increasing red blood cell production, decreasing the binding affinity of hemoglobin and by increasing breathing rate. Many tribes live in the high altitude of Himalayas. Find out if they normally have a higher red blood cell count (or total hemoglobin) than people living in the plains. In most animals, the metabolic reactions and hence all the physiological functions proceed optimally in a narrow temperature range (in humans, it is 37°C). But there are microbes (archaeobacteria) that flourish in hot springs and deep sea hydrothermal vents where temperatures far exceed 100°C. How is this possible? Many fish thrive in Antarctic waters where the temperature is always below zero. *How do they manage to keep their body fluids from freezing?* A large variety of marine invertebrates and fish live at great depths in the ocean where the pressure could be >100 times the normal atmospheric pressure that we experience. *How do they live under such crushing pressures and do they have any special enzymes?* Organisms living in such extreme environments show a fascinating array of biochemical adaptations. Some organisms show behavioral responses to cope with variations in their environment. Desert lizards lack the physiological ability that mammals have to deal with the high temperatures of their habitat, but manage to keep their body temperature fairly constant by behavioral means. They bask in the sun and absorb heat when their body temperature drops below the comfort zone, but move into shade when the ambient temperature starts increasing. Some species are capable of burrowing into the soil to hide and escape from the above-ground heat

Population Attributes

A group of individuals resulting from even asexual reproduction is also generally considered a population for the purpose of ecological studies. All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond, are some examples of a population.

A population has certain attributes that an individual organism does not. An individual may have births and deaths, but a population has *birthrates* and *death rates*. Another attribute characteristic of a population is sex ratio. An individual is either a male or a female but a population has a sex ratio. A population at any given time is composed of individuals of different ages. The size, in nature, could be as low as <10 (Siberian cranes at Bharatpur wetlands in any year) or go into millions (*Chlamydomonas* in a pond). Population size, more technically called population density

Population Growth

(i) **Natality** refers to the number of births during a given period in the population that are added to the initial density.

(ii) **Mortality** is the number of deaths in the population during a given period.

(iii) **Immigration** is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.

(iv) **Emigration** is the number of individuals of the population who left the habitat and gone elsewhere during the time period under consideration

GROWTH MODELS

(i) **Exponential growth:** Resource (food and space) availability is obviously essential for the unimpeded growth of a population. Ideally, when resources in the habitat are unlimited, each species has the ability to realise fully its innate potential to grow in

number, as Darwin observed while developing his theory of natural selection. Then the population grows in an exponential or geometric fashion.

(ii) Logistic growth:

population growing in a habitat with limited resources OR survival of fittest

LIFE HISTORY VARIATION: Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times during their lifetime (most birds and mammals). Some produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals)

BIOTIC-BIOTIC INTERACTIONS:

PREDATION:

It is a biological interaction where a **predator** (an organism that is hunting) feeds on its **prey** (the organism that is attacked). It is nature's way of transferring to higher trophic levels the energy fixed by plants.

When we think of predator and prey, most probably it is the tiger and the deer that readily come to our mind, but a sparrow eating any seed is no less a predator. Although animals eating plants are categorized separately as *herbivores*, they are, in a broad ecological context, not very different from predators. Besides acting as 'conduits' for energy transfer across trophic levels, predators play other important roles. They keep prey populations under control. But for predators, prey species could achieve very high population densities and cause ecosystem instability. When certain exotic species are introduced into a geographical area, they become invasive and start spreading fast because the invaded land does not have its natural predators. The prickly pear cactus introduced into Australia in the early 1920's caused havoc by spreading rapidly into millions of hectares of rangeland. Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) from its natural habitat was introduced into the country. Biological control methods adopted in agricultural pest control are based on the ability of the predator to regulate prey population. Predators also help in maintaining species diversity in a community, by reducing the intensity of competition among competing prey species. In the rocky intertidal communities of the American Pacific Coast the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, because of interspecific competition. If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct for lack of food. This is the reason why predators in nature are 'prudent'. Prey species have evolved various defenses to lessen the impact of predation. Some species of insects and frogs are cryptically-coloured (camouflaged) to avoid being detected easily by the predator. Some are poisonous and therefore avoided by the predators. The Monarch butterfly is highly distasteful to its predator(bird) because of a special chemical present in its body. Interestingly, the butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous weed.

For plants, herbivores are the predators. Nearly 25 per cent of all insects are known to be *phytophagous* (feeding on plant sap and other parts of plants). The problem is particularly severe for plants because, unlike animals, they cannot run away from their predators. Plants therefore have evolved an astonishing variety of morphological and chemical defences against herbivores. Thorns(*Acacia*, *Cactus*) are the most common morphological means of defence. Many plants produce and store chemicals that make the herbivore sick

when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it. You must have seen the weed *Calotropis* growing in abandoned fields. The plant produces highly poisonous cardiac glycosides and that is why you never see any cattle or goats browsing on this plant. A wide variety of chemical substances that we extract from plants on a commercial scale (nicotine, caffeine, quinine, strychnine, opium, etc.,) are produced by them actually as defences against grazers and browsers.

(ii) Competition:

When Darwin spoke of the struggle for existence and survival of the fittest in nature, he was convinced that interspecific competition is a potent force in organic evolution. It is generally believed that competition occurs when closely related species compete for the same resources that are limiting, but this is not entirely true. Firstly, totally unrelated species could also compete for the same resource.

For instance, in some shallow South American lakes visiting flamingoes and resident fishes compete for their common food, the zooplankton in the lake. Secondly, resources need not be limiting for competition to occur; in interference competition, the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant. Therefore, competition is best defined as a process in which the fitness of one species (measured in terms of its 'r' the intrinsic rate of increase) is significantly lower in the presence of another species. The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats. The larger and competitively superior barnacle *Balanus* dominates the intertidal area, and excludes the smaller barnacle *Chathamalus* from that zone. In general, herbivores and plants appear to be more adversely affected by competition than carnivores. Gause's '*Competitive Exclusion Principle*' states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This may be true if resources are limiting,

but not otherwise. More recent studies do not support such gross generalisations about competition

(iii) Parasitism:

It is a non-mutual symbiotic relationship between species, where one species, the parasite, benefits at the expense of the other, the host. Traditionally parasite referred primarily to organisms visible to the naked eye, or macroparasites (such as helminths).

Parasite now includes microparasites, which are typically smaller, such as viruses and bacteria.

Some examples of parasites include the plants mistletoe and cuscuta, and animals such as hookworms.

Unlike predators, parasites do not kill their host, are generally much smaller than their host, and will often live in or on their host for an extended period. Both are special cases of consumer-resource interaction.

Their life ensures free lodging and meals, it is not surprising that parasitism has evolved in so many taxonomic groups from plants to higher vertebrates. The life cycles of parasites are often complex, involving one or two intermediate hosts or vectors to facilitate parasitisation of its primary host. Majority harm the host; they may reduce the survival, growth and reproduction of the host and reduce its population density. They might render the host more vulnerable to predation by making it physically weak.

Parasites that feed on the external surface of the host organism are called **ectoparasites**. The most familiar examples of this group are the lice on humans and ticks on dogs. Many marine fish are infested with ectoparasitic copepods. *Cuscuta*, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution. It derives its nutrition from the host plant which it parasitises. The female mosquito is not considered a parasite, although it needs our blood for reproduction. *Can you explain why?*

In contrast, **endoparasites** are those that live inside the host body at different sites (liver, kidney, lungs, red blood cells, etc.). The life cycles of endoparasites are more complex because of their extreme specialisation. Their morphological and anatomical features are greatly simplified while emphasising their reproductive potential. *Brood parasitism* in birds is a fascinating example of parasitism in which the parasitic bird lays its eggs in the nest of its host and lets the host incubate them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest. Try to follow the movements of the cuckoo (koel) and the crow in your neighborhood park during the breeding season (spring to summer) and watch brood parasitism in action.

COMMENSALISM:

This is the interaction in which one species benefits and the other is neither harmed nor benefited. An orchid grow in gas an *epiphyte* on a mango branch, and barnacles growing on the back of a whale benefit while neither the mango tree nor the whale derives any apparent benefit. The cattle egret and grazing cattle in close association, a sight you are most likely to catch if you live in farmed rural areas, is a classic example of commensalism. The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and flush out from the vegetation insects that otherwise might be difficult for the egrets to find and catch. Another example of commensalism is the interaction between sea anemone that has stinging tentacles and the clown fish that lives among them. The fish gets protection from predators which stay away from the stinging tentacles. The anemone does not appear to derive any benefit by hosting the clown fish

Mutualism:

This interaction confers benefits on both the interacting species. Lichens represent an intimate mutualistic relationship between a fungus and photosynthesising algae or cyanobacteria. Similarly, the mycorrhizae are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant in turn provides the fungi with energy-yielding carbohydrates. The most spectacular and evolutionarily fascinating examples of mutualism are found in plant-animal relationships. Plants need the help of animals for pollinating their flowers and dispersing their seeds. Animals obviously have to be paid 'fees' for the services that plants expect from them. Plants offer rewards or fees in the form of pollen and nectar for pollinators and juicy and nutritious fruits for seed dispersers. But the mutually beneficial system should also be safeguarded against 'cheaters', for example, animals that try to steal nectar without aiding in pollination. The Mediterranean orchid *Ophrys* employs 'sexual deceit' to get pollination done by a species of bee.