25.1 ENVIRONMENT, ECOLOGY AND BIOSPHERE

25.1.1 Environment

The term environment denotes all the physical, chemical and biotic conditions surrounding and influencing a living organism. Favourable environmental conditions are required to sustain life on earth.

The environment can be divided into two main components : Non Living and Living

1. **Abiotic or Non-living components include** the physical (climatic), edaphic (nature of soil) and chemical. For example temperature, light, pressure, humidity, precipitation, wind, mineral elements of soil and composition of air. Some of these environmental factors serve as **resources** (air, soil and water) while others act as **regulatory factors** (light, temperature and pressure etc).
2. **Biotic or Living components include** All living organisms found in the environment including plants, animals and microorganisms.

25.1.2 Ecology

Ecology is the scientific study of the relationship and interactions between organisms and their environment. The term ecology is derived from a Greek word *Oekologie* where "*oikos*" meaning "household"and "*logos*" means "the study of".

25.1.3 Organisation of Life

Various levels of organization exist in the living systems starting from the molecules such as DNA (genes) to the whole **biosphere**. The **levels of organization** are as follows :

Genes → Cell → organ → organism → Species Population → Community → Ecosystem → Biome → Biosphere

25.1.4 Levels of biotic organizations show direct impact of the environment

- An organism is a self reproducing system capable of growing and maintaining itself and is directly influenced by the surrounding environment.
- A population is an assemblage of similar organisms belonging to the same species, living together at one place at a given time. A population always lives a specific place known as its *habitat*. Habitat is thus the physical environment in which an organism lives. The environment provides for its needs. For example, the environmental requirement of an elephant would be a forest and not the ocean. Many different species with similar requirements may share a habitat. For example, a single ocean as a habitat may support a whale, a sea-horse, seal, phytoplankton, sea weeds and many other kinds of organisms. Forest, ocean, river etc. are some examples of **'habitat'** which in common language are the

'addresses' of organisms. The features of the habitat can be represented by its structural components (Fig. 1), namely:

1. Space
2. Food
3. Water
4. Cover or Shelter

Earth has four major habitats-(1) Terrestrial (2) Freshwater (3) Estuarine (where rivers meet the ocean) and (4) Oceanic. The human gut is the habitat of a tapeworm and the rotting log, a habitat of a fungus.

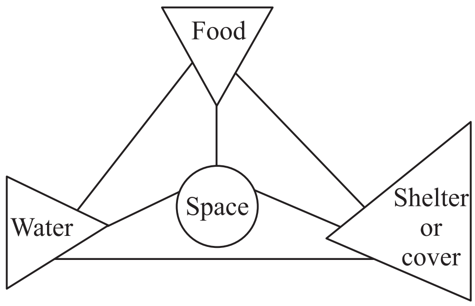


Fig. 25.1: Structural components of a habitat

Niche and Organism

In nature, many species occupy the same habitat but they perform different functions. The functional characteristics of a species in its habitat is referred to as "**niche".** While habitat of a species is like its 'address' (i.e. where it lives), niche can be thought of as its "profession" (i.e. activities and responses specific to the species). The term **niche means the sum of all the activities and relationships of a species by which it uses the resources in its habitat for its survival and reproduction.**

A niche is unique for a species (Fig. 25.2) while many species may share the same habitat. No two species in a habitat can have the same niche. This is because, if two species occupy the same niche they will compete with one another until one is displaced. For example different species of insects may be pests of the same plant but they can co-exist as they feed on different parts of the same plant that is because their niches are different (Fig. 25.3).

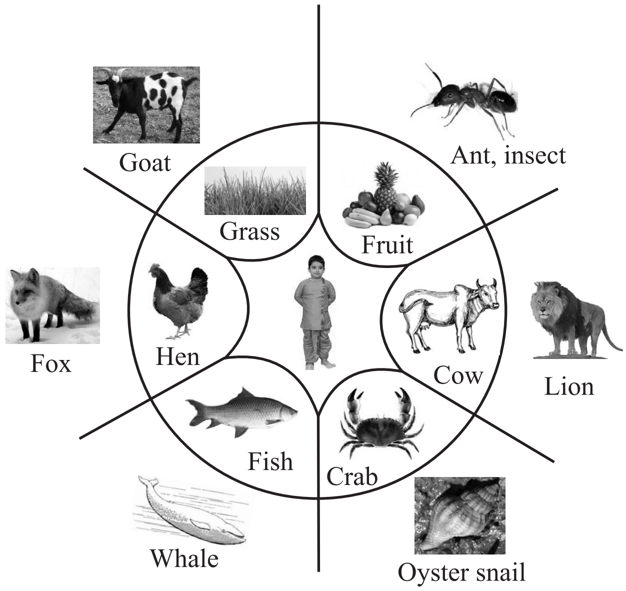


Fig. 25.2: The ecological niche of human being

Another such example is the vegetation of the forest. The forest can support a large number of plant species as they occupy different niches: the tall trees, the short trees, shrubs, bushes and grasses. Their heights vary and they differ in their requirements for sunlight and nutrients and so they can all survive together (Fig. 4)

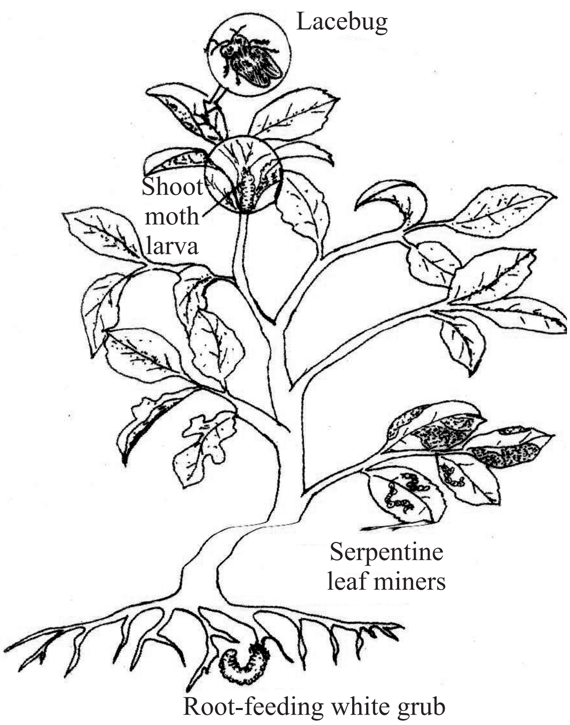


Fig. 25.3: Different species of insects feeding on different parts of the same plant

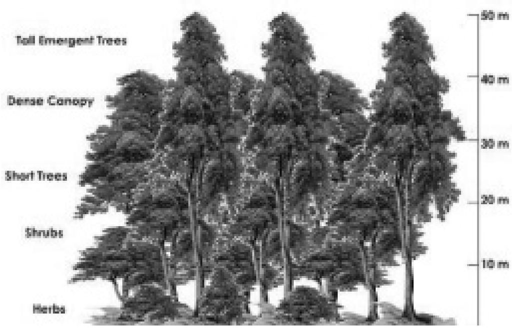


Fig. 25.4: Stratification a Tropical Rain Forest (Forest Ecosystem)

The most important resources available in the niches of animals are food and shelter while in case of plants, they are moisture and nutrients (phosphorus and nitrogen).

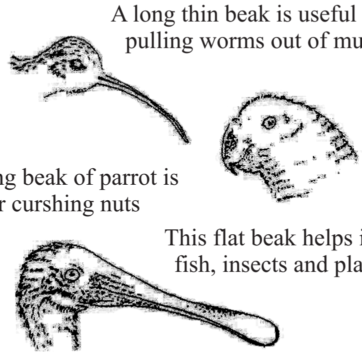
Adaptation

Every organism is suited to live in its particular habitat. You know that coconuts are adapted for growing in water while a camel is adapted for life in the desert. **An adaptation is thus, "the appearance or behaviour or structure or mode of life of an organism that allows it to survive in a particular environment".**

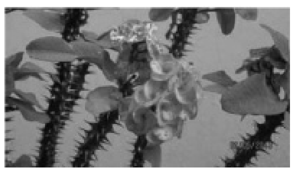
Presence of gills and fins are examples of adaptation of fish to aquatic habitat. In aquatic flowering plants, absence of wood formation and highly reduced root system are adaptations to aquatic environment. Adaptations can be observed in structure or behaviour or physiology of an organism. Adaptations have a genetic basis and have been evolved and perfected through the evolutionary process.

Following are examples of basic adaptations that help animals and plants to survive in their respective environments.

- Shape of bird's beak suited to the kind of food it needs to procure. (Fig. 25.5a)
- The thickness or thinness of fur depends on the elimate in which the animal lives.
- Presence of feathers and wings in birds for movement in air.
- Presence of thorns on leaves and stems for protection, from herbivores (Fig. 25.5b).



(a)



(b)

Fig. 25.5: (a) Adaptation in the types of beaks in birds: The beaks of different birds are adapted for feeding on different kinds of food (b) Plant with thorns for protection

Density: The number of individuals per unit area at a given time is termed population density which may vary from time to time and place to place.

For example, you may notice more plant and animal species in the garden during the monsoon season.

Density of a particular organism in a region is determined by selecting random samples from an area of particular dimension (size) called quadrat from that region.

In case of large mobile animals like tigers, leopards, lions, deer etc, the density may be determined by counting individual animals directly or by the pugmarks (foot imprints) left by the animals in a defined area (Fig. 25.6).

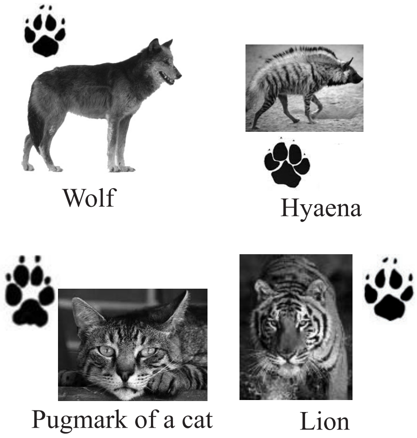


Fig. 25.6: Pugmarks (Foot prints of soft padded feet) of wild animals

Counting of human population is called **census** and is carried out by the Indian government every 10 years. In census however each individual is physically counted.

Birth Rate or Natality: The rate at which new individuals are born and added to a population under given environmental conditions is called natality.

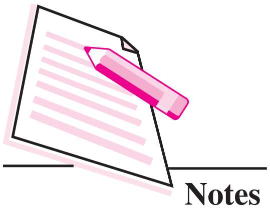
In case of humans, natality or birth rate is usually expressed in terms of births per thousand per year.

Death Rate or Mortality: Loss of individuals from a population due to death under given environmental conditions is called mortality.

Mortality rate in human population may be expressed in terms of number of persons dead per thousand per year.

Dispersal: The movement of individuals of a population out of a region on a permanent basis is termed **emigration**. **Immigration** refers to the movement of individuals into a new area. Dispersal includes both emigration (going away permanently from an area) and immigration (influx of new individuals into the area).

The density of a population thus basically depends on four factors: (i) natality, (ii) mortality, (iii) immigration and (iv) emigration (Fig. 25.7)



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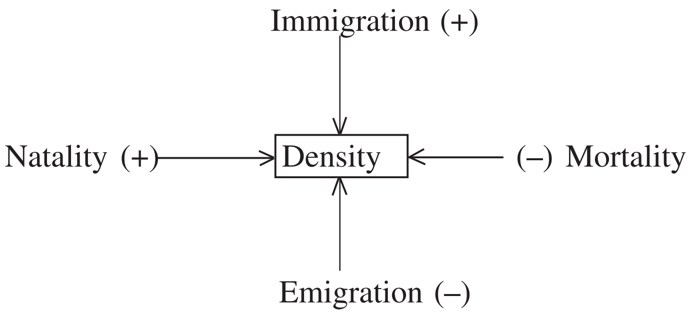


Fig. 25.7: Parameters of population.

Age distribution: Natural populations include individuals of all age groups. **Age distribution refers to the proportion of individuals of different age groups in a population**.The population may be broadly divided into three age groups:

- **pre-reproductive group**: comprising of juvenile individuals or children,
- **reproductive group**: consisting of individuals capable of reproduction ,
- **post-reproductive group**: contains aged individuals who are incapable of reproduction.

A rapidly growing population will usually contain a large proportion of individuals in the reproductive age group; a stationary population (where there is no increase or decrease in population) contains an even distribution of all age groups, and a declining population contains a large proportion of old or individuals of post-reproductive age.

Sex ratio: Sex ratio is an important aspect of population. It refers to the ratio between female and male individuals in a population.

Population Growth

The growth, stability or decline in number of individuals in a population is influenced by its relationship with the environment. Populations have characteristic patterns of growth with time, which is depicted by population growth curves. Two basic forms of population growth curves can be identified:

(i) 'J'shaped growth curve

(ii) 'S' shaped or sigmoid growth curve.

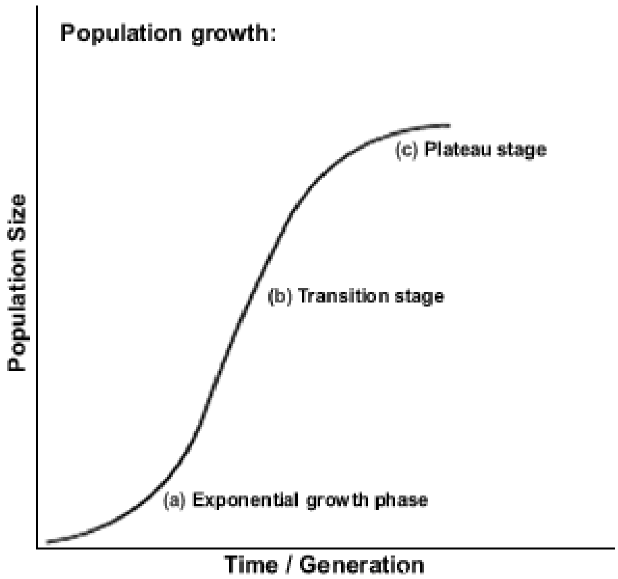


Fig. 25.8

Biosphere

A thin layer on and around the earth which sustains life is called **biosphere**. Life exists in the diverse forms of living organisms. All these living organisms of the biosphere are directly or indirectly dependent on one another as well as on the physical components of the earth. The three physical components of the earth are **atmosphere, lithosphere** and **hydrosphere** (air, land and water).

The **atmosphere** is a gaseous envelope surrounding the earth's surface, It is made up of nitrogen, oxygen, carbon dioxide and many other gases in very small amounts.

Hydrosphere is all the water supply to the earth which exists as liquid, vapour or frozen form of fresh and salt water.

Lithosphere comprises the soil and rock of the earth's crust.

Recently the term ecosphere is being used more commonly. It is used to denote biosphere (living components) along with its three abiotic components –atmosphere, hydrosphere and lithosphere of the earth as one entity (unit).

Ecosphere = Biosphere + Lithosphere + Hydrosphere + Atmosphere)

25.3 ECOSYSTEM

Ecosystem is a self sustaining unit of nature. It is defined as a functionally independent unit (of nature) where living organisms interact among themselves as well as with their physical environment. In nature two major categories of ecosystems exist : **terrestrial** and **aquatic**.

Forests, deserts and grasslands are examples of terrestrial ecosystem.

Ponds, lakes, wet lands and salt water are some example of aquatic ecosystem. Crop lands and aquarium are the example of man made ecosystems.

The interaction between the living organisms and their environment can be studied in a puddle of water or a hole in a tree, which are very small ecosystems or in large ecosystems such a forest, river or ocean. Irrespective of their sizes all ecosystems share many common characteristics. Let us study moderate sized pond ecosystem to understand its structural and functional components.

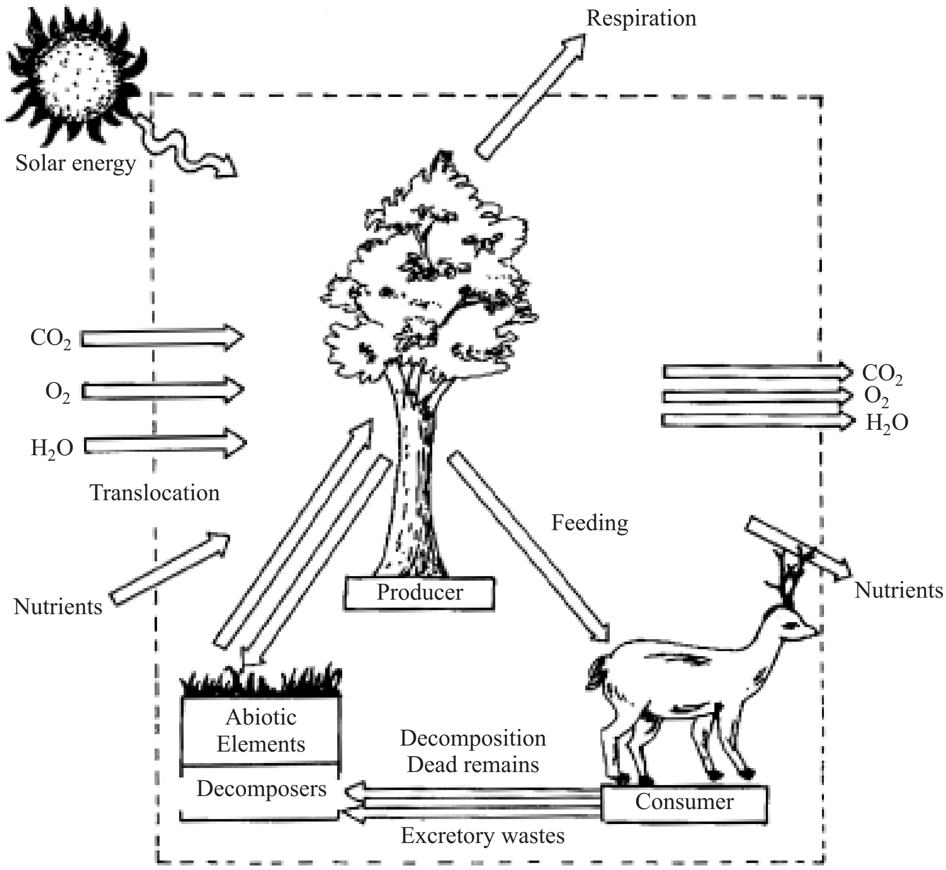


Fig. 25.10: Components of an ecosystem.

In the Fig. 25.2 (pond ecosystem), you can see that it is a shallow body of water. Sun's light can penetrate into it. It has sediment as a substrate at the bottom that is a source of nutrition for living organisms. The living organisms in it are small floating plants, submerged vegetation and rooted plants. There are animals of various sizes ranging from microscopic to large fishes. All these components of the pond ecosystem can be arranged to give it a definite structure.

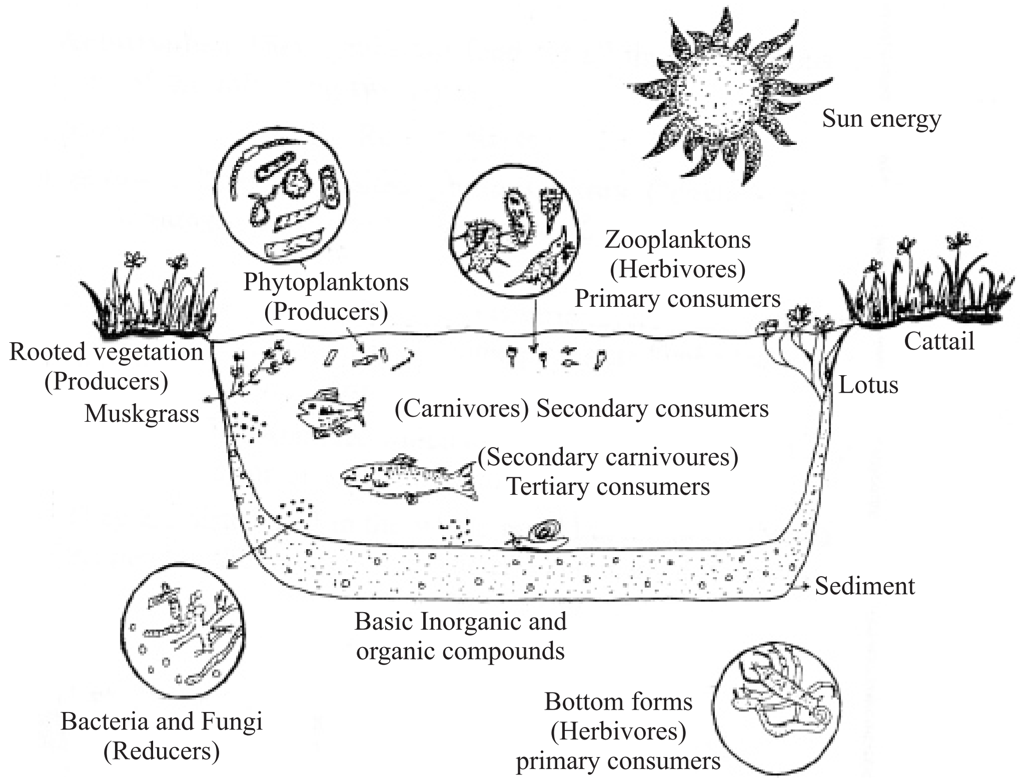


Fig. 25.11: Pond ecosystem

25.3.1 Structure of Pond Ecosystem

Abiotic Components

1. **Physical or climatic regime :** Pond receives solar radiation, which provides it heat and light energy to sustain life.

   (a) **Light :** In case of shallow ponds with clear water sun light can penetrate up to the bottom . In deep ponds penetration of light depends on the transparency of water The amount of dissolved/suspended particles, nutrients and number of animals and plants determine the transparency of water and control the penetration of light in it.

   (b) **Temperature :** Heating effect of solar radiation leads to diurnal (day and night) or seasonal temperature cycles. In the tropical regions there are not much temperature variations. At higher latitudes there are remarkable seasonal temperature variations.

2. **Inorganic substances :** These are water, carbon, nitrogen, phosphorus, calcium and a few other elements like sulphur or phosphorus depending on the location of the pond. O_2 and CO_2 are in the dissolved state in water. All animals and plants depend on water for their food and exchange of gases.

3. **Organic compounds :** The commonly found organic matter in the pond is amino acids and humic acids and the breakdown products of dead animal and plant tissues. They are partly dissolved in water and the remaining are accumulated in sediment.

Biotic Components

1. **Producers or Autotrophs :** They synthesize food for all the heterotrophs of the pond. They are of the following two types.

   (a) Floating plants (b) Rooted plants

   (a) **Floating plants :** They are called **phytoplankton** ("phyto"- plants, "plankton" - floating.) for example, *Spirogyra*, *Ulothrix*, diatoms and *Volvox*.

   (b) **Rooted plants :** These plants occur in concentric layers from periphery to the deeper zones. Some examples of rooted plants are *Typha bulrushes*, *Sagittaria*, *Hydrilla*, *Rupia*, *Chara.*

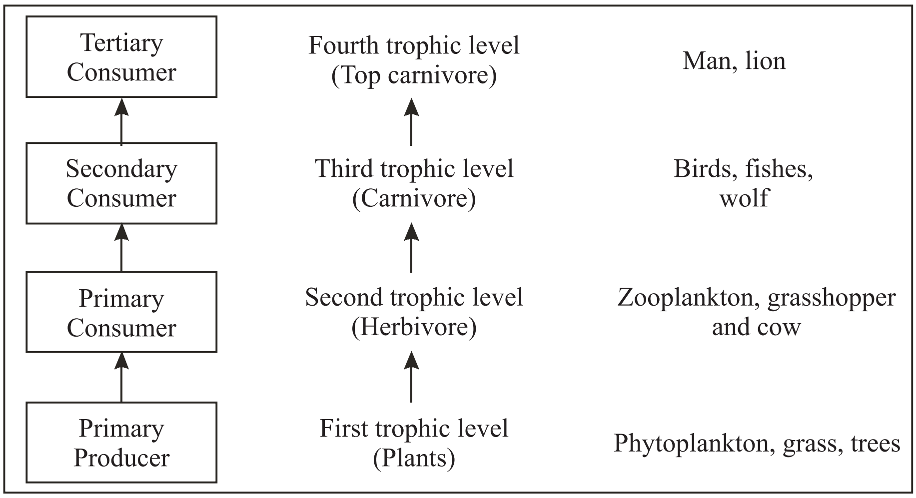
2. **Consumers or Heterotrophs :** Animals, which feed directly on autotrophs (e.g. insect larvae, tadpole, snails) or on other animals (sunfish and bass)

3. **Decomposers :** They are distributed in the whole pond but are most abundant at the bottom of the pond in the sediment e.g. bacteria and many different types of microbes.

25.4 ECOSYSTEM : STRUCTURE AND FUNCTION

You have already learnt that ecosystems are capable of persisting as independent units of nature. In the following part of the lesson you will learn about the structure and functions of ecosystem. Interaction between biotic and abiotic components results in a physical structure characteristic of each type of ecosystem. The important structural features are **species composition** (types of plants and animals) and **stratification** (vertical and horizontal distribution of various species occupying different levels). Another way of looking at the structural components is through food relationships of producers and consumers. Several **trophic levels** exist in the ecosystem. These feeding relationships can be studied as food chain, food web and standing crops. These structural components function as a unit and produce certain functional aspects of ecosystem. Some of these aspects are :

- Productivity, energy flow, nutrient cycle



Diagrammatic representation of trophic levels in an ecosystem

25.4.1 Species Composition

A community is an assemblage of many populations that are living together at the same place and time. For example a tropical forest community consists of trees, vines, herbs and shrubs along with large number of different species of animals. This is known as species composition of tropical forest ecosystem. Each ecosystem has its own species composition depending upon the suitability of its habitat and climate. If you compare animal and plant populations of a forest they are entirely different from those of a grass land. Not only are the types of species different in these two ecosystems but even their total number and biomass varies. A forest ecosystem supports much larger number of species of plants and animals than a grassland. The total number and types of species in a community determine its stability and **ecosystem balance** (ecosystem equilibrium).

25.4.2 Stratification

The vertical and horizontal distribution of plants in the ecosystem is called **ecosystem stratification**. You would have observed that the plants are of different heights in forests. Tallest trees make the top canopy. This is followed by short trees and shrubs and then the forest floor is covered with herbs and grasses. Some burrowing animals live underground in their tunnels or on the roots of the plants. Each layer from the tree top to the forest floor has its characteristic fauna and flora. This is termed as vertical stratification of forest ecosystem. On the other hand desert ecosystem shows low discontinuous layers of scant vegetation and animals with some bare patches of soil showing a type of horizontal stratification.

Species

If you bring the sunfish from two different ponds and put them together in one pond, they can interbreed. So both the populations of sunfish belong to one species. *A **species** is defined as a group of organisms which can interbreed and reproduce successfully. These organisms may be separated in space and time into smaller groups called **populations***. For example human populations live in different geographical areas but all belong to the species, *Homo Sapiens*.

25.4 POPULATION

'Population' is defined as a group of freely interbreeding individuals of the same species present in a specific geographical area at a given time.

A population has traits of its own which are different from those of the individuals forming the population. For example (i) An individual is born and dies but a population continues. Population may change in size depending on birth and death rates of the population. (ii) An individual is either female or male, young or old but a population has a sex ratio which means, the ratio of male to female in the population which also has (iii) age structure, which means the various age groups into which the population may be divided.

The **characteristics of any population** depends on the following factors.

(i) density of the population, (ii) natality (birth rate), (iii) mortality (death rate), (iv) dispersal, (v) biotic potential (vi) age distribution (vii) dispersion and (viii) growth form.

The ‘J’ shaped growth curve is typical of the species which reproduce rapidly and which are greatly affected by seasonally fluctuating environmental factors such as light, temperature and rainfall. In this type of curve, population density increases rapidly in exponential (geometric) progression (total number doubles at regular intervals of time). **This type of exponential growth occurs in nature when a population has abundant supply of resources**. After reaching a peak there is a sudden crash or decline due to environmental or other factors. Such type of growth may be exhibited by insect populations which show explosive growth during the monsoon season and then abruptly disappear at the end of the season.

S-shaped curve or sigmoid growth curve has a lag phase, growth phase and a stable phase as shown in the figure, when few organisms occupy a hitherto unoccupied area reproduction occurs after some time (lag phase). Natality and mortality remain small. When growth phase begins, rapid increase in size of population occurs as there is plenty of food and no competition. Eventually, food or water or some source (e.g. nutrients in soil for plants) becomes limiting and population enters stable phase (plateau). Natality and mortality then become almost equal.

I had two inspirations for this venture. One was Eugene Odum's classic "Fundamentals of Ecology", the famous "yellow book" that was the go-to text for much of ecology's early years. Odum organized the book around chapters with titles that begin "Principles and concepts pertaining to…." (e.g., "Limiting factors). He would then carve each chapter into a series of expositions each with a "Statement", followed by an "Explanation" followed by "Examples". I just love Odum's book and this organization because it fits so well how I organize my own thoughts. I recommend finding a used copy. It holds up remarkably well.

The second inspiration was Meghan Duffy's and colleagues' recent discussion of how to organize an Intro Bio version of Ecology. I think I lifted Principle 2 and 4 directly from that blogpost. Lots of good pedagogy there.

So here is my working list of the Ten Principles of Ecology, stated first as tweet-worthy statement, followed by a short explanation of each. The idea is that my 48 students will be seeing this the first week of class and we will sample, expand on, and recombine them throughout the rest of the semester. I realize every ecologist is different, and that this lays bare my own intellectual DNA on the subject. None-the-less, I'd love to see more lists like this.

Also, has anyone else tried a similar approach to structuring their class? That is, start with the big picture, then backfill? I'd love to hear about it.

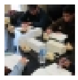
The Ten Principles of Ecology

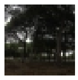
1. Evolution organizes ecological systems into hierarchies.

Individual organisms combine into populations, populations combine into species, species combine into higher taxa like genera and phyla. Each can be characterized by its abundance and diversity (number of kinds) in a given ecosystem or study plot. How and why abundance and diversity vary in time and space is the basic question of ecology.

2. The sun is the ultimate source of energy for most ecosystems.

Life runs on the carbon-rich sugars produced by photosynthesis; every ecosystem's sugar output depends on how much solar energy


Teaching


Manifesto

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and precipitation it receives.

3. Organisms are chemical machines that run on energy.

The laws of chemistry and physics limit the ways each organism makes a living and provide a basic framework for ecology. The supply of chemical elements and the sugars needed to fuel their assembly into organisms limit the abundance and diversity of life.

4. Chemical nutrients cycle repeatedly while energy flows through an ecosystem.

The atoms of elements like C, N, P, and Na go back and forth from spending time in living to spending time in dead parts of an ecosystem. But the photons of solar energy can be used only once before they are lost to the universe.

5. dN/dt=B-X+I

The rate that a population's abundance in a given area increases or decreases reflects the balance of its births, deaths, and net migration into the area. Individuals with features that improve their ability to survive (i.e., not die) and make copies of themselves will tend to increase in that population.

6. dS/dt=D-X+I

The rate that the diversity of species in an area changes reflects the balance of the number of new forms that arise, those that go extinct, and those that migrate into the area. Individuals and species that have features allowing them to survive and reproduce in a local environment will tend to persist there.

7. Organisms interact—do things to each other—in ways that influence their abundance.

Individual organisms can eat one another, compete for shared resources, and help each other survive. Each pair of species in an ecosystem can be characterized by the kind and strength of these interactions, measured as their contribution to dN/dt.

8. Ecosystems are organized into webs of interactions.

The abundance of a population is influenced by the chains of interactions that connect it to the other species in its ecosystem. This often leads to complex behavior, and a key challenge in ecology is to determine what patterns of abundance and diversity can be predicted.

9. Human populations have an outsized role in competing with, preying upon, and helping other organisms.

Humans are one of millions of species embedded in Earth's ecosystems. The ability of humans to change the planet, abetted by our large population size and technological prowess, increases our ability to shape the biosphere's future. Humans, through principles 1-8, are currently changing the climate, re-arranging its chemistry, decreasing populations of food, moving around its species, and decreasing its diversity.

10. Ecosystems provide essential services to human populations.

These include products like timber, fiber and food, regulating water and air quality, and cultural benefits like recreation. A key goal of ecology is to use principles 1-9 to preserve ecosystem services.