ANIMAL ECOLOGY AND WILDLIFE

(DZO004)

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LESSON - 1.1

NATURE AND SCOPE OF ECOLOGY

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1.1 INTRODUCTION

Ecology is the study of organisms in relation to the surroundings in which they live. These surroundings are called the environment of the organism. This environment is made up of many different components, including other living organisms and their effects, and purely physical features such as the climate and soil type.

Ecologists, those who study ecology, are always aiming to understand how an organism fits into its environment. The environment is of supreme importance to an organism and its ability to exist in the environment where it lives will determine its success or failure as an individual.

There are several definitions of ecology. Many workers have produced their own description of this branch of biology. The word ecology was first used by a German called Ernst Haeckel in 1869. It comes from two Greek words *logos* meaning home and *logos* meaning understanding. Haeckel described ecology as 'the domestic side of organic life' and 'the knowledge of the sum of the relations of organisms to the surrounding outer world, to organic and inorganic conditions of existence'. This 'surrounding outer world' is another way of saying the environment. In 1927, Charles Elton wrote that ecology is 'the study of animals and plants in relation to their habits and habitats'. Today an ecologist would probably substitute the word 'organisms' for 'animals and plants' because we now recognise other categories of organisms (fungi, protoctists and bacteria) which are not in the plant or animal kingdoms. Many of these are extremely important in ecology although they are seldom as well studied as the plants and animals. More recently Krebs (1985) has defined ecology as 'the scientific study of the interactions that determine the distribution and abundance of organisms'.

Ecology is like an enormous jigsaw puzzle. Each organism has requirements for life which interlock with those of the many other individuals in the area. Some of these individuals belong to the same species, but most are very different organisms with very different ways of living or interacting. Figure 1.1 is a diagrammatic representation of this interlocking jigsaw. It illustrates some of the ways in which a single individual fits in with others. In this case an animal is represented which catches other animals for food (it is a predator) and which in turn is hunted and may be killed by another species of predator. During the animal's lifetime it needs to find a mate of the same species to produce offspring. During its life, it also competes with other animals (competitors) for food and will probably catch diseases.

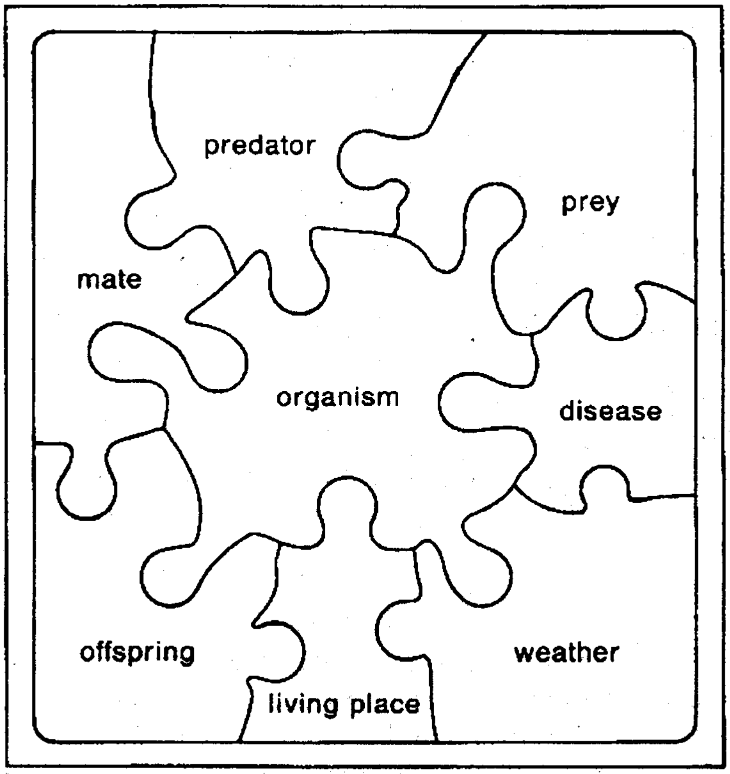

Fig. 1.1. Diagram showing the interlocking nature of the features of the environment which influence an organism. In this case the organism is a predator, but to generalise the diagram, the word 'prey' could be replaced by 'food', or, for a plant, by 'light and nutrients'. For simplicity, this figure is two dimensional, but the ecological interactions of organisms and their environment are really multi-dimensional.

The ability of the animal to avoid the predator, catch its prey, withstand disease and so on will depend on the relationships it has with the organisms around it. Its life will also be affected by the weather, time of year and the quality of nesting or sleeping sites. In fact, this simplified example is already becoming complicated as more and more pieces of the puzzle are added. The study of these ecological relationships from the point of view of a single species, as is illustrated by Figure 1.1, is called autecology. If all the species living together are studied as a community, then this study is called synecology.

1.2 SCOPE OF ECOLOGY

The only way to find out how any organism survives, reproduces and interacts with other organisms is to study it. This makes ecology a practical science. There are three main approaches to the study of ecology. The simplest method is to observe and record the organism in its natural environment. This is sometimes described as observation 'in the field' of fieldwork, although the term can be confusing as 'field' suggests open grasslands or the site of human cultivation. A second type of study is to carry out experiments in the field to find out how the organism reacts to certain changes in its surroundings. The third approach involves bringing organisms into a controlled environment in a laboratory, cage or greenhouse. This experimental aspect can be very useful as it is often easier to record information accurately under controlled conditions. However, it must be remembered that the organisms may react differently because they have been removed from their natural home.

No single study can hope to discover everything there is to know about the relationships between an organism and its environment. These relationships are so varied that different kinds of investigation are needed to study them. Often both study in the natural environment and experiments in the laboratory are required to discover even part of the picture. Also, as the environment changes, so an organism may respond differently, with the result that an experiment under one set of conditions may well give different results to the same experiment carried out under different conditions.

So we have a picture of ecology as a subject full of complexity where an organism has many different responses and needs. Theoretically, therefore, there is an almost infinite amount to be discovered about the ecology of the world. Even after a century of ecological study we are just scratching the surface of possible knowledge. A large amount has been discovered over the years, but our knowledge is patchy; we know far more about northern hemisphere temperate woodland than we know about tropical rainforest, more about English rocky sea shores than the Australian barrier reef.

What makes ecology exciting, rather than an endless list of things to be learned about organisms, is that we are studying a living, working system. Because the system fits together so neatly it forms repeated patterns which can be recognised by the ecologist. Organisms with similar life styles often respond to their environment in similar ways. For example our predator in Figure

1.1 can only catch its prey in certain ways. If its prey becomes scarce it may starve, eat something else or migrate to where food is more plentiful. In other words it only has a certain number of options and its response to certain conditions may well be predictable. Understanding why organisms react to various conditions in one way rather than another takes us a long way towards an understanding of the principles of ecology.

These principles, with which this book is concerned, are only becoming understood because of the many studies of organisms both in the field and in the laboratory. Throughout this book you will find examples of how particular organisms relate to their environment given as evidence to support the principles being described. Because the relationship of organisms to their environment may be very subtle, it can often be difficult to unravel the situation to discover the principles involved. Yet finding out how organisms interact and applying these principles can be an absorbing and fascinating pursuit.

1.3 AUTECOLOGY

Autecology is the name given to ecological studies which concentrate on one species *(autos* is the Greek for self). To find out all there is to know about a species is an enormous task which requires considerable time, a great deal of observation and numerous experiments. Usually different ecologists are involved over many years in finding out about one species. Often they are working on specimens from different parts of the world. Several fields of biology are usually involved including genetics and biochemistry as well as the more traditional forms of ecology.

There are an estimated 30-40 million species in existence today. Very few of these have as yet been studied sufficiently for us to understand much of their autecology. This chapter gives two examples of species which have been investigated fairly extensively. One, the bracken fern, is an autotrophic plant, and the other, the European starling, is a heterotrophic vertebrate. These examples will give you an idea of how the results of many autecological studies can be combined to help us to understand the whole life cycle of a species. Much more is known about each of these species than is mentioned here, but you can get a flavour of the scope of autecology from these accounts.

1.4 ECOLOGY - GENETICS

Every organism has a collection of genes consisting of lengths of DNA (deoxyribonucleic acid). This DNA can be read like a book and is used by the organism to construct proteins including enzymes. Each cell has a copy of this genetic material stored in the nucleus. The genes are arranged in a set order on several chromosomes. Most cells have two sets of chromosomes and, usually, one set comes from each of the two parents of the individual. The genes are responsible for the growth, development, maturation and reproduction of the individual.

A single gene can have many different forms called alleles. If a gene has more than one allele, it is said to be polymorphic. Because many genes are polymorphic considerable variation is possible between different organisms of the same species. The set of alleles an individual possesses on its chromosomes is called its genotype. Different genotypes result in individuals with different appearances. An obvious instance of this is hair colour and pattern in cats, or shapes and sizes of dogs. In wild populations genetic differences are not usually as obvious as these examples. Many alleles affect the organism in ways which are not immediately apparent, for example differences in blood groups. The genotype of each individual causes the organism to interact with its environment. Together the genotype and the environment are responsible for the physical appearance of the individual. This outward expression of the genotype is called its phenotype. It is the variation in genotype and the expression of this in different phenotypes which is of interest to the ecological geneticist.

1.5 ECOLOGY - SOCIOBIOLOGY

Many animals are social. that is, they associate in a group with other individuals, usually of the same species. For example, starlings feed in small flocks and join large communal roosts at night, although during the mating season they go off in pairs. Other species, such as most termites, ants and bees, have much more rigidly organised social units than the starling. Whether an animal lives in a loose and changing association or in a tight family unit it has to live with and relate to the other animals around it. The study of the origins and biological basis for such social behaviour is called sociobiology.

Many species are social, while others are solitary. This suggests that for some there are advantages to group living, while for others the disadvantages are such that a solitary existence is preferred by natural selection. Once a species evolves group living there often follow important consequences for the individuals in the group in terms of inter-individual relationships and group structure. This chapter looks at the advantages, disadvantages and consequences of social behaviour. The evolutionary pressures favouring helping behaviour are investigated as is the way in which social behaviour plays a vital role in the lives of many species including termites, army ants, lions and naked mole rats.

1.6 ECOLOGY - ENVIRONMENTS

The astronaut in Figure 1.2 is surrounded by very hostile conditions on the Moon. There is no breathable atmosphere, no running water, very high temperatures in the glare of the Sun and very low ones on the dark side of the Moon, no soil, just dust and rocks and the risk of meteors. In fact the Moon is probably unable to sustain any form of life, although biologists live in hope that some micro-organisms may be found there. This is why the astronaut has to wear a spacesuit to carry his oxygen supply and maintain his temperature correctly.

All these characteristics of temperature, light, aridity and ground structure make up the environment on the Moon. It is a very unusual environment, by Earth standards, because there are no living organisms; in other words the environment on the Moon is abiotic: it is made up only of physical conditions. On Earth, the abiotic environment of an organism is composed of physical variables such as temperature, rain- or snowfall, nutrient and toxic content of the soil, the power of wave action and wind speed. Unlike on the Moon, on Earth an organism also experiences the influence of other organisms, for example through competition, predation, herbivory, pollination and seed dispersal. The effects of such organisms forms the biotic part of the environment.

Fig. 1.2 Commander David R. Scott from Apollo 15. The spacesult contains a portable environment to support him.

Although the abiotic and biotic components of the environment can be treated separately, the relationships between them are complex. For example, the amount of incident light falling on a leaf may depend not only upon the position of the sun and the amount of cloud cover, but also on the angle at which the leaf is held, and the shading effect of the surrounding vegetation. A nutrient-poor soil may be colonised by plants with root nodules containing nitrogen-fixing bacteria, but the presence of such plants alters the soil by increasing nitrogen availability, thus allowing subsequent colonisation by other plant species. Fire is a physical phenomenon which depends on the weather, but a fire can only burn because of the build-up of organic matter from the biotic environment as occurs in savannah grasslands.

For any organism within a community, the environment which it experiences will be the result of these complex interactions between biotic and abiotic factors. Some factors will be more important than others for limiting an individual's growth development, survival or reproductive success. Different factors may be important at different times in the life of the organism: a caterpillar will have different requirements from an adult butterfly; seed germination will be affected by different aspects of the environment than those which affect a mature plant. Whether or not an organism can survive the environment at all stages of its life in a particular environment is therefore of considerable importance in determining the distribution within habitats and the overall global range of individual species. Figure 1.3 summarises the complex interactions between the abiotic and biotic environments of an organism.

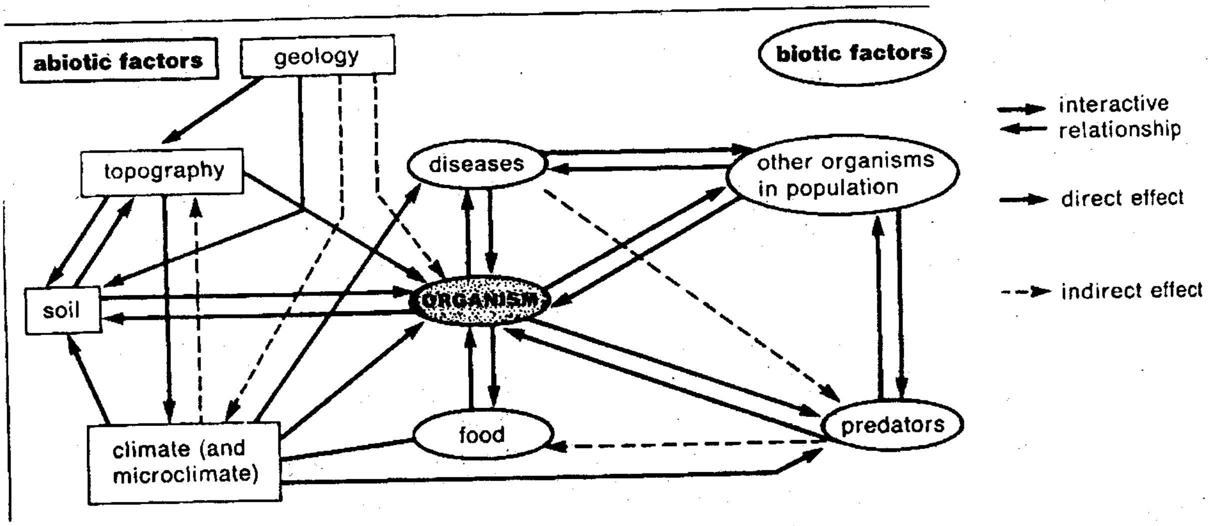

Fig. 1.3 Summary of the complexity of interaction between an organism and the biotic and abiotic components of the environment.

Investigations of the components of the environment and the responses of organisms play a crucial part in ecological study as they add to our understanding of both the distribution of species and the structure of communities.

1.7 ECOLOGY – TROPHIC LEVELS

There are many approaches to studying the ecology of organisms in their natural surroundings. We have already seen several of these: changes in population size the occupation of niches and so on. Another way is for ecologists to study organisms from the point of view of their feeding relationships - what they feed on and what feeds on them. There are a number of reasons why this is a good approach. First, one of the major problems faced by all organisms is how to obtain enough energy and nutrients to survive grow and reproduce. Second, if the feeding relationships of a group of organisms can be unravelled, then we get a clearer understanding of how those organisms interact. Finally, there simply is not enough time, nor sufficient funds, to study every species in detail. Ecologists therefore often cannot always look at each and every species, one by one. Rather they study the autotrophs, the herbivores, the carnivores, the decomposers and so on, lumping together the species that have a similar role in the community.

Trophic literally means feeding, so trophic levels are the levels or positions at which species feed. Examples of trophic levels include 'herbivores' and 'decomposers'. In this chapter we will look at the characteristics of organisms in each of the trophic levels. We will then examine approaches to the study of the feeding relationships of organisms. Finally, we will see whether there are any rules governing the trophic levels and feeding relationships observed in nature.

1.8 ECOLOGY - ECOSYSTEMS

The word ecosystem is a relatively recent term. Sir Arthur Tansley invented the word in 1935 to apply to a whole community of organisms and its environment as one unit. Tansley realised that the community could not be separated from the particular environment in which it lived. The physical features of the habitat plus the climatic influences determine which species form the basic structure of the community. For many years, ecologists had realised that a habitat, and the community it contains. are a single working system. They applied many terms to this concept, but apart from ecosystem, only one earlier word. biocoenose (Mobius. 1877), is frequently used, especially in Europe and Russia.

The ecosystem, or biocoenose, consists of the community of organisms plus the associated physical environment. The main features of the abiotic environment are climate, soil and water status (land, freshwater aquatic or marine); other features include geology, topography and depth below sea level. or altitude above it. We have already looked at some of the organisms which occur in ecosystems: both autecological studies of species and species in communities. The study of ecosystems is included in synecology as all the organisms and environmental factors are studied as an integrated unit.

Many features of the ecosystem are difficult to separate out and look at in isolation from the communities they support. This is the case, for instance. with the soils of terrestrial ecosystems and the water relationships within ecosystems. The importance of water in freshwater ecosystems, including bogs and lakes, is described. The relationships of soils to vegetation and climate is also investigated, including soil classification and distribution on a global scale.

1.9 ECOLOGY - CONSERVATION

As the human population and its domination over this planet increases, the threat to the naturally evolved life forms also increases. As the human population continues to rise more and more land is brought under direct human control for agriculture, the amount of natural vegetation diminishes and with it the space available for the species which live in such habitats. The vast expanses of tropical forest have become increasingly threatened in the last few decades, as large commercial companies back clearance schemes for cattle ranching and timber exploitation. Even in the oceans fishing is so intensive that populations are diminishing rapidly. In European waters most fish now caught for food, such as cod, are not fully grown. The large mature fish have already been caught and the smaller ones are captured before they can grow to replace them. We have become too efficient as predators.

Some animals are hunted not for food but for luxury items. The African elephant populations have been severely affected by poachers hunting for ivory. The various rhinoceroses are even closer to extinction as they are killed for their horns. Our leisure activities also affect the wildlife: exotic species such as parrots and coral reef fish are captured in their millions for the pet trade. Most die before they ever reach the countries where they are to be sold. All this leads to a feeling that *Homo sapiens* is out of control. We have become a species which is no longer in co-evolved balance with its environment. Conservation is management of the Earth's resources in a way which aims to restore and maintain the balance between human requirements and the other species in the world.

1.10 SUMMARY

1. Ecology is the study of how organisms live and how they interact with their environment.
2. The environment includes other organisms and physical features.
3. Autecology is the study of the ecology of a single species.
4. Synecology is the study of the ecology of whole communities of organisms.
5. Ecology is a practical science – observations and experiments are required to investigate organisms.
6. There are underlying principles in ecology which predict how organisms will react in particular circumstances.
7. Experimental design is extremely important and requires, wherever possible, controls, replicates, the accurate collection of data and careful interpretation of results.

The face that we are destroying species, habitats and perhaps even the life-support system of the planet by our irresponsible behaviour is a depressing thought. However we do have the knowledge to realise what we are doing and the understanding of what we could do to stop the decline and put things right. This is where ecology fits in to the picture. The autecology of rare or threatened species, the synecology of communities and the role of the abiotic environment in ecosystems are all relevant to conservation. The population dynamics of a threatened species and how it fits into the food web indicate how likely it will be to recover population size once its habitat is secure. The setting up of protected areas or nature reserves is often a feature of conservation practice; theories of biogeography, an understanding of succession and the processes of nutrient cycling are all of importance in understanding these ecosystems.

1.11 EXPECTED QUESTIONS

1. Describe the Nature and Scope of Ecology.
2. Explain in detail the relation between Ecology and other sciences.
3. Give an account on ecology relevance to civilization.

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LESSON-1.2

LIFE SUPPORTING PROPERTIES OF WATER

1.2.1 INTRODUCTION

1.2.2 LIFE SUPPORTING PROPERTIES OF WATER

1.2.2.1 Pressure
1.2.2.2 Density variations due to Pressure
1.2.2.3 Variations due to Temperature
1.2.2.4 Changes due to dissolved substances
1.2.2.5 Changes due to dissolved substances
1.2.2.6 Changes due to substances in suspension
1.2.2.7 Viscosity
1.2.2.8 Buoyancy
1.2.2.9 Surface Film
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1.2.2.12 Latent Heat of fusion
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1.2.2.14 Evaporation
1.2.2.15 Thermal conductivity
1.2.2.16 Convection
1.2.2.17 Thermal relations of Ice
1.2.3 EXPECTED QUESTIONS
1.2.4 REFERENCES

1.2.1 INTRODUCTION

That branch of limnology which deals with the measurement of significant morphological features of any basin and its included water mass is known as *morphometry*. Certain fundamental conditions of production arise directly out of size and form interrelations. Therefore it becomes necessary for the limnologist to make various measurements of shore line, area, depth, slope, volume, and other morphological features and to establish from them certain ratios which serve as indices of lake differences. Details of these procedures belong more properly to field and laboratory work (see Welch, 1948) and will not be treated here.

1.2.2 LIFE SUPPORTING PROPERTIES OF WATER

1.2.2.1 Pressure: Water is a heavy substance. Pure water weighs 62.4 lb. per cu. ft. at 4°C. This is a direct result of its density. Since density changes with differences in temperature, compression, substances in solution, and substances in suspension, the weight of a cubic foot of natural water is not always the same. It is roughly about 0.2 lb. per cu. ft. lighter at 27°C than at 4°C., and it has been estimated that substances in solution and suspension in inland waters usually do not add more than about 0.1 lb. per cu. ft. to the weight. However, for ordinary purposes, calculations of pressure on the basis of 62.4 lb. per cu. ft. are customary. In calculating pressures in the sea, a value of 64 lb. per cu. ft. is commonly used. The pressure at any subsurface position is the weight of the superimposed column of water plus the atmospheric pressure at the surface. Pressures in water, as depth increases, rapidly become great, so that ultimately a crushing effect is imposed upon objects submerged to considerable depths. This collapse under pressure is called *implosion.* Apparatus which includes inner spaces to which water has no access must be protected against the crushing effects of pressure in deep water.

1.2.2.2 Density: Some of the most remarkable phenomena in limnology are dependent upon density relations in water.

1.2.2.3 Variations Due to Pressure: Water at the surface, subject to a pressure of only 1 atmosphere, is considered as having a density of unity (1.0); at a pressure of 10 atmospheres, the density is about 1.0005; at 20 atmospheres, the density is about 1.001; and at 30 atmospheres, it is about 1.0015.

1.2.2.4 Variations due to Temperature: Pure water forms ice at 0°C., and steam at 100°C., but the main interest here is in the changes of density of the liquid due to temperature. Water possesses that unique quality of having its maximum density (Fig. 1__) not just before it forms ice but at 4°C (39.2°F). Strangely enough, it actually becomes progressively less dense (lighter) as it cools from 4°C, to the freezing point.

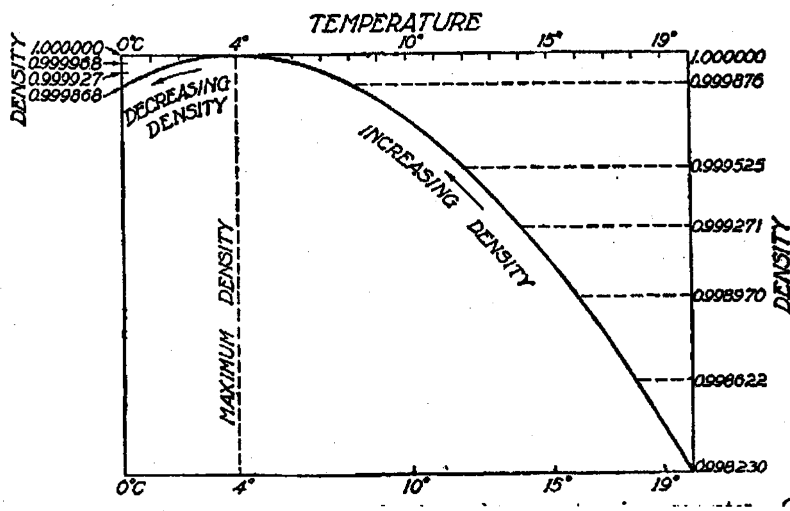

Fig.1. Graph showing relation between density and temperature in pure water discontinued at 20°C.

The performance of many, possibly most, inland waters parallels closely that of pure water, as shown in Fig.1. However, one departure should be mentioned, viz., it is a well-established fact that with increasing hydrostatic pressure the temperature of maximum density in pure water becomes lower than 4°C. although the change is of small magnitude. It seems likely that this fact explains the occurrence of temperatures slightly lower than 4°C. at the bottom of very deep inland lakes in summer (Wright, 1931; Eddy, 1943).

In natural environments, water is ordinarily least dense (lightest) at the maximum summer temperature. As it cools down during autumn and early winter, it gradually increases in density until 4°C. is reached. Further cooling decreases density until the 0°C. is reached.

According to Coker (1938), sea water becomes heavier as it cools until the freezing point is reached, i.e., the temperature of maximum density is at 0°C. instead of 4°C. as in pure water.

1.2.2.5 Changes due to Dissolved Substances: All natural waters contain substances in solution. The concentrations of these substances vary widely, although, as a rule, the total amount in fresh water is less than that in sea water. Such substances usually increase the density of water, the amount of increase depending upon the concentration of dissolved materials and upon their specific gravity. A marked influence of this sort occurs in salt lakes in which the density may exceed that of the oceans. Evaporation increases density by concentrating the dissolved materials; dilution reduces the density.

1.2.2.6 Changes Due to Substances in Suspension: All waters, as they occur in nature, contain some suspended particulate matter. The quality and quantity of these substances vary greatly in different waters and at different times. Silt and certain other materials are heavier than water and thus increase its weight; others may have a specific gravity similar to that of water and cause no significant change in its weight. *Density currents* and related phenomena may be caused by substances in suspension.

1.2.2.7 Mobility (Viscosity) : Water is an exceedingly mobile liquid. Nevertheless, it has internal friction (viscosity). This viscosity varies with the temperature. Water is distinctly more mobile at ordinary summer temperatures than it is just before it freezes (Fig. 2). For the present purposes, the values given in Table 1 indicate the essential features of this variation with temperature.

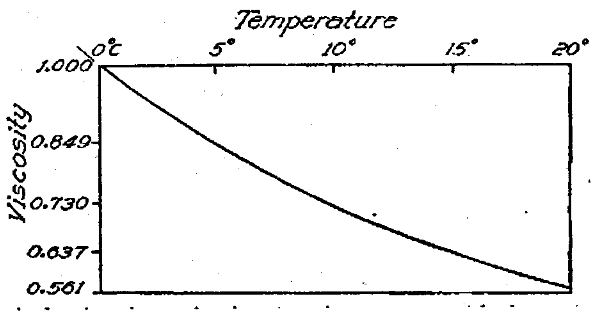

Table 1. Changes in the viscosity of pure water due to temperature .

Temperature, °C	Percentage of Viscosity
0	100.0
5	84.9
10	73.0
15	63.7
20	56.1
25	49.8
30	44.6

The mixing and stirring of water in nature are largely due to wind action. It is evident from the table given above that the response of water to a wind of fixed velocity would differ with different temperatures of the water. Much more work is required of the wind to produce a certain result when the water is near freezing than when it is near summer temperatures. Pressure does not cause any significant change in viscosity.

1.2.2.8 Buoyancy: Buoyancy is a direct outcome of density and varies with the same factors. The law of Archimedes is as follows: A body in water is buoyed up by a force equal to the weight of the water displaced. (The greater the density the greater the buoyant force; the denser the water the higher will a floating object ride in the water. Ships passing from fresh water into sea water rise a little higher, and the same ships with the same loads would ride somewhat higher in winter than in summer. Submerged bodies of all sorts are, of course, under the same influences and subject to the same changes of buoyant force.

1.2.2.9 Surface Film: When water is exposed to air, it acts as if it were encased within an extremely thin, elastic, surface membrane. This boundary is commonly known as the *surface film* and is interpreted as a manifestation of unbalanced molecular action. In the interior of the water, the molecules do not exhibit any such phenomena, since in that position they are attracted to each other in all directions, neutralize the attraction of one another, and are thus balanced. However, at the surface film, a phenomenon called *surface tension* occurs, due to unbalanced attractions between molecules at the surface, since the surface molecules are attracted on one side only, and upward attraction is lacking because there are no water molecules above them. It happens, therefore, that a surface tension is produced which acts inwardly, and the molecules act as if they formed a tightly stretched, elastic membrane over the water. This surface tension diminishes with rise of temperature, and it is also lowered by organic substances in solution, although most salts increase it. In pure water, it is said to be greater than in any other liquid except mercury. Objects which do not wet may be supported on top of this film, even though their specific gravity is several times greater than that of the underlying water. A time-honored demonstration is the supporting of a dry, steel needle on the surface film. The limnologist is accustomed to seeing, at times along sandy lake shores, patches of sand floating on the surface film. The under surface of the surface film also serves as a mechanical support for certain objects in nature. Light rays, impinging from above, penetrate it if the angle of incidence is not too great, but beyond a certain angle the surface film reflects light. Viewed from below, especially at an angle, it appears as an exceedingly smooth, somewhat silvery, opaque film.

This film is now known to have many limnological relations, the more important ones of which will be discussed later.

Masses of foam, sometimes of considerable size, appear occasionally along the shore in inland lakes. Hardman observed reduced surface tension in regions of foam formation and suggested that the piling up of an organic film by a steady, strong, onshore wind operating for several hours might cause such an emulsion.

Table 2. Range of surface-tension depressions in various situations

From Hardman

Situation	Surface-tension Depression, Dynes per cm.
Oligotrophic lakes	0-2
Eutrophic lakes	0-20
Bog lakes	0-20
Lakes with foam	2-9
Near *Lemna* and lilies	5-20
During plankton bloom	0-20

1.2.2.10 Temperature: Temperature is one of the most important factors in an aquatic environment. In fact, it is possible that no other single factor has so many profound influences and so many direct and indirect effects. It, therefore, becomes necessary to give a rather detailed discussion here. Certain inherent thermal properties of water will be treated first.

1.2.2.11 Specific Heat: Water has the greatest *specific heat* of all substances, except liquid hydrogen and lithium at high temperatures. Since this heat capacity is so great, it is used as the standard in expressing specific heats of other substances. The heat capacity of water is given the value of 1 (i.e., specific heat of water is 1), and. the specific heats of other substances are recorded as the ratios of their thermal capacities to that of water. More specifically, the numerical value of the specific heat of any substance is the number of calories of heat necessary to raise the temperature of 1 g. of the substance to the extent of 1°C.

Since the specific heat of water is so great, a lake must absorb vast quantities of heat in order to increase its temperature by 1°C., and this explains the slow rate of warming up of lake water in spring; likewise, its slow cooling in autumn is due to the large amounts of heat which must be given off. Thus, it is seen that the response to the major changes in air temperatures is a very deliberate one. Water temperatures always lag far behind the larger changes of air temperatures.

1.2.2.12 Latent Heat of Fusion: Another peculiarity is that before water at 0°C. can become ice, it must give off a large amount of heat, and, conversely, when ice has just been formed at the freezing point, it must absorb a large amount of heat before it can transform into the fluid state. Actually, it requires about 80 units of heat to change 1 g. of ice to the liquid state when both are at 0°C. The heat thus involved is called *latent heat of fusion.* From the statement just made, it follows that the amount of heat required merely to convert ice into water with no change of temperature would, after the conversion has occurred, raise the temperature of the same amount of water about 80°C. Latent heat of fusion is thus eighty times greater than the specific heat, although the specific heat of water is greater than that of all other substances save two.

1.2.2.13 Combined Effect of Specific Heat and Latent Heat of Fusion: In lakes and other natural waters, the cooling of water in autumn with subsequent ice formation in winter and the disappearance of ice followed by warming up of the water in spring involve interchanges with the air of vast quantities of heat. As a consequence, the changes of water temperature are slow. In northern Michigan, for example, where the winter comes early, the larger inland lakes may not freeze over until December or early January; while in spring, the ice may not disappear completely until April.

1.2.2.14 Evaporation: Water, including ice and snow, evaporates at all environmental temperatures. In evaporation heat is consumed. That quantity of heat necessary to convert 1 g. of water at 100°C. into steam without altering the temperature of the latter is known as *latent heat of evaporation,* sometimes called *heat of vaporization.* Water has the remarkable peculiarity of requiring 536 heat units for this conversion, a quantity of heat much greater than that of many other liquids. When evaporation occurs, the necessary heat required to make the change from water to steam must come from somewhere. It may come from some source of high temperature, such as the sun; it may be withdrawn from the water itself from bodies in or around it, thus lowering their temperature. Rate of evaporation is determined by several factors usually acting simultaneously, viz., temperature, relative amount of free surface of the water, vapor pressure, barometric pressure, and amount of wind action. The manner in which these factors operate is too well known to require description here. Still another factor, viz., quality of the water, sometimes affects evaporation in a significant way. According to Harding (1942), the rate of evaporation of water decreases about 1 per cent for each 1 per cent increase in salt content until such content reaches about 30 per cent. Sea water "would be expected to have a rate of evaporation about 2 to 3 per cent less than that of similarly exposed fresh water." It would thus seem that in various inland saline waters evaporation is significantly slower than in comparable fresh waters, There appears to be little information available as to the extent to which rate of evaporation is affected by substances in solution in the so-called fresh waters; possibly, for limnological purposes, the effect is commonly negligible.

The removal of heat by vaporization of water in nature goes on more or less continuously and plays an important part in the heat cycle of water and the superimposed air.

1.2.2.15 Thermal Conductivity: The thermal conductivity of water is very low. If the water of a lake were heated only by conduction from the surface, the whole thermal complex would be radically different. Heating of water artificially by conduction alone would alter man's whole economic scheme. The influence of conduction in the transmission and distribution of heat, compared with certain other factors, is distinctly minor. Heat coming to a lake from the sun is partly absorbed and to some extent conducted, but the really effective heat distribution is due to wind action in agitating the water and, to a much more limited extent, to convection currents.

1.2.2.16 Convection: When water in a beaker is heated by a flame placed below it, those portions of water first heated expand and rise while the upper, colder, denser (and therefore heavier) portions sink. If the heat supply continues for some time, there are thus set up ascending and descending currents, by means of which heat is carried all through the total water mass. This form of heat distribution is known as convection. Most forms of artificial heating of water are of this type. It should be noted, however, that the relation of the sun to a lake surface is just the, reverse of that of a beaker and flame, since the source of heat is above instead of below; and it might appear at first thought that no convection currents would result, since the water being heated is already at the surface. However, convection does occur under the following conditions: (1) cooling and sinking of surface water, as when the sun sets and, under conditions of falling air temperature; (2) entry of colder water from a surface tributary; (3) cooling of surface water with the passing of autumn into winter; (4) alternations of cloudy and clear skies; (5) alternations of winds and calm; (6) entry of cooler subterranean water at a high level in the basin; (7) advent of a cold rain; and (8) cooling of the surface water by evaporation. These and other possible conditions produce a situation in which convection currents are in action most of the time in surface waters at least during the open season.

1.2.2.17 Thermal Relations of Ice: When water has reached a temperature of 0°C. and has given up the large amount of latent heat of fusion, it changes its physical state and becomes ice. In so doing, certain other significant thermal changes suddenly come into existence. The ice expands (coefficient of expansion = 1.125), and its density becomes less (0.917), thereby becoming lighter than the underlying water, and hence it floats. The specific heat is only about one-half that of the water from which it was formed (0.505 at temperature 0 to -21°C.), but the thermal conductivity becomes twice as great (0.005). Transmission of sun's heat to the water through the ice in winter, but it should be pointed out here that while it might appear that because of its reduced specific heat and its increased conductivity the ice would facilitate passage of heat from the water to the colder air in winter, only a relatively small amount of heat is actually lost in this way. The thermal conductivity of ice, even though twice that of water, is nevertheless relatively ineffective, and the ice cover seriously interferes with the passage of heat from water to the air.

1.2.3 EXPECTED QUESTIONS

1. Explain the life supporting properties of water.
2. Explain the various physical features of water. Write a note on their limnological significance.

1.2.4 REFERENCES

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LESSON 1.3

THERMAL STRATIFICATION OF NATURAL WATER BODIES

1.3.1Introduction
1.3.2 Thermal Stratification
1.3.3 Spring Overturn
1.3.4 Stratification
1.3.5 Epilimnion.
1.3.6 Hypolimnion
1.3.7 Modifications of thermal stratification.
1.3.8 Diminutive stratification
1.3.9 Terminology of Thermal Stratification
1.3.10 Fall Overturn
1.3.11 Thermal stratification in the Great Lakes and Larger Bodies of Water
1.3.12 Thermal Stratification in Tropical Lakes
1.3.13 Modified Thermal Stratification

1.3.1 Introduction

Water is unique in a number of respects. Upon these unique features rests the explanation of many phenomena in aquatic biology. It is interesting to speculate on the nature of that aquatic world which would have existed if specific heat, latent heat of fusion, and latent heat of evaporation were smaller than they are. Under present circumstances, water in nature is a great storehouse of heat without at the same time becoming a menace to the adjustments of life to temperature as they now exist.

1.3.2 Thermal Stratification

In the deeper lakes, a seasonal, thermal phenomenon occurs which is so profound and so far-reaching in its influence that it forms, directly and indirectly, the substructure upon which the whole biological framework rests, particularly in the temperate zone. Therefore, a clear understanding of the salient features of *thermal stratification* is a necessity. The cycle of events now to be described is the normal expectation in temperate lakes.

1.3.3 Spring Overturn

If a vertical series of temperature records is taken at regular intervals of depth from surface to bottom just before the ice cover goes off, it will be found that the temperature of the water just under the ice is very near the freezing point and that at successive depths it is gradually and very slightly warmer. Bottom-water temperatures differ somewhat in different lakes and according to conditions described later but they tend to be near the temperature of maximum density (4^0C.).

This condition is one in which the *colder but lighter (less dense)* water is on top of *warmer but heavier* water at the bottom. With the coming of spring and its gradually rising air temperatures, the ice begins to disappear, and the surface water rises in temperature. When the *surface* water rises to 4^0C., or thereabouts, *heavier water is now produced on top of the lighter water* immediately below, and the former tends to sink through the latter, the mixing often being aided by spring winds. In this process, the underlying colder but lighter water tends to rise to the surface where it, in turn, is warmed up to a temperature of 4^0C. And then sinks if there still remains any colder but lighter water below. This continues until the whole lake becomes *homothermous* (of the same temperature throughout from surface to bottom) and therefore of the same density. Being now of the same density throughout, the whole lake, under the influence of spring winds, will circulate or mix from surface to bottom, producing the phenomenon known as the spring overturn, or the spring circulation. Thermal resistance is at a minimum, and relatively light winds may cause complete circulation. Mixing by convection has become essentially nil, except at night when the surface layer cools and tends to sink, the convection currents so produced playing a part in mixing some of the upper water only. Rise of temperature of the lake to 4^0C., after the disappearance of ice, may take place in a few days.

Disappearance of the permanent ice cover of winter now exposes surface water to the atmosphere. Surface water then slowly gains heat. The slightly warmed water, reaching a temperature above 4^0C., is *lighter* than the underlying water mass and if immobile will remain at the top.

However, the difference in density between surface and underlying water is very slight, and resistance to mixing is correspondingly small. This resistance is known as *thermal resistance.* When thermal resistance is small, the amount of work requires to mix the lighter, warmer water with the heavier, colder underlying water is minimal. For example, it requires only 0.0067 erg to mix a column of water 1 sq. mc. In transverse area and 1 m. high in which the temperature gradient is uniform and whose upper surface has a temperature of 5^0C, and its lower surface a temperature of 4^0C. Thus a tiny breeze can stir this lighter water into the heavier water. Heavy winds, common in spring, continue to circulate the whole lake. As the slow heating process at the surface continues and the thermal resistance remains small at all horizontal levels, warmer water may be mixed all the way to the bottom. Consequently, the temperature of bottom water also slowly rises as spring advances. Heat intake at the surface accelerates as spring advances, owing primarily to increasing length of day and increasing verticalness of the sun. Presently, the rate of heat intake by surface water begins to overturn the ability of average winds to continue mixing warmer water into underlying colder waters, thus setting up differences of thermal resistance of increasing magnitude at various horizontal levels. By late spring or early summer these differences in thermal resistance finally become too great to be overcome by existing winds, and mixing of the whole water mass ceases. This marks the end of the spring overturn. During this overturn period the temperature of bottom water may have been built up to a level several degrees above the initial 4^0C. For example, in one of the submerged depressions in Douglas Lake, Michigan, bottom temperatures (depth 22 m.) at the end of the spring overturn, period of 1939-1948, were successively as follows: 7.5, 5.4, 6.2, 7.0, 8.3, 6.0, 9, 5, 9, 7, 7.8, 10.00C. Thus the initial bottom-water temperature for the subsequent summmer stagnation period is determined. On some occasions it may happen in a temperate lake of the second order that, because of unusually vigorous and long protracted wind action, bottom temperature builds up so high that the thermal resistance between top and bottom water is too slight to overcome wind action at the surface. Then circulation of the water mass continues more or less all summer. For example, in Douglas Lake, Michigan, which stratifies thermally in summer with great regularity, peculiar spring meteorological conditions in 1918 built up the bottom temperature to 15^{0}C. In June, thus living but a very few degree difference in temperature between top and bottom, and no stratification occurred during that summer.

1.3.4 Stratification

As stated above, the spring overturn is terminated when accelerating heat intake at the surface leads to the formation of a vertical temperature gradient within which the thermal resistance becomes too great for the existing winds to continue mixing the whole water mass. Then the circulation becomes partial and increasingly confined to the upper water. As the surface-water temperature continues to rise and becomes correspondingly lighter, more and more thermal resistance is offered to a mixing by wind action of surface water with the lower heavier water, until the situation rises when surface-water-temperature is much higher than that of underlying water, possibly a difference of 10^{0}C. or more. Then only surface water can be circulated by the wind. Coincident with this situation, or shortly thereafter, a *thermal stratification* comes into existence. A series of vertical temperature records taken at regular and frequent depth intervals from top to bottom, using apparatus suitable for such work, would show 1 the upper layer of the lake, known as the *epilimnion*, in which the water temperature is essentially uniform; 2 a stratum next below, know as the *thermocline* in which there is a a phenomenal drop in temperature per unit of depth; and 3 the lowermost region or stratum, know as the *hypolimnion*, in which the temperature from its upper limit to the bottom is nearly uniform.

The transition from spring overturn to thermal stratification is a struggle for supremacy between the two events. It is a direct reflection of events in the atmosphere. Incipient stratification develops only to be dispersed within the next few hours by rising wind. Temporary thermoclines may form, disappear, re-form possibly at some other level, and disappear again. Late in the transition period, two or three thermoclines sometimes form along the same vertical temperature gradient one above the other; these may be broken up by a vigorous storm, or, if weather conditions permit, they may consolidate later to form the permanent thermocline. Occasionally a temporary thermocline may last for several days before it is dispersed.

The dates of beginning and ending of the spring overturn vary from year to year. In Michigan this overturn usually has duration of about 4 to 6 weeks. In some lakes and under unusual circumstances the overturn may extend much beyond these limits; e.g., the writer has records of spring overturns which lasted 7 to 13 weeks. The long extent of the overturn usually provides ample opportunity for the whole water mass to become thoroughly mixed and circulated.

Occasionally, and under the following special circumstances, an *incomplete or partial overturn* may occur: 1 larger inland lake with unusually great depths, 2 small lakes with depths much greater than ordinary ones, 3 small lakes of ordinary depth under the influence of calm weather and a spring season of rapidly rising air temperatures, and 4 small lakes unusually well sheltered from the wind. In the first instance 1 unusually great depth alone imposes a possible difficulty to a complete mixing at the bottom. The second condition 2 is one in which the area is too small to permit sufficient wind action to produce complete circulation. In the third instance 3 a combination of a clam period with rapidly rising air temperature may cause the surface water to become warm enough, and hence light enough, to make it impossible for subsequent winds to force the upper water very far into the heavier, underlying water. Under the last condition 4 virtual absence of wind action leaves only the mixing due to convection.

1.3.5 Epilimnion.

The epilimnion, being almost homothermous throughout, is the zone of summer circulation. Because of this circulation, any significant changes in air temperatures are followed, to some extent, by the water of the epilimnion, so that there may be periods of thermal rise or fall, within summer limits, of the whole stratum.

Thermocline

The most unique stratum is the *thermocline*. When once formed, the demarcation between epilimnion and thermocline is very distinct. The water of the epilimnion, with its almost uniform temperatures, is rather abruptly succeeded by a layer of water in which the fall in temperature throughout its whole thickness is very rapid. This sudden transition from epilimnion to thermocline is often very abrupt. When a series of vertical temperature records taken during conditions of thermal stratification is plotted in the form of a curve, it will be seen that the part of the curve representing the epilimnion rounds off into the part representing the thermocline, so that there is, even in the sharpest of thermocline formations, a small transition stratum. Therefore, any rule to determine the exact position of the upper limit of the thermocline would be arbitrary. However, the need for a standard practice in recording thermocline position led Birge to formulate, about forty-five years ago, the rule which is now widely followed. The essential feature of this rule is that where the fall in temperature with increasing depth forms the surface is *less than* 1^0*C. per m.* (0.548^{0}F. per ft.), that position is still within the epilimnion; but where the temperature decline *becomes* 10^C. *Per m. of depth,* that circumstance marks the ***upper limit*** of the thermocline; and, finally, the *lower limit* of the thermocline is similarly determined but in the reverse order, viz., where the drop in temperature with increasing depth ***first becomes less than*** 1^0C. Per m. it should be noted that the typical transition from epilimnion to thermocline, and the demarcation established by the rule described above is to that extent a more arbitrary one.

The fall of temperature within the thermocline varies with different lakes, with different seasons, and with the progress of the summer. Temperature changes as great as 7.8^{0}C. Per foot have been recorded, but it is probable that such extreme drops are very rare. In fact, the author has never met conditions, in many hundreds of temperature records taken on many diverse lakes, in which the temperature fall exceeded about 5.5^{0}C. Per foot. Temperature fall in the thermocline is not uniform but is commonly greater in the upper levels.

The initial date of definite thermal stratification varies with different lakes, with latitude, with altitude, with meteorological differences in the same latitudes, with physiographic characters, with different submerged depressions, and with different seasons. Seasonal differences in the same lake are often striking, as, for example, in certain northern Michigan lakes, the date of beginning of thermal stratification has varied, during a period of fifteen years, form late May in one season to the last week in July in another. In the early stages of formation, thermal stratification may appear temporarily, only to disappear again under the influence of increased wind action. The date of permanent stratification is, to a large extent, determined by the area of the lake, the date usually being earlier in the smaller lakes within the same region.

Ordinarily, the thermocline forms first as a relatively thick stratum, often with its upper limit not very remote from the surface, and the lower limit quite deep. In Douglas Lake, Michigan, it is not uncommon for the initial thermocline limits to be about 4 to 18 m. the decline of temperature per unit of depth is less than it will be later in the season, although sufficient to qualify the whole stratum as a thermocline. Sometimes, the thermocline originates as two or three thermoclines, one above the other, which subsequently fuse to form one thermocline. Once formed, the thermocline undergoes a gradual seasonal change as the summer progresses. Its upper limit gradually drops in depth, thus increasing the volume of the epilimnion and reducing the thermocline volume. Likewise, the lower limit may rise in position for a time, but the amount of rise is usually slight. In the record mentioned above (initial thermocline position at about 4 to 18 m.), the thermocline position was about 12 to 17 m. by the middle of August, with the concentration still continuing; also the drop in temperature per unit of depth had doubled. In some instances, this concentration may reduce the thickness of the thermocline to 1 m. or less just before the autumn overturn, and the descent of the upper limit of the thermocline may be such as to increase the epilimnion four or five times its original volume. Not infrequently, the thermocline manifests, in addition to its concentration, a gradual sinking of its median plane so that the whole thermocline is dropping to a lower and lower depth level, a process which continues until the overturn. In the subsequent discussion of chemical stratification and its relation to the productivity of the lake it will be shown that this sinking of the upper limit of the thermocline has a compensating effect on biological production. It should be noted that there are exceptions to the seasonal history just described, but it represents the ordinary expectation in temperate lakes of the second order.

The general position of the thermocline for the whole summer depends a great deal upon the area over which the wind has full opportunity to exert its influence. In lakes having similar conditions of depth, exposure, altitude, location, and so on, the smalle the surface area the higher the thermocline position, irregular lakes with long ramifying arms and lakes containing islands of unusual size or number may have a total area of considerable size, but the areas of free wind sweep may be very much reduced and thus actually be less exposed than many smaller lakes; also the thermocline position may be high. In a certain small, ovoid Michigan lake, about 305 X 215 m. and approximately 18 m. in depth, the thermocline position at the end of August, 1926, was 2 to 6 m. in this lake, the epilimnion is of very small volume throughout the season, while the hypolimnion has a relatively large volume.

A secondary thermocline is sometimes formed but is never permanent, lasting, ordinarily, but a short time. Such a phenomenon may occur when the primary thermocline is deep and when the epilimnion shows a difference of several degrees of temperature between the surface and its lower limit. Such a thermocline is a thin one, and the drop of temperature per unit of depth is small although sufficient to qualify as thermocline conditions. So far as known, it is always formed above the primary thermocline. As many as three thermocline strata may be present temporarily, when thermal stratification conditions are just taking form.

It must not be assumed that because thermocline formation is found in a certain lake it is an invariable feature. Since meteorological conditions are intimately concerned with thermal stratification, they may actually be of such a nature during the spring and early summer fo a particular season as to prevent completely any stratification. There are, of course, all gradations between those lakes which are too shallow to stratify permanently in the summer and those whose depths are such that stratification is certain. Among these intergrades are lakes whose depths are just great enough to establish thermal stratification during a clam spring and summer but which would not stratify during more blustery seasons. Such intermediates would, over an extensive series of years, show about an equal number of stratified and uncertified conditions. However, in lakes whose depth-area relations are such that thermal stratification is the regular expectation, exceptional meteorological conditions may, at more or less rare intervals, prevent stratification completely. In one Michigan lake, whose summer thermal history has been followed carefully, thermal stratification was absent for one out of 37 summers, the exceptional instance being due, apparently, to an unusually regular series of spring and early summer storms, spaced at intervals of about one week and of sufficient vigor to circulate the water and gradually to raise the bottom-water temperature far above the normal condition, so that finally the contrast (thermal resistance) between bottom-and surface-water temperatures was not great enough to prevent summer circulation from affecting the whole lake. The very deep inland lakes are probably never subject to this occasional absence of stratification.

Vertical oscillations of the thermocline are not uncommon. Vertical temperature records taken at regular and frequent intervals sometimes show the upper surface of the thermocline at one level at one time and at another level a short time later. Such oscillations are usually the result of violent summer squalls which pile up surface water on the exposed side of the lake, the increased weight of the water depressing the thermocline locally. When calm follows, the colder, heavier water of the thermocline and hypolimnion returns to its former position as the surface water again seeks its normal level, but in so doing a swing is set up this continues for a time. Thus, the thermocline rises and falls with decreasing amplitude until, with continued calm, it may finally manifest only very minor swings, which may be due to irregular currents in the hypolimnion resulting from the original major movement. These swings of the thermally stratified water constitute a *temperature seiches.*

1.3.6 Hypolimnion

One of the principal influences of the thermocline, when once permanently formed, is to isolate the hypolimnion from the epilimnion and its circulation. While it is claimed that under some circumstances a certain amount of water from the epilimnion may be forced down into the hypolimnion and a minor, subthermocline circulation thus set up, the thermocline constitutes an effective barrier against influences or disturbances originating at the surface. Subsurface seiches may swing hypolimnion waters from side to side, and, and, in those special cases in which subterranean water supplies enter the lake basin below the thermocline, the hypolimnion may show deviations from the usual condition. Alsterberg and others claim that the wind not only causes circulation of the epilimnion but also produces secondary and tertiary horizontal currents in the hypolimnion. Subthermocline movements are greatly in need of further study.

A small but definite rise of temperature during the summer at the bottom of the hypolimnion has been observed (Welch, 1927) in certain lakes. The increment seems always to be of a gradual nature. The total temperature increase for the season is usually small. In Douglas Lake, Michigan, where it is known to occur, it is not a regular event, but appears to be absent during some summers. No satisfactory explanation of these heat gains is yet available.

1.3.7 Modifications of thermal stratification.

While the type of thermal stratification just described prevails, so far as is known, for the vast majority of North American temperate lakes of the first and second orders various modifications may occur either temporarily or permanently. Some of them are as follows:

1. **Thermocline at the surface;**

In such an instance, temperature decline of thermocline magnitude begins at the surface, extends to some depth, and gives place to a typical hypolimnion. The epilimnion is thus eliminated. It is sometimes argued that such a condition should not be designated as a thermocline. However, since it is typical in all respects save the presence of its upper limit at the surface, there seems to be some justification in regarding it as a thermocline. The writer has found this phenomenon only as a temporary condition. It is said to appear occasionally as a local and temporary phenomenon in Lake Erie. An extensive calm seems to be a necessry element in the existence of such a situation. Ordinarily, it is of rare occurrence.

1.3.8 Diminutive stratification

Under special conditions, very shallow water, sometimes not more than 0.5m. In depth may show a typical diminutive thermal stratification. Complete protection from surface disturbance, as, for example, in a small, almost completely enclosed cover, and certain bottom conditions which seemed to function in helping to keep the bottom water cold (large amounts of semi suspended and suspended materials) appear to be important factors in those instances observed by the writer.

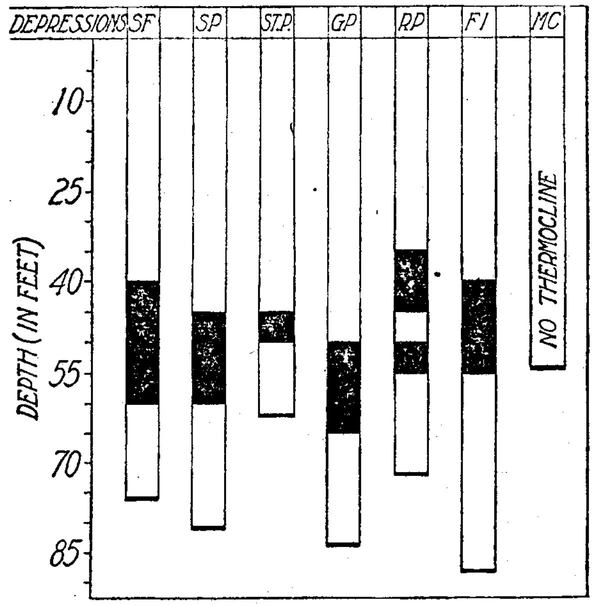

FIG.-. Diagram showing depression individuality in thermal stratification as exemplified in Douglas Lake, Michigan. Aug. 12, 1922. Each vertical column represents a vertical section through the region of maximum depth of each of the seven, isolated, submerged depressions within the main lake basin. Shaded blocks in each column indicate the positions of the thermocline. Each depression is acting independently. Letters at top of columns are abbreviations for names of the depressions. One depression (*RP*) shows both a primary and a secondary thermocline on this date.

2. Partial or complete absence of thermal stratification in lakes having large inflow of cold, heavy, mountain water and large outflow. Certain lakes of northern Italy are said to lack the typical thermal stratification for this reason.

3. Submersed depressor individuality. In lake basins which contain in the general basin, isolated depressions separated completely from each other by relatively shallow water, it may happen that each depression acts as a separate unit or as if it were a separate lake, except that all such depressions in the same lake possess essentially the same epilimnion. Each depression may have its own thermocline which differs in position and thickness in the different depressions and each depression may have its own individual seasonal history. Furthermore, certain depressions may stratify thermally, while certain ones nearby and of similar depth and exposure may not stratify at all. Douglas Lake, Michigan, manifests this depression individuality in a striking way in its six, major, submerged depressions, and instances in other lakes are now known. Obviously, temperature records made in one depression of a multiple depression lake basin would not give a correct picture of conditions in that lake.

1.3.8 Terminology of Thermal Stratification

The terms *epilimnion* and *hypolimnion* were first proposed by Birge in 1910 and have had almost universal adoption in work on lakes, but several names are applied to the thermocline. The term *thermocline* was first used by Birge in 1897 as equivalent to the German term *Sprungschicht* employed earlier by Richter. Later, Weddeburn proposed the term *discontinuity layer.* Since then, the terms *transition some, mesolimnion,* and *metalimnion* have been proposed. It is sometimes referred to in French as the *couche desaut thermique.* However, the term *thermocline* is now so widely used that it will probably continue to be the approved designation.

Since the terms epilimnion and hypolimnion, because of their derivation, are not strictly applicable to the sea where thermal stratification is occasionally found, Atkins (1925) has proposed the term *epithalassa* for the upper stratum and *hypothalassa* for the lowest stratum of the sea but retaining the term *thermocline* for the for the intermediate stratum.

Summer Stagnation Period.

When thermal stratification is permanently established, the lake enters upon what is known as the summer stagnation period, so named, probably, because the water of the hypolimnion becomes "stagnated" for the summer and at least part of the autumn. Birge has expressed the condition of the summer stagnation period as follows:
During the summer, then , our typical northern lakes really consist of two lakes, one superimposed on the other: first, the lake above the thermocline, whose temperature is high and whose water is kept in active movement by the wind; and below this, the stagnant mass of water below the thermocline, having a low temperature, denser and more viscous than the upper water, in which the gaseous and other products of decomposition are accumulating and from which they are only slowly and partially discharged.

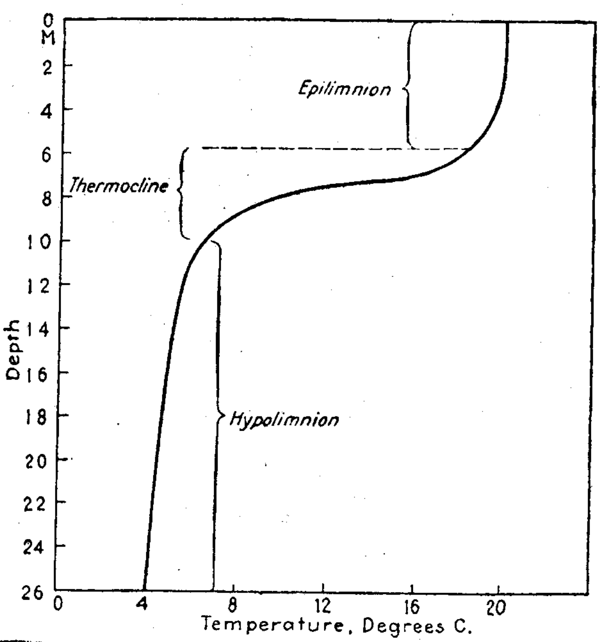

Fig. Curve representing a typical vertical distribution of temperature during the summer stagnation period in a temperate lake of the second order. The form of the curve characteristic of the usual condition in thermal stratification.

1.3.9 Fall Overturn

With the passing of summer and early autumn, declining air temperatures begin to cause a cooling of the surface waters of the lake. Water thus cooled and rendered heavier sinks, and convection currents are set up so that the temperature throughout the epilimnion is equalized and lowered. This lowering of temperature progresses until the epilimnion comes to have as low temperature as has the upper part of the thermocline; then successively it attains the same temperature at the various deeper levels in the thermocline, and finally it drops to the same temperature level as the hypolimnion, and then the whole lake becomes homothermous and consequently of the same density. Conditions are now such that wind action can circulate the water from top to bottom, with the result that the whole lake takes on a uniform character in all of its various strata.

If the hypolimnion maintains during the summer a temperature higher than 4^{0}C., the overturn will begin when the water of the epilimnion and thermocline falls to that higher temperature, but the circulation will continue while the whole lake cools down to 4^{0}C. by the formation, sinking, and mixing of colder, heavier water at the surface. Essentially, the fall overturn is a repetition of the spring overturn, the only outstanding difference being that the former is terminated by declining air temperatures and not by increasing temperatures. That the total mass of water is stirred thoroughly in a complete, typical overturn is clearly demonstrated by the resulting physical, chemical, and, to a certain extent, biological uniformity of the water during the period of the overturn.

Like this spring overturn, the fall overturn usually continues for a considerable but variable period. In Michigan lakes the period is known to have a variation of 3 to 8 weeks. Its duration depends upon the general rate of decline of air temperatures. Seasons vary greatly with respect to the date of onset of ice cover. Delayed ice cover usually results in prolonged fall overturn. A fall-overturn period of several weeks and the usual autumn winds ensure that again the lake is thoroughly mixed from top to bottom.

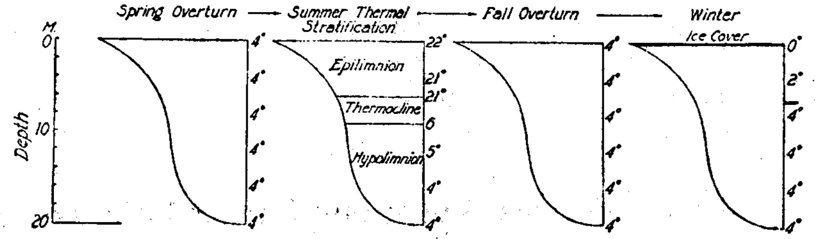

FIG. Diagrams showing essential temperature relations in a temperate lake of the second order, during the four principal seasons. Numbers to the right of each diagram represent the temperature conditions from surface to bottom expressed in degrees centigrade. Various detailed values used in these diagrams, such as depths, temperature decline in the thermocline, and temperature distribution, differ in different lakes, but the essential features in this seasonal cycle remain the same in temperate lakes of the second order.

Winter Stagnation Period.

Declining air temperatures in early winter lower the temperature of the surface water until it falls below 4^0C., after which the water becomes colder but progressively lighter. Being lighter, It no longer sinks but remains at the surface. When compared with the summer stagnation period, the temperature conditions are just the reverse the warmer water is at the bottom with the cold water on top but with respect to density the conditions are the same, i.e., the lighter water is at the top. Ultimately, the permanent ice cover forms on the surface and blankets off the lake completely from wind disturbances; then the whole like resembles, in a general way, the hypolimnion of the summer stagnation period.

Coleman (1922) describes the consequences which would result if that peculiar property of water of becoming lighter instead of heavier on cooling below 4^0C. Were absent as follows:

If water followed the usual law when cooled below 39.20 (40^0C.), it would sink to the bottom instead of remaining at the surface, and at length the whole body of water would reach the freezing point of 32^0 (00C), when ice would be formed and, being heavier than water, would accumulate at the bottom. During a long winter, the whole lake would be transformed into a solid block of ice ... some of the surface ice would thaw in the summer, but in deep lakes the lower parts would be perpetually frozen.

A very thin layer of water just below the ice is near freezing temperature, and, for a relatively short distance below, the rise in temperature is rapid, up to about 30C. From that point on to the bottom, the rise in temperature may be very slight. This vertical temperature distribution, when plotted in the usual way, gives a graph which in mere form has a certain resemblance to the curve of thermal distribution during the summer stagnation period, except that the curve is reversed and lacks the epilimnion portion. This condition is sometimes spoken of as an inverse stratification, but it falls far short of the stratification of the summer period, and it is an open question whether it should be referred to as a true stratification.

The temperature of the bottom waters, during this period, depends upon local circumstances. In the deeper lakes, it tends to be at or near the temperature of maximum density (4.00C); in shallow lakes, it is likely to be colder than 40C., although exceptions may occur. Gain of heat through the ice and exchange of heat with the basin will be discussed later. Certain very important, far-reaching chemical and biological changes occur during the winter stagnation period which, in some respects, represent a close parallel to those of the summer stagnation period. These will also be described in a subsequent chapter,

1.3.11 Thermal stratification in the Great Lakes and Larger Bodies of Water

That large bodies of water tend to manifest thermal stratification seems evident from what is now known. However, the great mass of water makes possible certain influences not present to any important degree in inland lakes, as, for example, the much greater depths to which wave action may extend, and the existence of vertical currents of considerable magnitude. Such influences, particularly the large vertical currents, interrupt a thermal stratification or prevent it from forming.

While the whole subject of thermal stratification in vast bodies of water is still in a formative stage, it appears that in such waters there is no continuous thermocline extending from one shore to the other, as is the case in the inland lakes of the first and second orders, but instead it is formed only in certain regions. A well-defined thermocline was found in the eastern portion of Lake Erie (Parmenter, 1929) and in Lake Michigan (Church 1942, 1945). Eddy (1943) found no thermocline in western Lake Superior. Regional thermoclines may occur at certain times and places, in the Great Lakes may be obtained from the fact that summer records from the deeper parts show bottom temperatures at or very near 40C.; also that the surface waters of Lakes Ontario, Erie, Michigan, and Huron usually warm up in summer to about 20C. (variations in both directions) so that the difference between bottom and surface temperature is ample for the formation of thermal stratification, whenever the disturbing influences of such vast lakes will permit. In Lake Superior, surface temperatures in summer are ordinarily somewhat lower, but even there regional thermal stratification may occur.

Its has been found that the temperature of the lowermost water in certain deep lakes is below 40C. Kemmerer, Bovard, and Boorman (1923) reported that in Crater Lake, Oregon, the water temperatures decreased from 3.90 at 100 m. depth to 3.50C. At 600 m. depth. Similar phenomena have long been known for the very deep waters of certain European lakes and similar ones have been found in the Great Lakes (Wright, 1931: Eddy, 1943) and in certain Japanese lakes (Yoshimura, 1932). Without doubt, this reduction of temperature below 40C. is the result of pressure Physicists have already established the fact that water at maximum density under pressure exhibits temperatures below 40, however, since the abyssal temperatures are not so low as those which accompany the physical effects of pressure on pure water under experimental conditions deep-water temperatures may be the outcome to pressure modified by other influence not yet understood.

It is intresting to note here that thermal stratification occurs, at least to a limited extent, in the oceans. It is a well-developed phenomenon in the English Channel where a definite thermocline occurs at times during the summer; also in October or November, the waters become homothermous from top to bottom. Oceanographic literature contains several records of vertical temperature distribution in the open ocean which when plotted in the usual way yield curves whose shape is that of a typical thermal stratification curve. Hentschel reported a thermocline in the Atlantic Ocean at a depth of 100 m.

1.3.12 Thermal Stratification in Tropical Lakes

It has been reported (Ruttner, 1931) that in tropical East India (Java, Sumatra, and elsewhere) smaller lakes with areas of about 0.4 to 0.8 sq. mile have distinct thermoclines but that in larger lakes where the wind action has greater effect, thermal stratification is less marked. It should be noted, however, that while it is claimed that thermal stratification occurs, and while Ruttner's curves are so drawn that they have the characteristic shape of an epilimnion-thermocline-hypolimnion curve, the fall in temperature within the region referred to as the thermocline fails to qualify as a thermocline under-Birge's rule (temperature decline of 10C. or more per meter). During the period over which these lakes were studied by Ruttner, the contrast between bottom and surface temperatures was only about 4.50C., sometimes less, even in lakes of considerable depths.

The thermal resistance is, therefore, small, and this so-called thermal stratification is easily eliminated by wind action. If Ruttner's curves had been so drawn that the space units on both ordinates and abscissas were of equal dimension, as is commonly done, the curves would have little resemblance to those representing a typical thermal stratification. Examinations of tropical African lakes (Worthington and Beadle, 1932) have demonstrated no thermoclines in large ones, such as Lake Rudolph, Lake Victoria Nyanza, and others, although in one large lake (Lake Edward; area, 580sq. miles; depth, 117m.), a definite thermocline at 40 to 66 m. was found. But this is interpreted by the discoverers not as a true thermocline but as due to a heavier layer of more saline water introduced by rivers from surrounding volcanic regions or from underground sources and prevented from mixing by its greater density.

Few limnologists find objections to Birge's definition of the limits of a thermocline. Some of them contend that a stratum of water, irrespective of the amount of fall of temperature within it, be it ever so slight, which contains sufficient density difference (thermal resistance) to establish any kind of thermal stratification should be designated as a thermocline. Such an interpretation provides no specific limits and inevitably leads to uncertainty. An extreme departure from common usage is that of Hutchinson (1941) who, apparently for certain purposes at least, prefers to regard the thermocline as a plane chosen at the lower termination of the epilimnion. It seems likely that some of the reported occurrences of thermal stratification in tropical lakes and elsewhere were based upon unusual criteria for identifying thermoclines.

1.3.13 Modified Thermal Stratification

Many departures from typical thermal stratification have been described. They arise from the great array of conditions under which lakes exist. Names have been given to some of these atypical temperature conditions, as, for example: Dichothermy summer stratification with minimum temperature at some intervening level, sometimes in upper part of hypolimnion, instead of the usual minimum at bottom; sometimes called temperature inversion phenomenon; may be either temporary or permanent. Mesothermy maximum temperature at some intervening level; may occur in late summer or early autumn; temporary. Poikilothermy both maximum and minimum temperatures in some intervening layer; said to occur on warm days following a cool period; temporary.

Expected Questions:

1. Give an account on Thermal stratification.
2. What is spring overturn? Describe it's role in Thermal stratification.
3. Define the terms Epilimnion and Hypolimnion.
4. Describe the process of Diminutive stratification.
5. Describe the Thermal stratification in tropical lakes.

Dr. K. VEERAIAH

Lesson 1.4

Light

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1.4.1 Introduction

One of the most obvious and familiar properties of water is its transparency. Natural waters manifest great differences in the degree to which sunlight can illuminate them. The extremely turbid waters of the Missouri River and some of its tributaries offer striking contrast to those mountain lakes in which light penetrates to unusual depths. Also, many natural waters show seasonal and irregular variations, due to several possible causes, in the degree to which they permit passage of light. Light exerts a very profound influence upon a whole series of biological phenomena in water, but, despite its fundamental importance, inherent difficulties involved in the perfection of methods and instruments for measuring light in water, qualitatively and quantitatively, have long resisted solution, and this subject is still among the least satisfactorily known of the important limnological influences.

1.4.2 Light Penetration and Light Absorption

Methods of Measurement. Limit of visibility methods: Sechi's Disk. In 1965, A. Secchi of Rome, Italy, devised a method for studying the transparency of the waters of the Mediterranean Sea. It consisted in lowering into the water a white plate, 20 cm. in diameter, on a graduated rope, noting the depth at which the plate disappeared, then lifting the plate and noting the depth at which it reappeared. The average of these two readings on the graduated rope was considered the limit of visibility. Later, Forel used the same method, employing either a white zinc disk or a white crockery plate, and pointed out conditions under which such tests should be made to secure best results. This method was subsequently used by many investigators. Whipple modified the method by dividing the disk into guardant and painting them in such a way that two of the quadrants which were directly opposite to each other were black and the intervening ones white. He also increased the efficiency of the method by viewing the disk, as it sank in the water, through a water telescope held under a sunshade.

This method has come into a wide use as a means of comparing different waters. Obviously, it is not an actual measure of light penetration, but, instead, merely a useful, rough index of visibility when used under standard conditions. It is also useful in making comparisons of the same waters at different times. See Welch (1948) for further information.

1.4.3 Geneva Commission Method

In 1883, the Physical Society of Geneva Switzerland, established a committee for the study of transparency in Lake Geneva. This committee made use of a method the essential feature of which is the substitution of an incandescent lamp for the white disk of Secchi. The point of disappearance of the bright spot (the lamp was designated as the limit of clear vision, while the subsequent disappearance at a lower level of the last vestige of the surrounding glow of diffused light was specified as the limit of diffused light. This method has the same limitations as that of Secchi's disk, and it's had had a very restricted use.

1.4.4 Photographic Methods

Early methods. In 1873, Forel, hoping to make use of the well-known fact that silver chloride (a white precipitate) blackens when exposed to light, tried lowering a bottle of this substance into water for known depths and exposures, but the results were not satisfactory. He later devised small, square frames which could be suspended horizontally on a rope and in each of which a sheet of sensitized albumen paper was so placed that one-half of its surface was exposed and one-half was protected against light action this equipment, lowered into the lake at night and brought up the next night, enabled the observer not only to determine the depth at which no light effect occurred on the photographic paper, but also, some effect of light intensity at different depths was distinguishable in the degree of change in the sensitive paper. Not only did the exposed and unexposed portions of the sheet provide means of judging degree of light effect, but an additional aid was devised in the form of a photographic intensity scale made by exposing sheets of the same paper to sunlight, in air, for different lengths of time.

During the three decades succeeding the work of Forel, many photochemical devices were invented the more important of which have been discussed by Klugh (1925). Many of these early instruments are preserved in the Oceanographical Museum of Monaco and afford an interesting picture of the evolution of effort in this direction. While increasing perfection and ingenuity of method are exhibited in this early history, all of the devices fell short in one or more respects. However, it appears that for securing records of that faint light which penetrates to great depths, photographic methods are the best yet know.

Recent Methods Knudesen (1922) proposed a method the essential features of which were two spectrophotometers placed on a line, one above the other, the distance between them representing the thickness of the layer of water to be examined. A system of slits made possible the determination of the coefficient of absorption for each region of the spectrum through the effect on a photographic plate.

Klugh (1925) devised an instrument the principle of which is the use of panchromatic photographic plates "exposed beneath a set of neutral percentage transmission filters, the plates exposed to the lower intensities being read against the plate exposed to the highest intensity, the results being given directly in percentages." The instrument is said to measure both total intensity and the spectral quality of light in water and to be sensitive to radiation representing most of the visible spectrum.

Certain other modifications of the photographic method have been devised during recent years but need not be described here.

1.4.5 Photoelectric Cell Methods.

One of the promising developments of recent years is the use of photoelectric cells in measuring penetration of light into water. Shelford and Gail (1922), Atkins and Poole (1930), and others have made extensive use of various forms of instruments in which the photoelectric cell was the essential feature and have, from time to time, made certain improvements. The principle of the photoelectric cell is described by Shelford as follows:

All metals emit electrons under the influence of light. This emission depends upon the kind of metal, upon the condition of the surface, and upon the surrounding conditions. In most cases, the emission is imperceptible. By using a very active metal, such as strontium, rubidium, caesium, lithium, sodium, or postasium, and placing it in a vacuum or, much better, in an atmosphere of helium, hydrogen, or argon, the photoelectric effects become very considerable with a potential of 20 to 300 volts across the cell.

Gas-filled cells are said to be sensitive to all wave lengths except red but only slightly sensitive to yellow and extreme ultraviolet. It appears that the most promising use of these cells is due to their greater sensitivity for the short wave lengths (violet, blue, green). These instruments are undergoing a rapid evolution at the present time, and perhaps their complete possibilities are not yet known. Detailed description of a modern photoelectric cell outfit designed for work in water is given by Welch (1948).

1.4.6 The Pyrlimnometer

Birge and Juday (1929, 1931) developed an instrument known as a Pyrlimnometer. The first instrument, described by Birge in 1922, has undergone numerous improvements. In its present form, its essential features are

1 at large-surface Moll thermopile, mounted in a special carrier; this thermopile receives the solar radiation; 2 apparatus for measuring the electrical currents thus caused. Two types of measuring instruments are employed; A Millivoltmeters to be taken out in the boat with the Pyrlimnometer; B a galvanometer, for special studies, to be set up onshore and connected by an insulated cable with the boat the carrier of the thermopile has a rotating shutter, with eight openings, which may be open or may carry opaque disks or light filters. The filters are of Jena glass. The sun's radiation, acting on the thermopile, produces an electrical effect, registered on the recording instrument, which is proportional to the energy of the sun's radiation. Thus, this instrument measures sun's energy penetrating lake water to a given level. It furnishes data on transmission through lake waters of light and heat; it also gives the composition of the visible spectrum in water, in terms of either wave length or color bands, and the changes in composition which the spectrum undergoes as light passes through lake waters. The apparatus is designed for use in small inland lakes and has been much used by Birge and Juday in such waters.

1.4.7 Factors Influencing Light Penetration.

Several factors affect the way in which light illuminates natural waters. The following are important;

1. **Intensity at Surface:**

The intensity of illumination at the surface of water varies with a number of circumstances, such as degree of cloudiness or clearness of sky, presence of fog, smoke, dust, or other occasional features of atmospheric condition, time of day, and season of the year. Some of these variations are cyclic, such as the alternation of day and night; others are irregular meteorological phenomena; and still others originate in various ways moonlight is known to illuminate water to some extent; also starlight in a much more limited way; but these sources of light are likewise subject to variations in intensity at the surface. Strictly speaking, light intensity at the surface of natural waters is highly variable, and periods of uniform intensity are of limited duration are of limited duration. it should be understood that on a clear day, the light reaching the surface of the water is the sum total of the light coming 1 directly from the sun and 2 from the hemisphere of the sky. Clouds passing across the sun produce alterations in the relative amounts of light from the two sources.

2. **Angle of Contact of Light with surface:**

Light rays meeting the surface of water at right angles pass into it without deviation from the original axis. If, however, the angle of contact is less than 900, those rays passing into the water are refracted, i.e., bent toward the perpendicular. The refractive index from air to water is about 4/3, or 1.33. It is therefore evident that the position of the sun with reference to the surface of water is concerned with the depth to which light will penetrate. The greatest penetration in a body of water would result from zenith sun. As the sun departs from the zenith, the rays on entering the water, even though bent toward the perpendicular, penetrate in a diagonal direction and hence to shallower depths.

In general, when light waves encounter the surface of water, a part of light will be reflected, and another part will enter the water and become refracted. This is true under practically all conditions, but the nature of the reflection depends upon the angle of the rays with the general water surface and also upon the degree of agitation of the water surface since water is so commonly in a state of disturbance of some sort, varying from the most gentle swings to severe wave action, at least a part of the reflection is usually a very irregular, momentary feature owing to this common motion of the water surface, light at a given time may, in a series of successive moments, meet the surface film momentarily at a given time may, in a series of successive moments, meet the surface film momentarily at many different angles of incidence; hence, the irregularity of the reflection. Even in times of greatest calm, there is a certain change of surface level; i.e., it is never absolutely immobile. Therefore, under no circumstances would all of the light impinging upon the surface enter the water; some is always reflected.

3. Differences in Latitude:

Obviously, latitude determines the relation of a lake surface to the general incidence of light from the sun. the more remote a lake is from the equatorial region the greater the departure of the sun's rays from the vertical.

4. Seasonal Differences

Closely associated with latitude are the seasonal changes in the position of the sun. only locations at or between the tropics of Cancer and Capricorn (23^{0}28'N. lat. And 23028'S. lat., respectively) ever have a vertical sun. Beyond this zone (torrid), north or south, not only do locations have an angular sun but the angle changes progressively with the sequence of seasons.

5. Diurnal Differences

The apparent daily journey of the sun from east to west results in its rise in the sky from the horizon to the meridian for a chosen location and a succeeding drop across the sky to the western horizon. Therefore, the angle of contact of light rays increases, in an east-west plane, from 0 to 90^{0} and then declines to 0in the evening. The angle of contact of light with the water surface is constantly changing during the day, reaching its nearest approach to the zenith at noon.

6. Dissolved Materials

Natural waters differ from pure water in the way in which they absorb light; also, natural waters differ widely among themselves in this respect. Dissolved materials constitute one of the influences responsible for this difference unfortunately, too little is yet known concerning this subject It has been claimed that chlorides of calcium and magnesium and similar salts diminish light absorption traces of ammonia, proteins, and nitrates in solution in pure water are said greatly to reduce its transparency to ultraviolet light, whereas dissolved salts usually have little effect. Differences in light transmission between ordinary "hard water" and "soft water" lakes, assignable to the mineral content of their waters, are apparently minimal. That dissolved gases have an influence is probable, but at present little seems to be known about it.

7. Suspended Materials

Finely divided materials in suspension, organic or inorganic, tend to screen out light. These materials will be discussed more fully under the subject of turbidity. In general, the more suspended matter in water the more completely is light shut out. In very highly turbid waters, light seems to be excluded by a relatively thin stratum at the surface.

1.4.8 Light Penetration in Pure Water

Since natural waters have various substances and circumstances associated with them which affect light penetration, it is better to approach the subject by considering first the phenomena of light penetration and light absorption in pure water. In this way, the inherent, unmodified effects of water alone upon entering light may be distinguished.

When light enters pure waters, two changes occur; 1) a certain part of the light is absorbed by the water, and 2) some of the light undergoes a scattering within the water, this scattering being in the form of a deflection in all directions. Absorption is a selective performance in which certain wave lengths are absorbed more quickly than others. It has been estimated (Shelford and Gail, 1922) that very small quantities of the violet, blue, green, and yellow penetrate to a depth of at least 1,800 m. of pure water.

Light Penetration in Natural Waters:

Early work on light penetration was concerned, by interest and by limitations of method, with the depth to which any light was transmitted, without reference to selective absorption. Also, it was concerned almost wholly with marine waters whose transparencies are greater than those of most fresh waters. Some of the early records will now be mentioned. Forel (1895) found light affecting his photographic apparatus in Lake Geneva at 200 m. depth. Fol and Sarasin, using a photographic-plate method, obtained light effects at a depth of almost 480m. in the Mediterranean Sea near the Riviera. Petersen, also working in the Mediterranean near Capri, got light influence on a photographic plate at a depth of 550m. Luksch obtained a photographic effect in the eastern Mediterranean at 600 m. by means of an improved photographic apparatus (Helland-Hansen photometer) used in the Atlantic Ocean during the Michael Sars Expedition, records of light penetration to a depth of 1,000 m. after an exposure of 80 min. were secured (noon, June 6, 1910, clear sky, near Azores), a depth much greater than had formerly been found; but an exposure of the same apparatus at 1,700 m. for 2 hr. yielded no light effect. Somewhere between these depths, light, as determined by this type of apparatus, faded out completely. Photographic evidence of light at 1, 500 m. has since been found. Early workers also discovered that the length of "day" in water is very different from that in air; that this day varies in duration with depth; and that the dawn and twilight periods, present in air, are virtually absent in water.

Modern Records:

It appears that methods employing photographic plates or photographic paper are probably the best for securing records of that very feeble light which is transmitted to great depths.

However, in modern work, the interest has shifted from a desire to know the depth of final disappearance of all light to the more fundamental matters of light absorption in the upper strata. For that reason, little has been added to the knowledge of greatest depths of penetration. Beebe reported the disappearance of all color from the spectrum at a depth of 213 m. in the Atlantic Ocean near the Bermuda islands.

There is a general law sometimes employed in estimating the rate of diminution of light with increasing depth in a body of water, viz., that as the depth increases arithmetically the light decreases geometrically. Occasionally, the actual conditions in a lake tend to follow this law, but caution should be exercised in using it as the general expectation since modifying influences are many, and departures from values given by this law are common and often marked.

Because of the various factors and combinations of factors which affect light penetration in natural waters, inland lakes vary widely in the way in which they transmit light. In the large number of lakes in Wisconsin studied by Birge and Juday, the depth at which the amount of radiation delivered at the surface would be reduced to 1 per cent varied from about 1.5 to 29 m., with various intergradations between them. Without doubt, even wider variations exist.

1.4.8. Qualitative Determinations

The selective absorption, characteristic of pure water, is manifested by natural waters, modified by those additional factors already mentioned which affect absorption. Since these modifying influences vary so widely in different waters, only a very general statement of the usual character of selective absorption can be given here for fresh-water lakes. A considerable study of this phenomenon in sea water has been made by various investigators, and while in some respects sea water and fresh water behave similarly in light absorption, there are certain inherent differences. In this discussion, attention will be confined largely to the results from fresh water. Birge and Juday (1930), in their work on more than 30 Wisconsin lakes, found that the general story of changes in the composition of the sun's radiation as it passes through the waters of these lakes is as follows:

1. In lakes containing heavily stained water, very little radiation of wave lengths less than 6000 A0 occurs below a depth of 1 m.: the blue is negligible, the amount of green is very small and disappears rapidly as depth increases, and the same is true of the adjacent region of the yellow. The red may be higher than any other color in fact; it may equal or exceed all other radiation. The red is less affected by stain and by suspended matters, and, in waters where stain and suspended matters are at a maximum, the transmission of red may be higher than any other color. In such lakes, the radiation at and below 1 m. depth comes from that part of the spectrum whose wave lengths are greater than 6000 A^0.

2. In lakes of moderate transparency, the central part of the spectrum (about 5500 A^0; yellow) has a much greater transmission than either end, although both red and blue are present. Radiation passing through a few meters of water contains very little from the blue or the red, although there is more of the latter.

3. In the most transparent lakes, blue exceeds the red. The shortwave half of the spectrum contributes much at all depths, and radiation from the whole region, extending to wave length 5700 A^0, is transmitted through the water at much the same rate.

1.4.9 Light Penetration through Ice Cover

Ice cover interposes a partial barrier to light penetration, the effectiveness of which depends upon circumstances such as thickness of the ice, its degree of transparency, and the presence or absence of accumulated snow on its surface. It has already been pointed out that a lake accumulates heat during the winter from the sun's rays that pass through the ice. Some of the sun's energy penetrating the ice is in the form of light. Detailed knowledge of this whole subject is still imperfect although a few studies have been made by the use of modern techniques for measuring light transmission, one of the latest being that of Greenbank (1945) from which the following quotation is taken:

It is readily apparent that the penetration of light through ice varies greatly with the condition of the ice. For example, 71/2 in. of clear ice transmitted 84 per cent, as against 22 per cent for 71/2 in. of "partly cloudy" ice. This ice was full of minute air bubbles, which gave it somewhat the appearance of opal glass, and rendered it probably as opaque as any ice likely to be encountered on natural waters, except that which might have inclusions of dirt or other foreign matter. Similarly, the "clear" ice just mentioned was probably as crystal-clear as any which ever freezes on inland lakes. Between these two extremes, the ice of most lakes, varies greatly in character, and in ability to transmit light, depending on the manner in which it was frozen, on various thaws and refreezings, and so forth.

Green bank also found that ice may have a differential effect upon qualitative transmission of light, depending upon the physical character of the ice itself. Clear ice seemed to produce no significant differences in the relative transmission of light of different colors, but turbid ice caused a distinctly lower relative penetration of blue light, a result which he attributed to the effect of air bubbles and other inclusions.

Snow accumulation on the surface of ice are common, and when present they act as an additional even more effective barrier to light, thus reducing to varying degrees the amount of light which reaches the snow-ice interface. Snow reduces the initial sunlight in two principal ways: 1) reflection from the surface of snow greatly exceeds that from the surface of water or ice; 2) light entering the snow is rapidly shut out. According to Greenbank, only a very small amount of light penetrates through a layer of snow a few inches in thickness. It appears reasonably certain that heavy snow fall, in its ordinary physical state, may for the time practically prevent all light from reaching the underlying ice. Snow is also said to have a differential effect upon the quality of light which penetrates it, apparently effecting a greater reducing in the red and blue portion of the spectrum.

1.4.10 Color of Water

The following substances are said to play a part in producing color in natural waters:

1) Iron, as ferrous sulphate or as ferric oxide, produces various shades of yellow depending upon the amounts present.

2) Humic matters, originating from peat deposits, produce colors varying, with increasing amounts, from blue through green, yellow, and yellow brown to dark brown.

3) Large quantities of calcium carbonate are claimed to produce a green color.

4) Carbon and managanese are supposed to be involved in color production, but the exact effect is uncertain. Juday and Birge (1933) found a definite correlation between the brown color of bog and marsh waters and the amount of organic carbon in the surface waters. Color production by some of the substances mentioned above has been denied outright by certain investigators. According to James and Birge (1938), all colors found in lake waters, subsequent to setting, are originally colloid in their nature or are associated with colloids; hence such colors are reducible by filtration. It seems certain that the whole matter of color production in water is a very complex one and is still badly in need of critical study.

In some lakes, the color is essentially the same at all depths from surface to bottom; in others particularly the brown lakes, there may be a very distinct increase in the brown color with increasing depths, increases being due to such causes as the increase of vegetable stain or of iron in the lower waters.

Changes in color with season are well known. Some of these are rhythmic; for example, certain waters have two periods of maximum color (May or June and November or December) and one of minimum color in each of the intervening periods. Other changes are irregular, such as those produced by rainfall.

That colored water bleaches on exposure to direct sunlight seems to be well established. According to Whipple, certain waters lose 20 per cent of the original color by 100 hr. Exposure to sunlight, and complete color loss results from long exposure to sunlight, and complete color loss results from long exposure. Such bleaching is most effective in the surface layer and diminishes rapidly with increasing depth. This bleaching, if and when it occurs, bears directly upon several important limnological phenomena.

Color of water is determined by comparing a sample with some form of colorimeter. Long ago, Forel devised a set of color standards by mixing in various proportions two aqueous solutions, one containing copper sulfate and the other potassium chromate. His color chart contained 11 graded colors raining from the deep blue of the copper sulfate solution alone to a distinct yellow produced by a mixture of the two solutions in which the yellow solution (potassium chromate) predominated. Forel's color scale was the basis for measurement of color in natural waters for many years, and even yet there is an occasional mention of it in the current European literature. Two different methods are commonly used in America at the present time, viz.,

1. the platinum-cobalt standards method, the essential feature of which is a series of color standards method, the essential feature of which is a series of color standards prepared by the progressive dilutions of a solution containing potassium chlorolatinate; and
2. The U.S. Geological Survey field apparatus in which the color standards are colored glass disks, calibrated individually to correspond to the colors of the platinum-cobalt scale. It should be noted hat in spite of the distinctions commonly made between the true and the apparent color of water, field practice often consists merely in the measurement of color in a sample taken directly from the water and without change of any sort, such as filtration or centrifuging to remove suspended matter.

1.4.11Turbidity

Turbidity is a condition of water resulting from the presence of suspended matter. Is conspicuous, but, as a matter of fact, all natural waters contain suspended materials, and therefore all are turbid, although the vary widely in the amount. The clearest of mountain lakes have a very low turbidity, while the Missouri River represents the opposite extreme. The timeworn statement that "there is not enough silt in the world to make the oceans turbid" is mere fiction, since the oceans are already turbid.

The sources of substances producing turbidity are innumerable. Any materials, finely divided or later becoming so, which find their way into waters contribute to turbidity, and the great array of materials which may get into a lake and the variety of ways of delivering such materials to a lake are such as almost to defy complete enumeration. Prominent among these materials are plankton organisms, finely divided substances of organic origin, and silts.

From the point of view of their relation to water, turbidity-producing substances may be divided into two groups, viz., the settling suspended matters and the non settling suspended matters.

1.4.12 Setting Suspended Matters.

Those substances which in motionless water will sooner or later settle to the bottom are known as the seitling suspended matter. Certain materials settle very slowly; others settle with considerable promptness. Rate of setting is determined largely by the specific gravity of the particle, by the size of the particle, by the ratio of surface to volume of the particle (shape), and by the viscosity of the water.

Table Rate of Settling in Pure, Still Water[1] Temperature of water, 50^0 F.; specific gravity of particles, 2.65; shape of particles, spherical

Material	Diameter, mm.	Hydraulic subsidling value, mm. per sec.	Time required to settle 1 ft.
Gravel	10.0	1000.0	0.3 sec.
Coarse sand	1.0	100.0	3.0 sec.
Silt	0.01	0.154	33.0min
Bacteria	0.001	0.00154	55.0 hr
Clay	0.0001	·0.0000154	230.0 days
Colloidal particles	0.0001	0.000000154	63 years

1 Reprinted by permission from Whipple, 'the Microscopy f drinking water, '4th ed., John Wiley & Sons, Inc., 1927.

The substances mentioned above represent but one class of particles (on basis of specific gravity0 and must be regarded largely as suggestive only. In every lake and at all times of year, there is a continuous settling through to the bottom of particulate matter. This continuous rain of material varies in amount from to time, and without doubt the settling is a differential one depending upon the various conditions expressed in Stokes's law. Furthermore, it may well be that cretin additional influences are also operative, as, for example, the effect of surrounding particles upon a single particle in the sinking performance. Unfortunately, almost nothing is known about the interrelation of the various particles as the whole mass settles through the water.

1. Delayed settling of fine, suspended matter in the epilimnion facilitates its oxidation and largely controls the character of other biochemical changes in the sediments which are dependent upon temperatures.

2. Delayed settling promotes a sorting and a selecting of sediments, since the various kinds of particles settle through a stratified liquid until they reach a layer approximating their own specific gravity; and

3. In the alkaline epilimnion and the neutral or even acid hypolimnion, the biochemical products and the resulting sediments differ accordingly.

During the complete overturns of spring and fall, circulation of the water to all depths brings about a temporary, uniform distribution of the suspended matters and may also return into suspension finely divided matters previously settled to the bottom. Some of these materials are so finely divided and the specific gravity so low that any small movement of the water is sufficient to bring them into suspension again. Therefore, the turbidity of a lake may be greatly increased temporarily at overturns, although not all turbidity at those periods is due to the overturn alone. The early portion of the spring overturn may coincide with.

1. The spring thaw when the turbidity is further increased by much inflow of surface water bearing large amounts of silt.

2. The spring maximum of plankton; and

3. Release into the water of he winter accumulations of wind-blown materials in and upon the ice. Likewise, the autumn overturn may coincide, in part, with.

   1. The autumnal plankton maximum.

   2. a period of increased wind-blown material; and

   3. Autumn rains. After the overturn is completed, settling out of much of the materials occurs rather quickly, and the water resumes a more transparent condition. In those lakes having either an incomplete overturn or none at all, the permanently stagnant deep waters, although not themselves circulating, become temporarily more turbid by the increased amount of sediment settling through from above at those times when the surface waters become markedly turbid.

Turbidity conditions during the winter stagnation period are usually different from those of other seasons. Ice cover not only shuts out windblown particulate matter, but it eliminates all surface disturbance, imposing dead-calm conditions upon underlying water. Furthermore, density-viscosity relationships ae altered. The colder, lighter, but more viscous water is at the top, while the warmer, heavier, but less viscous water is below. While little is known about the actual facts of settling of particles under these conditions in a lake, it seems likely that those particles at the top which will settle do so at about a uniform rate from top to bottom, since the temperature conditions, operating as they do on the specific gravity of the particles themselves, on density, and on the viscosity apparently about balance each other. It should also be remembered that the difference in temperature between top and bottom is but 4^0C.when bottom water is at maximum density; also, that it is changed viscosity rather than changed density that exercises the major effect upon the rate of settling.

The more or less constant wave action of the upper waters of a lake not only tends to slow down settling of suspended materials but also, as pointed out elsewhere, erodes and transports shore materials some of which are finely divided and become, at least temporarily, suspended matter in the water. Irregularities of turbidity thus arise from that continuously changing character of surface-water disturbance of which there is every possible intergraded from calm to violent storms. Irregularities also arise out of

1. Inflowing waters at one side of the basin.
2. Floods and droughts affecting inflowing waters
3. Sudden contributions of wind-blown material.
4. Plankton swarms and plankton drift.
5. differences in shore configuration; and other possible local circumstances.

1.4.13 Nonsettling Suspended Matters

In a very general way, these nonsettling materials may be divided into two classes:

1. Plankton organisms and coarsely divided, nonliving substances whose specific gravity is such that they are constantly suspended. Certain of these materials are so constituted that only strong centrifuging will pull them down. The plankton Alga *Gloeotrichia*, so common in many lakes, is an excellent example.

2. Very finely divided, nonliving materials and organisms of exceedingly small size, such as some of the very minute nannoplankton.

There is reason for believing that all natural waters contain a certain amount of nonsettling suspended matter, the amounts varying in different waters and varying from time to time in the same water; also, that these materials grade down in size of particle to that of true colloids. Materials in colloidal suspension may undergo flocculation, forming particles sufficiently large to sink eventually under the influence of gravity.

Dr. K. VEERAIAH

LESSON 1.5

ECOSYSTEM : CONCEPT, STRUCTURE AND FUNCTIONS

1.5.1 INTRODUCTION
1.5.2 ECOSYSTEM
1.5.3 POND AS AN ECOSYSTEM
1.5.4 WATER SHED UNIT
1.5.5 THE MICRO ECOSYSTEM
1.5.6 SPACECRAFT AS AN ECOSYSTEM
1.5.7 SUMMARY
1.5.8 EXPECTED QUESTIONS
1.5.9 REFERENCES

1.5.1 INTRODUCTION

Living organisms and their nonliving (abiotic) environment are inseparably inter-related and interact upon each other. Any unit that includes all of the organisms (i.e., the "community") in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and nonliving parts) within the system is an ecological system or **ecosystem**. From the trophic (fr. trophe = nourishment) standpoint, an ecosystem has two components (which are usually partially separated ins apce and time), an autotrophic component (autotrophic = self-nourishing), in which fixation of light energy, use of simple inorganic substances, and buildup of complex substances predominate, and a heterotrophic component (heterotrophic = other-nourishing), in which utilization, rearrangement, and decomposition of complex materials predominate.

Another useful two-category subdivision for heterotrophs suggested by Wiegert and Owens (1970) is as flows: *biophages*, organisms consuming other living organisms, and saprophages, organisms feeding on dead organic matter. As will be explained below, such a classification takes into consideration the time lag between consumption of living and dead matter.

From the functional standpoint an ecosystem may be conveniently analyzed in terms of the following: (1) energy circuits, (2) food chains, (3) diversity patterns in time and space, (4) nutrient (biogeochemical) cycles, (5) development and evolution, and (6) control (cybernetics).

The ecosystem is the basic functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth.

1.5.2 ECOSYSTEM

Since no organism can exist by itself or without an environment, our first principle may well deal with the "interrelation" and the principle of "wholeness" that are part of our basic definition of ecology. The term ecosystem was first proposed by the British ecologist A.G. Tansley in 1935, but, of course, the concept is by no means so recent. Allusions to the idea of the unity of organisms and environment (as well as the oneness of man and nature) can be found as far back in written history as one might care to look. Thus, Karl Mobius in 1877 wrote (in German) about the community of organisms in an oyster reef as a "biocoenosis," and in 1887 the American S. A. Forbes wrote his classic essay on the lake as a "microcosm." The Russian pioneering ecologist V.V. Dokuchaev (1846-1903) and his chief disciple G.F. Morozov (who specialized in forest ecology)[1] placed great emphasis on the concept of the "biocoenosis," a term later expanded by Russian ecologists to "geobiocoenosis" (see Sukachev, 1944). Thus, no matter what the environment (whether freshwater, marine, or terrestrial), biologists around the turn of the century began serious consideration of the idea of the unity of nature. Some other terms that have been used to express the holistic viewpoint are holocoen (Friederichs, 1930), biosystem (Thienemann, 1939), and bioenert body (Vernadsky, 1944). Ecosystem is as might be expected, the preferred term in English, while *biogeocoenosis* (or *geobiocoenosis*) is preferred by writers using the Germanic and Slavic languages. Some writers have attempted to make a distinction between the two words, but as far as this textbook is concerned the two are considered to be synonyms. "Ecosystem" has the very great advantage of being a short word which is easily assimilated into any language!

The concept of the ecosystem is and should be a broad one, its main function in ecological thought being to emphasize obligatory relationships, interdependence, and causal relationships, that is, the coupling of components to form functional units. A corollary to this is that since parts are operationally inseparable from the whole, the ecosystem is the level of biological organization most suitable for the application of systems analysis techniques, a subject to be dealt. Ecosystems may be conceived of and studied in various sizes. A pond, a lake, a tract of forest or even a laboratory culture (micro-ecosystem) provide convenient units of study. As long as the major components are present and operate together to achieve some sort of functional stability, even if for only a short time, the entity may be considered an ecosystem. A temporary pond, for example, is a definite ecosystem with characteristic organisms and processes even though its active existence is limited to a short period of time. The practical considerations involved in delimiting and classifying ecosystems will be considered later.

One of the universal features of all ecosystems, whether terrestrial, freshwater, or marine, or whether man-engineered (agricultural, etc.) or not, is the interaction of the autotrophic and heterotrophic components, as outlined in the Statement. Very frequently these functions and the organisms responsible for the processes are partially separated in space in that they are stratified one above the other with greatest autotrophic metabolism occurring in the upper "green belt"

[1] Dokuchaev's chief work, reprinted in Moscow in 1948 was *Uchenie o zonax prirody (Teaching About the zones of Nature)*. Morozov's chief book is Uchenie o lese (Teaching About Forests). We are indebted to Dr. Roman Jakobson, Professor of Slavic Languages at Harvard University, for information on these two works which are but little known in the United States.

stratum in which light energy is available and the most intense heterotrophic metabolism taking place in the "brown belt" below in which organic matter accumulates in soils and sediments. Also, the basic functions are partially separated in time in that there may be a considerable delay in the heterotrophic utilization of the products of autotrophic organisms. For example, photosynthesis predominates in the canopy of a forest ecosystem. Only a part, often only a small part, of the photosynthate is immediately and directly used by the plant and by herbivores and parasites which feed on foliage and new wood; much of the synthesized material (in the form of leaves, wood, and stored food in seeds and roots) eventually reaches the litter and soil, which together constitute a well-defined heterotrophic system.

This space-time separation leads to a convenient classification of energy circuits into (1) a *grazing* circuit, in which the term grazing refers to the direct consumption of living plants or plant parts, and (2) an *organic detritus* circuit, which involves the accumulation and decomposition of dead materials. The term detritus (= a product of disintegration, from the Latin *deterere,* to wear away) is borrowed from geology where it is traditionally used to designate the products of rock disintegration. As used in this text, "detritus," unless otherwise indicated, refers to all the particulate organic matter involved in the decomposition of dead organisms. Detritus seems the most suitable of many terms that have been suggested to designate this important link between the living and the inorganic world (see Odum and de la Cruz, 1963).

Further subdivision of the ecosystem into six "components" and six "processes" provides a convenient, if somewhat arbitrary, ecological classification, the former emphasizing structure and the latter emphasizing function. Although different methods are often required to delineate structure, on the one hand and to measure rates of function on the other, the ultimate goal of study at any level of biological organization is the understanding of the relationships between structure and function.

As a general principle we can point out that from the operational standpoint (the living and nonliving parts of ecosystems are so interwoven into the fabric of nature that it is difficult to separate them hence the operational classifications that do not make a sharp distinction between biotic and abiotic. Most of the vital elements (C, H, O, N, P, and so on) and organic compounds (carbohydrates, proteins, lipids, and so on) are not only found both inside and outside of living organisms, but they are in a constant state of flux between living and nonliving states. There are, however, some substances that appear to be unique to one or the other state. The high energy storage material, ATP (adenosine triphosphate), for example, is found only inside living cells (or at least its existence outside is very transitory), whereas *humic substances,* which are resistant end products of decomposition (see page 29), are never found inside cells yet are a major and characteristic component of all ecosystems. Other key biotic complexes, such as the genetic material DNA (deoxyribonucleic acid) and the chlorophylls, occur both inside and outside organisms but become nonfunctional when outside the cell. As will be noted later, quantitative measurement of ATP, humus, and chlorophyll on an area or volume basis provides indices of biomass, decomposition and production respectively.

The three living components (producers, phagotrophs, and saprotrophs) may be thought of as the three "functional kingdoms of nature" since they are based on the type of nutrition and the energy source used. These ecological categories should not be confused with taxonomic kingdoms, although there are certain parallels, as pointed out by Whittaker (1969) and as shown in Fig. 1. In Whittaker's arrangement of the phyla into an evolutionary "family tree" all three types of nutrition are found in the Monera and Protista, while the three higher branches, namely "plants," Fungi, and "animals," specialize as "producers," "absorbers," and "ingesters" respectively. It should be

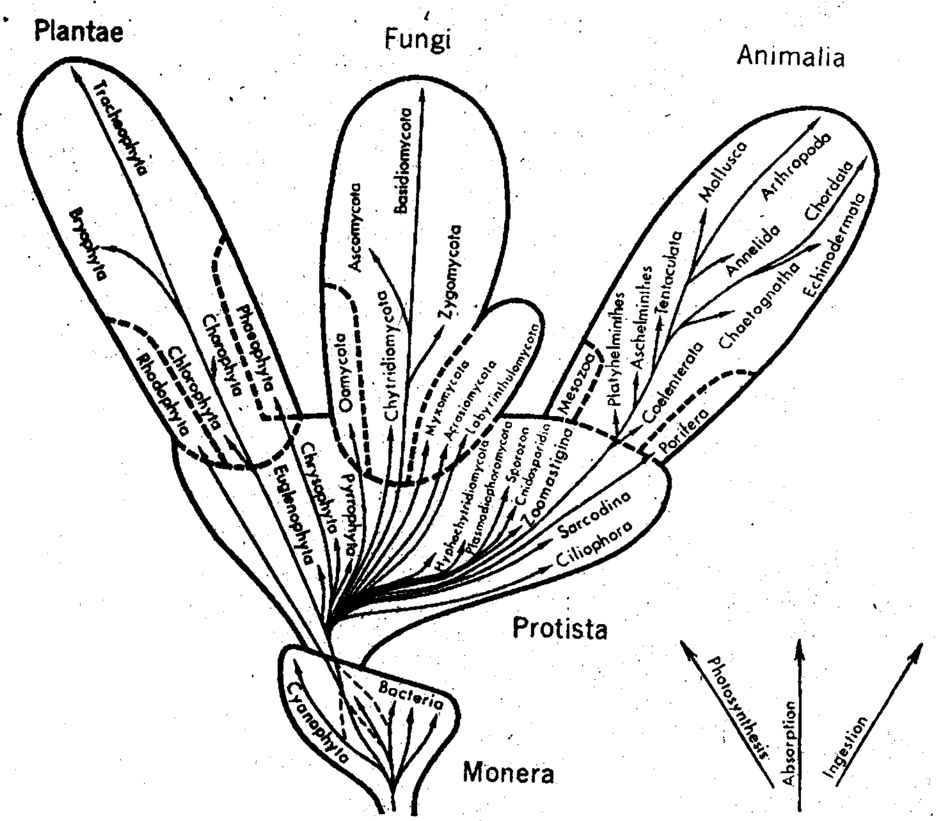

Fig.1. A five-kingdom system based on three levels of organization-the procaryotic (kingdom Monera), eucaryotic unicellular (kingdom Protista), and eucaryotic multicellular and multinucleate. On each level there is divergence in relation to three principal modes of nutrition-the photosynthetic, absorptive, and ingestive. Many biology and microbiology texts list four kingdoms by combining the "lower Protista" (i.e., Monera) with the "higher Protista" to form the "Protista." Evolutionary relations are much simplified, particularly in the Protista. Only major animal phyla are entered, and phyla of the bacteria are omitted. The Coelenterata comprise the Cnidaria and Ctenophora; the Tentaculata comprise the Bryozoa, Brachiopoda, and Phoronida, and in some treatments the Entoprocta. (From Whittaker, 1969.)

emphasized that the ecological classification is one of function rather than of species as such. Some species of organisms occupy intermediate positions in the series and others are able to shift their mode of nutrition according to environmental circumstances. Separation of heterotrophs into large and small consumers is arbitrary but justified in practice because of the very different study methods required. The heterotrophic microorganisms (bacteria, fungi, etc.) are relatively immobile (usually imbedded in the medium being decomposed) and are very small with high rates of metabolism and turnover. Specialization is more evident biochemically than morphologically; consequently, one cannot usually determine their role in the ecosystem by such direct methods as looking at them or counting their numbers. Organisms which we have designated as macro-consumers obtain their energy by heterotrophic ingestion of particulate organic matter. These are largely the "animals" in the broad sense. They tend to be morphologically adapted for active food seeking or food gathering, with the development of complex sensory-neuromotor as well as digestive, respiratory, and circulatory systems in the higher forms. In earlier editions of this text the microconsumers, or saprotrophs, were designated as "decomposers," but recent work has shown that in some ecosystems animals are more important than bacteria or fungi in the decomposition of organic matter. Consequently, it seems preferable not to designate any particular organisms as "decomposers" but rather to consider "decomposition" as a process involving all of the biota and abiotic processes as well. For additional general discussions of the ecosystem concept.

One of the best ways to begin the study of ecology is to go out and study a small pond, or a meadow or old-field. In fact, any area exposed to light, even a lawn, a window flower box, or a laboratory-cultured microcosm, can be the "guinea pig" for the beginning study of ecosystems, provided that the physical dimensions and biotic diversity are not so great as to make observations of the whole difficult. In other words, one does not begin the "practical" or "lab" study of ecology by tackling the great forest or an ocean! In order to illustrate as many aspects as possible, let us now consider five examples: a pond, a meadow, a watershed, a laboratory micro ecosystem, and a space-craft.

1.5.3 THE POND AS AN ECOSYSTEM

Let us consider the pond as a whole as an ecosystem, leaving the study of populations within the pond for the second section of this book. The inseparability of living organisms and the nonliving environment is at once apparent with the first sample collected. Not only is the pond a place where plants and animals live, but plants and animals make the pond what it is. Thus, a bottle full of the pond water or a scoop full of bottom mud is a mixture of living organisms, both plant and animal, and inorganic and organic compounds. Some of the larger animals and plants can be separated from the sample for study or counting, but it would be difficult to completely separate the myriad of small living things from the nonliving matrix without changing the character of the fluid. True, one could autoclave the sample of water or bottom mud so that only nonliving material remained, but this residue would then no longer be pond water or pond soil but would have entirely different appearances and characteristics.

Despite the complexities, the pond ecosystem may be reduced to the several basic units, as shown in Fig. 2.

1. **Abiotic substances (Fig. 2)** are basic inorganic and organic compounds, such as water, carbon dioxide, oxygen, calcium, nitrogen and phosphorus salts, amino and humic acids, etc. A small portion of the vital nutrients is in solution and immediately available to organisms, but a much larger portion is held in reserve in particulate matter (especially in the bottom sediments), as well as in the organisms them selves. As Hayes (1951) has expressed it, a pond or lake "is not, as one might think, a body of water containing nutrients, but an equilibrated system of water and solids, and under ordinary conditions nearly all of the nutrients are in a solid stage." The rate of release of nutrients from the solids, the solar input, and the cycle of temperature, day length and other climatic regimes are the most important processes' which regulate the rate of function of the entire ecosystem on a day-to-day basis.

2. **Producer organisms:** In a pond the producers may be of two main types: (1) rooted or large floating plants generally growing in shallow water only (Fig. 2 II A) and (2); minute floating plants, usually algae, called *phytoplankton (phyto* = plant; *plankton* = floating) (Fig. 2 II B), distributed throughout the pond as deep as light penetrates. In abundance, the phytoplankton gives the water a greenish color; otherwise, these producers are not visible to the casual observer, and their presence is not suspected by the layman. Yet, in large, deep ponds and lakes (as well as in the oceans) phytoplankton is much more important than is rooted vegetation in the production of basic food for the ecosystem.

3. **Macroconsumer organisms**: Animals, such as insect larvae, crustacea, and fish. The primary macroconsumers (herbivores) (Fig. 2, III-1A, III-1B) feed directly on living plants or plant remains, and are of two types, namely *zooplankton* (animal plankton) and *benthos* (= bottom forms), paralleling the two types of producers. The secondary consumers (carnivores) such as predaceous insects and game fish (Fig. 2, III-2, III-3) feed on the primary consumers or on other secondary consumers (thus making them tertiary consumers). Another important type of consumer is the *detritivore* (2 III-1A), which subsists on the "rain" of organic detritus from autotrophic layers above.

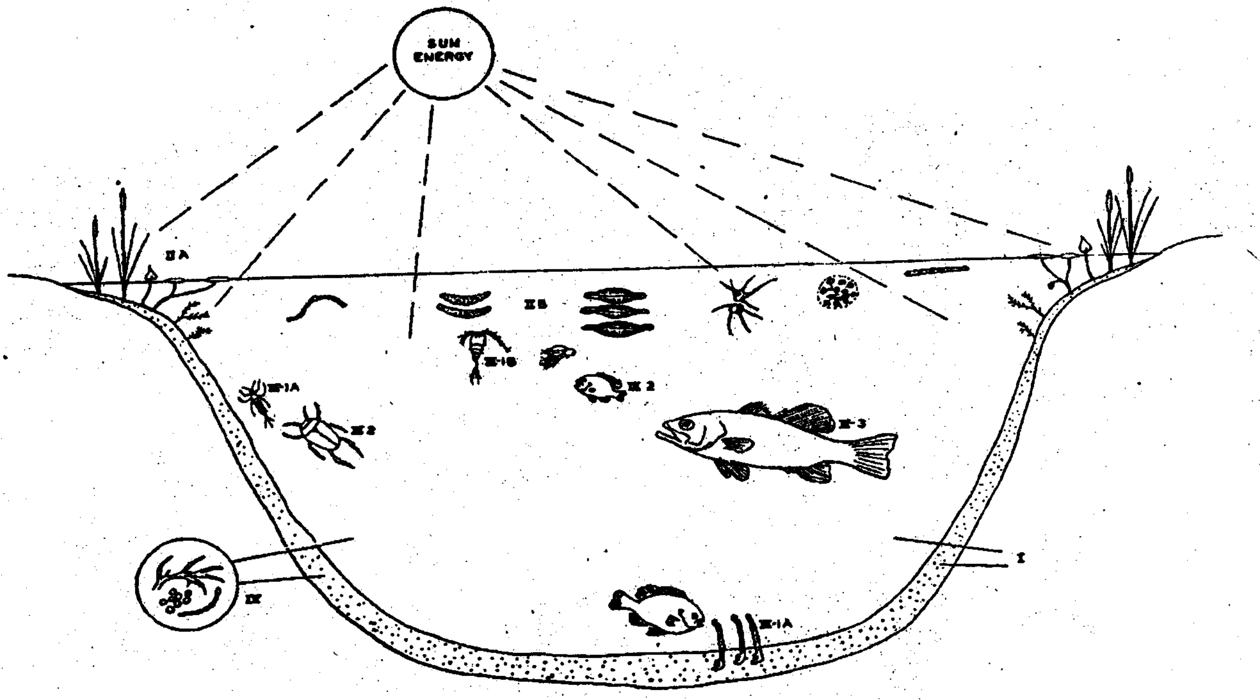

Fig. 2. Diagram of the pond ecosystem. Basic units are as follows: I, abiotic substances - basic inorganic and organic compounds; IIA, producers - rooted vegetation; IIB, producers - phytoplankton; III-IA, primary consumers (herbivores); bottom forms;. III-IB, primary consumers (herbivores)- zooplankton; III-2, secondary consumers (carnivores); III-3, tertiary consumers (secondary carnivores); IV, saprotrophs - bacteria and fungi of decay. The metabolism of the system runs on sun energy, while the rate of metabolism and relative stability of the pond depend on the rate of inflow of materials from rain and from the drainage basin in which the pond is located.

4. Saprotrophic organisms (Fig. 2, IV): The aquatic bacteria, flagellates, and fungi are distributed throughout the pond, but they are especially abundant in the mud water interface along the bottom where bodies of plants and animals accumulate. While a few of the bacteria and fungi are pathogenetic in that they will attack living organisms and cause disease, the great majority begin attack only after the organism dies. When temperature conditions are favorable, decomposition occurs rapidly in a body of water; dead organisms do not retain their identification for very long but are soon broken up into pieces, consumed by the combined action of detritus-feeding animals and microorganisms, and their nutrients released for reuse.

The partial stratification of the pond into an upper "production" zone and a lower "decomposition - nutrient regeneration" zone can be illustrated by simple measurements of total diurnal metabolism of water samples. A "light-and-dark bottle" technique may be employed for this purpose, and also to provide a starting point for charting energy flow (one of the six processes listed in the ecosystem definition). As shown in Fig. 2, samples of water from different depths are placed in paired bottles, one of which (the dark bottle) is covered with black tape or aluminum foil to exclude all light. Other water samples are "fixed" with reagents so that the original oxygen concentration at each depth can be determined.[2] Then the string of paired dark and light bottles is suspended in the pond so that the samples are at the same depth from which they were drawn. At the end of a 24 hour period, the string of bottles is removed and the oxygen concentration in each sample is determined and compared with the concentration at the beginning. The decline of oxygen in the dark bottle indicates the amount of respiration by producers and consumers (i.e., the total community) in the water, whereas oxygen change in the light bottle reflects the net result of oxygen consumed by respiration and oxygen produced by photosynthesis, if any. Adding respiration and net production together, or subtracting final oxygen concentration in the dark bottle from that in the light bottle (provided that both bottles had the same oxygen concentration to begin with) gives an estimate of the total or gross photosynthesis (food production) for the 24-hour period, since the oxygen released is proportional to dry matter produced.

The hypothetical data in Table I illustrates the kind of results one might expect to get with a light-and-dark bottle experiment in a shallow, fertile pond on a warm, sunny day. In this hypothetical case photosynthesis exceeds respiration in the top two meters[3] and just balances it in the third meter (zero change in light bottle); below three meters the light intensity is too low for photosynthesis so only respiration occurs. The point in a light gradient at which plants are just able to balance food production and utilization is called the *compensation level* and marks a convenient functional boundary between the autotrophic stratum *(euphotic zone)* and the heterotrophic stratum. A daily production of 8 grams O_2 per m^2 and excess production over respiration would indicate a healthy condition for the ecosystem, since excess food is being produced in the water column that becomes available to bottom organisms as well as to all the organisms during periods when light and temperature are not so favorable. If the hypothetical pond were being polluted with organic matter, O_2 consumption (respiration) would greatly exceed O_2 production, resulting in oxygen depletion and (should the imbalance continue) eventual anaerobic (= without oxygen) conditions which would eliminate fish and most other animals. In assaying the "health" of a body of water we need not only to measure the oxygen concentration as a condition for existence, but also to determine rates of change and the balance between production and use in the diurnal and annual cycle. Monitoring oxygen concentrations, then, is one convenient way of "feeling the pulse" of the aquatic ecosystem. Measurement of "biological oxygen demand" (B.O.D.) is also a standard method of pollution assay. Enclosing pond water in bottles or other containers such as plastic spheres or cylinders has obvious limitations, and the bottle method used here as an illustration is not adequate for

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[2] The Winkler method is the standard procedure for oxygen measurement in water. It involves fixation with $MnSO_4$, H_2SO_4, and alkaline iodide, which releases elemental iodine in proportion to oxygen. The iodine is titrated with sodium thiosulphate (the "hypo" used to fix photographs) at a concentration calibrated to estimate milligrams of oxygen per liter, which, conveniently, is also grams per m3 and parts per million (ppm). Electronic methods employing oxygen electrodes are now being developed which will probably eventually replace the standard chemical methods, especially when continuous monitoring of oxygen changes is desirable. For details on methods see reference listed under "American Public Health Association" in the bibliography.

[3] Where water is clear, as in large lakes and the ocean, photosynthesis is actually suppressed by highlight intensity near the surface so that the highest rate of photosynthesis usually occurs below the top meter.

assaying the metabolism of the whole pond since oxygen exchanges of bottom sediments and the larger plants and animals are not measured.

Table I. Daily Community Metabolism in the Water column of a pond as indicated by Mean Oxygen changes at successive depths

Depth	O_2 Change (GMS/M^3)		Gross Production (GMS O_2/M^3)	Community Respiration (GMS O_2/M^2)
	Light Bottle	Dark Bottle		
Top m^3	+3	-1	4	1
2^{nd} m^2	+2	-1	3	1
3^{rd} m^3	0	-1	1	1
Bottom m^3	-3	-3	0	3
Total metabolism of water column (gms O_2/m^2/day)	-	-	8	6

1.5.4 The Watershed Unit

Although the pond seems self-contained in terms of the biological components, its rate of metabolism and its relative stability over a period of years is very much determined by the input of sun energy and especially by the rate of inflow of water and materials from the watershed. A net inflow of materials often occurs particularly when bodies of water are small or outflow is restricted. When man increases soil erosion or introduces quantities of organic material (sewage, industrial wastes) at rates that can not be assimilated, the rapid accumulation of such materials may be destructive to the system. The phrase *cultural eutrophication* (= cultural enrichment) is becoming widely used to denote organic pollution resulting from man's activities. Therefore, *it* is *the whole drainage basin, not just the body of water, that must be considered as the minimum ecosystem unit when it comes to man's interests.* The ecosystem unit for practical management must then include for every square meter or acre of water at least 20 times an area of terrestrial watershed. The cause of and the solutions for water pollution are not to be found by looking only into the water; it is usually the bad management of the watershed that is destroying our water resources. The entire drainage or catchment basin must be considered as the management unit- but more about this later. The Everglades National Park in south Florida is a good example of this need to consider the whole drainage basin. Although it is large in area, the park does not now include the source of the freshwater that must drain southward into the park if it is to retain its unique ecology. The Everglades National Park, therefore, is completely vulnerable to reclamation, agricultural, and jetport developments north of the park boundary, which could divert or pollute the "life blood" of the "glades." For a picture of a watershed manipulated and monitored for experimental study, see Fig. 3.

The Microecosystem

Because outdoor ecosystems are complex, hard to delineate, and often difficult to study by traditional scientific means of "experiment and control," many ecologists are turning to laboratory and field micro-ecosystems which can have discrete boundaries and can be manipulated and replicated at will. Figs. 4 & 5 illustrate several types of systems that are being used to test ecological principles. These range from closed microcosms that require only light energy (miniature biospheres, as it were) to assemblages that are maintained in various kinds of chemostats and turbidostats with regulated inflow and outflow of nutrients and organisms. In terms of biological components, two basic types may be distinguished: (1) microecosystems derived directly from nature by multiple seeding of culture media with environmental samples, and (2) systems built up by adding species from axenic cultures (= free from other living organisms) until the desired combinations are obtained. The former systems represent nature "stripped down" or "simplified" to those organisms that are able to survive together within the limits of the container, the culture medium, and the light-temperature environment imposed by the experimenter. Such systems, therefore are usually intended to simulate some specific outdoor situation. As in open nature the investigator can easily find out by observation what major biotic components (such as algae or invertebrates) are present, but it is difficult to determine the exact composition especially in regard to bacteria (Gorden *et al.*, 1969). The ecological use of "derived" or "multiple-seeded" systems was pioneered by H.T. Odum and his students. In the second

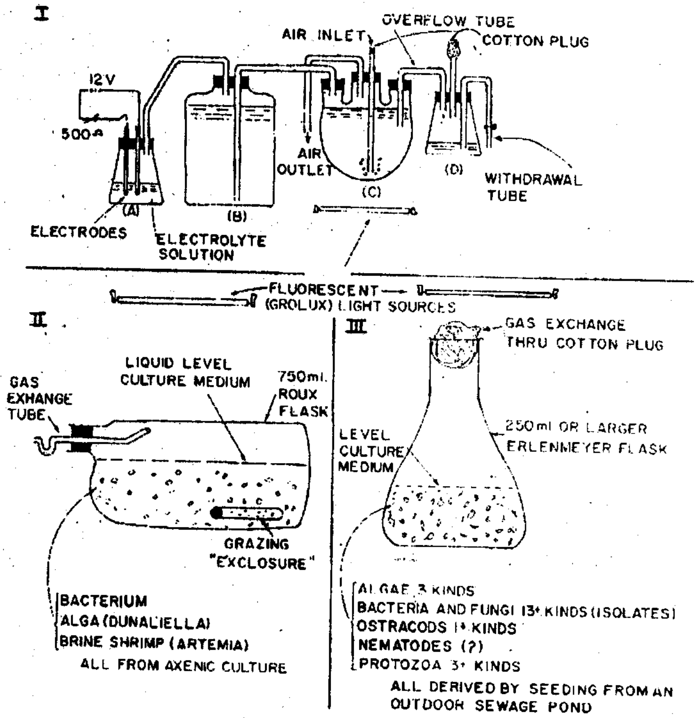

Fig. 4. Three types of laboratory microecosystems. *I.* A simple, inexpensive *chemostat* in which a flow of culture media, (B) through the culture chamber, (C) and into an overflow vessel, (D) is regulated by adjusting the electric current fed into an electrolysis pump (A). In the *turbidostat* a steady-state regulation is accomplished by a sensor, placed within the cultured community, that responds to the density (turbidity) of the organisms (internal regulation as contrasted to the external "constant input" regulation of the chemostat (After Carpenter, 1969.) *II.* A gnotobiotic or "defined" microcosm containing three species from axenic (i.e., "pure") culture. The tube provides an area in which algae can multiply free from grazing by the shrimp (hopefully, preventing "overgrazing"). (After Nixon, 1969.) *III.* A microcosm "derived" from an outdoor system by multiple seeding (see Beyers, 1963). System *I* is "open," and systems *II* and *III* are "closed" except for the input of light energy and gas exchange with the atmosphere. Equilibrium in the closed systems, if achieved, results from nutrient cycle regulation by the community, rather than by mechanical control devices (as in the chemostat or turbidostat.

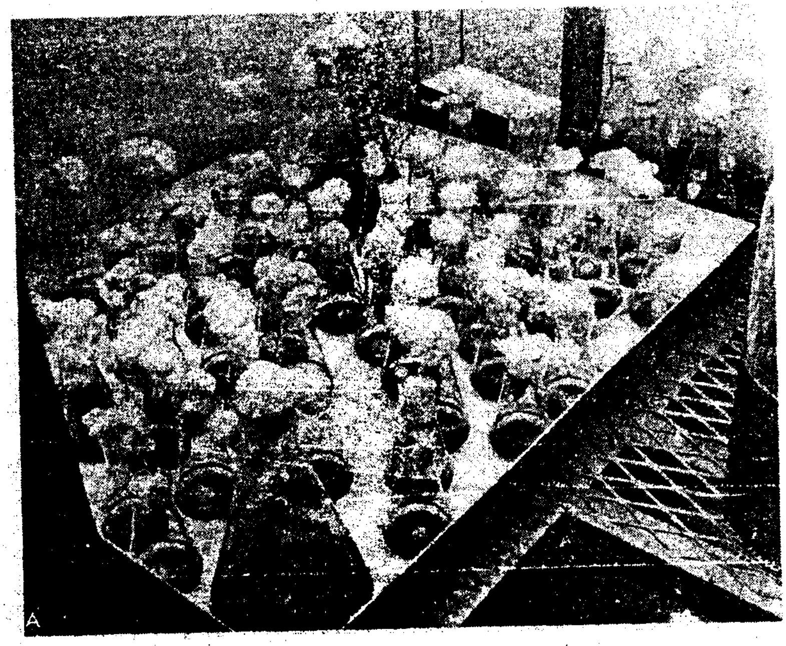

Fig.5. Laboratory microecosystems. A. Aquatic microecosystems derived from nature (see Figure *2-6 III*). The large flasks are "climax" systems that maintain themselves indefinitely with only light input and gas exchange through cotton plug. When samples of equilibrium systems are inoculated into new culture medium (small flasks) the systems undergo a period of ecological succession or development that mimics ecosystem development in nature. Micro-ecosystems shown in the photograph have been subjected to gamma irradiation to compare effect of stress on "youthful" and "mature" systems. (Courtesy of the Institute of Ecology, University of Georgia.) *B.* Terrestrial microecosystems maintained in plastic desiccators with transparent tops. Shown are forest floor herbaceous communities maintained under low light intensity as would be characteristic of forest floor vegetation and associated small organisms. (Courtesy of the Institute of Ecology, University of Georgia).

approach, "defined" systems are "built up" by adding previously isolated and carefully studied components. The resulting cultures are often called "gnotobiotic" (Dougherty, 1959, for a discussion of terminology because the exact composition, down to the presence or absence of bacteria, is known. Gnotobiotic cultures have been mostly used to study the nutrition, biochemistry, and other aspects of single species or strains, or for the study of two species interactions, but recently ecologists have begun to experiment with more complex "polyaxenic" cultures with the objective of building towards self-contained ecosystems (Nixon, 1969; Taub, 1969).

Actually these contrasting approaches to the laboratory microecosystem parallel the two long-standing ways ecologists have attempted to study lakes and other large systems of the real world.

At this point, a word about a common misconception regard-ing the "balanced" fish aquarium. It is quite possible to achieve an approximate gaseous and food balance in an aquarium provided that the ratio of fish to water and plants remains small. Back in 1857, George Warington "established that wondrous and admirable balance between the animal and vegetable kingdoms" in a 12-gallon aquarium using a few goldfish, snails, and lots of eelgrass *(Vallisneria)*, and, we might add, a diversity of associated micro-organisms. He not only clearly recognized the reciprocal role of fish and plants but correctly noted the importance of the snail detritivore "in decomposing vegetation and confevoid mucus" thus "converting that which would otherwise act as a poisonous agent into a rich and fruitful pablum for vegetable growth." Most amateur attempts to balance aquaria fail because far too many fish are stocked for the available resources (diagnosis: an elementary case of gross overpopulation!). A glance at Table I shows that for complete self-sufficiency a medium-sized fish requires many cubic meters of water and attendant food organisms. Since "fish-watching" is the usual motivation for keeping aquaria in the home, office, or school, supplemental food, aeration, and periodic cleaning are necessary if large numbers of fish are to be crowded into small spaces. The home fish culturist, in other words, is advised to forget about ecological balance and leave the self-contained microcosm to the student of ecology. This is a good time to remind ourselves, however, that big "critters," such as fish and men, require more room than you might think!

1.5.6 The Spacecraft as an Ecosystem

Perhaps the best way to visualize the ecosystem is to think about space travel, because when man leaves the biosphere he must take with him a sharply delimited, enclosed environment that must supply all vital needs using sunlight as the energy input from the surrounding and very hostile space environment. For journeys of a few weeks, such as to the moon and back, man does not need to take along a completely self-sustaining ecosystem since sufficient oxygen and food can be stored and CO_2 and other waste products can be fixed or detoxified for short periods of time. For long journeys, such as trips to the planets, man must engineer himself into a more closed or regenerative spacecraft. Such a self-contained vehicle must include not only all vital abiotic substances and the means to recycle them, but also the vital processes of production, consumption, and decomposition must be performed in a balanced manner by biotic components or their mechanical substitutes. In a very real sense the self-contained spacecraft is a microecosystern that contains man. It is interesting that the same two theoretical approaches as mentioned in the previous section, i.e., the "holological" and the "merological" approaches, are now being applied to the search for the "minimum ecosystem for man in space."

1.5.7 SUMMARY

For descriptive purposes it is convenient to recognize the following components as comprising the ecosystem: (1) *inorganic substances* (C, N, CO_2, H_2O, etc.) involved in material cycles; (2) *organic compounds* (proteins, carbohydrates, lipids, humic substances, etc.) that link biotic and abiotic; (3) *climate regime* (temperature and other physical factors); (4) *producers*, autotrophic organisms, largely green plants, which are able to manufacture food from simple inorganic substances; (5) *macroconsumers* or *phagotrophs* (phago = to eat), heterotrophic organisms, chiefly animals, which ingest other organisms or particulate organic matter; (6) *microconsumers, saprotrophs* (*sapro* = to decompose), or *osmotrophs* (*osmo* = to pass through a membrane), heterotrophic organisms, chiefly bacteria and fungi, which break down the complex compounds of dead protoplasms, absorb some of the decomposition products, and release inorganic nutrients that are usable by the producers together with organic substances, which may provide energy sources or which may be inhibitory or stimulatory to other biotic components of the ecosystem.

1.5.8 EXPECTED QUESTIONS

1. Explain the concept pertaining to ecosystem.
2. Describe an ecosystem taking hand as a typical example.
3. Explain the structure and functions of ecosystem.

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LESSON-1.6

CLASSIFICATION OF ECOSYSTEMS AND FEED BACK LOOP

1.6.1 INTRODUCTION
1.6.2 AQUATIC ECOSYSTEM
1.6.3 WET LAND ECOSYSTEM
1.6.4 MARINE WETLAND ECOSYSTEM
1.6.5 FOOD LAND ECOSYSTEM
1.6.6 SWAMP AND MARSH ECOSYSTEM
1.6.7 BOG ECOSYSTEMS
1.6.8 FEED BACK LOOP
1.6.9 SUMMARY
1.6.10 EXPECTED QUESTIONS
1.6.11 REFERENCES

1.6.1 INTRODUCTION

The word **ecosystem** is a relatively recent term. Sir Arthur Tansley invented the word in 1935 to apply to a whole community of organisms and its environment as one unit. Tansley realised that the community could not be separated from the particular environment in which it lived. The physical features of the habitat plus the climatic influences determine which species form the basic structure of the community. For many years, ecologists had realised that a habitat, and the community it contains are a single working system. They applied many terms to this concept, but apart from ecosystem, only one earlier word. **biocoenose** (Möbius, 1877), is frequently used, especially in Europe and Russia.

The ecosystem, or biocoenose, consists of the community of organisms plus the associated physical environment. The main features of the abiotic environment are climate, soil and water status (land, freshwater aquatic or marine); other features include geology, topography and depth below sea level or altitude above it. We lave already looked at some of the organisms which occur in ecosystems: both autecological studies of species, and species in communities. The study of ecosystems is included in **synecology** as all the organisms and environmental factors are studied as an integrated unit.

Many features of the ecosystem are difficult to separate out and look at in isolation from the communities they support. This is the case, for instance, with the soils of terrestrial ecosystems and the water relationships within ecosystems. Some of the importance of a marine environment has already been described in the rock-pool ecosystem in. The importance of water in freshwater ecosystems including bogs and lakes is described. The relationships of soils to vegetation and climate is also investigated, including soil classification and distribution on a global scale.

1.6.2 AQUATIC ECOSYSTEMS

We have just looked in detail at a whole series of terrestrial ecosystems where soils were a very important part of the inter-relationships between climate and communities. With wetlands and aquatic ecosystems the climate is a less important environmental factor than it is for terrestrial ecosystems. The effect of water is predominant and all-important in determining the type of wetland or aquatic ecosystem.

Aquatic habitats are, perhaps, easier to identify than wetlands. They have free-standing water covering the land surface which can either be fast moving, as in streams and rivers, or relatively still, as in lakes and ponds. If we consider all aquatic environments, then we must also include areas of marine influence such as brackish estuaries, the tidal zone and the open sea. Both ponds and lakes tend to be shallow at their edges and deeper at the centre. There are many ways in which lakes can form by build-up of standing water, including in depressions caused by earth movements and in valleys carved glaciers and dammed by the debris deposited when the ice melts. Large lakes, such as the Norfolk Broads in England, have even been produced by human excavation. The Broads were created, from Roman times onwards, when peat was excavated from the site and the depressions were subsequently flood.

Linear aquatic habitats are formed by moving water: streams form as rainwater runs off high ground and flows down valley bottoms from mountainous areas. Streams join up to form larger river by the time they reach the coastal lowlands. Streams are usually fast moving with little volume of water. When the water volume increases due to high rainfall or snow melt, the water has a lot of energy which is capable of eroding and carrying quite large particles away with it to leave a rocky or stony stream bed. Rivers usually flow more slowly than streams; they are large and carry enormous loads of debris from higher up the water flow. This is often deposited in the lower reaches of the river, so that it has a muddy floor. Such rivers often meander across large flat plains which flood periodically when the river bursts its banks.

Aquatic ecosystems are found in marine habitats, brackish estuaries, rivers, streams, lakes and ponds. Lake and pond ecosystems are considered here as they are the most likely habitats to occur in association with the wetlands already described.

Ponds are really at one end of the size range of standing water bodies. Many of the smaller and shallower ponds are ephemeral: they turn into muddy hollows in dry seasons. The pond life in these ecosystems has to be well adapted for survival of such extreme conditions, or mobile enough to move to another pond. Once a pond reaches a fairly arbitrary size, it can be called a lake. Lakes may be supplied by rivers, or only be fed by rainfall and surface runoff. Lake ecosystems have a wide variety of communities depending on their size, depth, edge structure and water source; but they do have many features in common.

The presence of deep standing water in the ecosystem produces an environment with many unusual properties. First, the amount of light penetrating the lake varies with depth and clarity of water. Really deep or murky lakes have much of their environment below the **photic zone** within which active photosynthesis takes place. Most of the primary producers have floating leaves, or grow underwater only in the shallower parts.

Second, the properties of water when heated can have quite astounding effects on lake ecosystems. In summer, lakes receive heat from the Sun. This warms up the surface of the water. This warmed water expands and therefore, because it is less dense than the cooler water beneath, remains as a surface layer. Fig. 1 shows the temperature gradient found in such a lake. The surface waters may be many degrees warmer than the bottom water. The region of changeover of

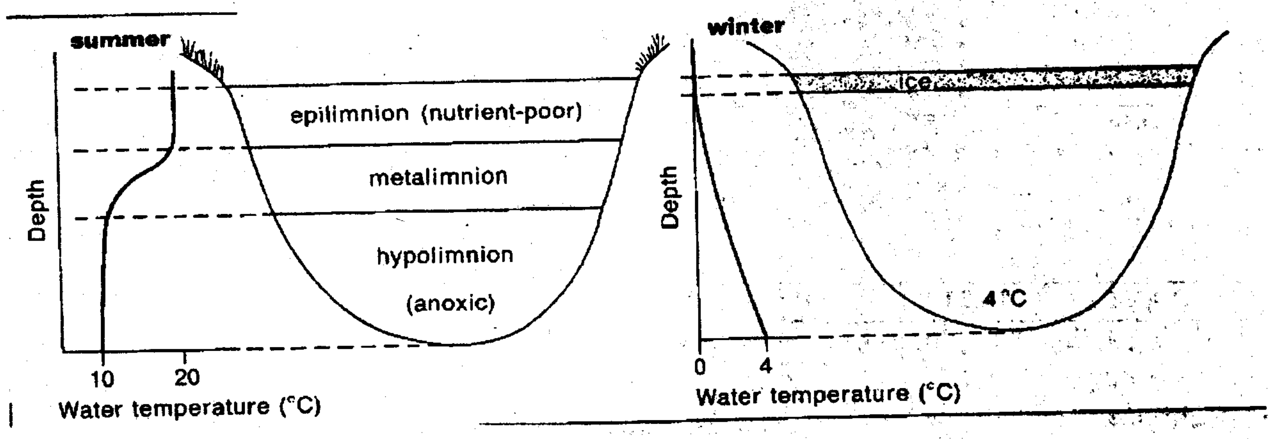


Fig. 1. The temperature gradients produced in a lake in summer, and in winter. In summer lakes often stratify into a layer of warm water (the epilimnion) which floats on denser cooler water (the hypolimnion). In winter the lake is warmest at the bottom, usually 4°C and gradually becomes cooler towards the ice layer at the surface.

temperature is called the **metalimnion**. This rapid changeover in temperature between the warmer **epilimnion** and cooler **hypolimnion** is called the **thermocline**. This stratification prevents the mixing of the layers of water, so that although debris from above can sink to the bottom and decay there, there is little transfer of soluble substances such as minerals and dissolved oxygen or carbon dioxide.

If the lake is fertile (**eutrophic**), primary productivity will be high, and considerable amounts of debris may fall to the hypolimnion. As the organic matter decomposes, the oxygen in the water is used up, but cannot be replaced because of the stratification. On the other hand, the nutrients in the epilimnion are taken in by the plants, then carried down to the hypolimnion when they die. This results in a temporary drop in fertility in the upper zones. If the lake is infertile there will be very low primary productivity, so very little debris falls below the thermocline. These infertile (**oligotrophic**) lakes, therefore, do not develop anoxic bottom waters. The stratification in lakes periodically breaks down and the water remixes. In eutrophic lakes the bottom waters are re-oxygenated and the upper ones replenished with nutrients. In most lakes partial mixing occurs several times a year, and total mixing at least once a year.

Temperate lakes become very cold in winter. Ice forms on the surface of lakes at 0°C yet the bottom waters are at about 4°C (see Fig. 1). This is because water at 4°C is denser than colder or warmer water, so it sinks to the bottom. The lake waters are well mixed from the autumn turnover and the temperatures are cool enough to prevent anoxic conditions or mineral depletion. In spring, as the lake warms up, phytoplankton flourish and stratification begins to occur but daily turnover is easily triggered. Later in the summer stratification becomes more severe, nutrients are depleted, the phytoplankton decreases and sinks to the bottom, and the thermocline becomes well developed. At this time of year, the temperature difference across the thermocline may be as much as 20°C. The lake mixes again as it cools in autumn when the surface waters are replenished with nutrients and the bottom waters with oxygen. There may be another bloom of phytoplankton before the winter temperatures fall too low. In the tropics, the difference between the epilimnion and the hypolimnion may be only 2 or 3°C, yet in some lakes the thermocline is very stable so that hardly any mixing occurs (Payne, 1986).

1.6.3 WETLAND ECOSYSTEMS

Wetlands, as their name suggests are ground, rather than standing water. Unlike ecosystems, they develop an organic soil profile, but the saturation with water alters the community structure. The waterlogging of the soil tends to cause a problem for plants as anaerobic conditions are produced with little or no oxygen available. Wetlands have been described as 'a halfway world between terrestrial and aquatic ecosystems' (Smith, 1980, p. 225). They are a transitional link between two extremes, and range from very nearly aquatic to almost dry. Indeed several wetland habitats dry out during dry seasons in the year and are then very difficult to identify as wetland at all!

There is an enormous variety of wetland ecosystems throughout the world. This has led to a large number of descriptive names for wetland types. Unfortunately, the same names often apply to different wetland types in different countries and many local terms are used for wetlands common in the region. Because water is more important than climate, very similar wetlands occur in many regions. The species in the community are often different, but the basic structure of the ecosystem is similar.

This variation, and the wide range of environments in which similar ecosystems occur, makes it quite difficult to classify wetlands into some wider system. We cannot use climate or global position as was possible for terrestrial ecosystems and soil types. It is perhaps easiest to divide wetlands according to the source and nature of the water which maintains the system. There are four possible sources of water, each of which have different properties:

(i) The sea – sea water is highly saline and tidal;
(ii) Streams and rivers – sediment rich and seasonally flooded;
(iii) Drainage from surface runoff or groundwater – usually nutrient rich and basic; and
(iv) Directly from rain or snow – rain is nutrient poor and acidic.

The distribution of these water sources depends on the occurrence of topographical features. For example, sea water will obviously only influence coastal regions, rivers tend to flood most in lowlands and rainfall is often highest in mountain regions close to oceans. For these reasons, the source of water is used here as the basis of the classification of wetland ecosystems.

1.6.4 MARINE WETLAND ECOSYSTEMS

Mangrove swamps

The coastline in the tropical and subtropical regions is fringed with a strip of swampland which is inundated every high tide with marine or brackish waters. Wherever the wave action is not too strong to prevent regeneration, these coastal wetlands are densely vegetated with thickets of mangrove trees. There are about 70 species of mangrove around the world, the most important genera being *Rhizophora* and *Avicennia.* Mangroves are capable of growing in fresh water, but it is thought that the saline conditions of the intertidal zone give these poor competitors an advantage over other species. They are well adapted to the salty conditions as they can prevent high concentrations of salt entering the roots and can secrete excess salt from their leaves. They may also jettison extra salt when they drop their leaves. Just like the ecosystems on the rocky shore, mangrove swamps are influenced strongly by the tides. Incoming tides import nutrients to the system, and tides are also responsible for dispersing seeds. Mangrove seeds often germinate while still held on the tree. They grow a thick spear-like hypocotyl so when the seed falls off the tree, the hypocotyl is embedded in the mud like a spear and then grows anchoring roots (Mitsch & Grosselink, 1986).

A variety of animals live within the mangrove including fiddler crabs *(Uca* spp.) and mudskippers *(Periophthalmus* spp.). The food web is based on the presence of many detritivores, but ascends to major carnivores like alligators, crocodiles and big cats such as tigers *(Panthera tigris).*

The most unusual feature of mangrove swamps is the structure of the trees. Fig. 2 is a photograph of a typical swamp at low tide. You can see that each tree has a whole series of aerial roots arising quite high up on the trunk and plunging into the mud beneath. These stilt roots help to support the trees and lessen the wave action of incoming tides. Sometimes considerable amounts of organic mud build up under the mangrove forest. Fig. 1 shows many stick-like structures protruding from the mud: these are called pneumatophores. Both these and the supporting aerial roots have little pores on them that can take in oxygen from the air. One of the problems of living in wetlands is the lack of oxygen for roots: mangroves have overcome this problem with these pneumatophores.

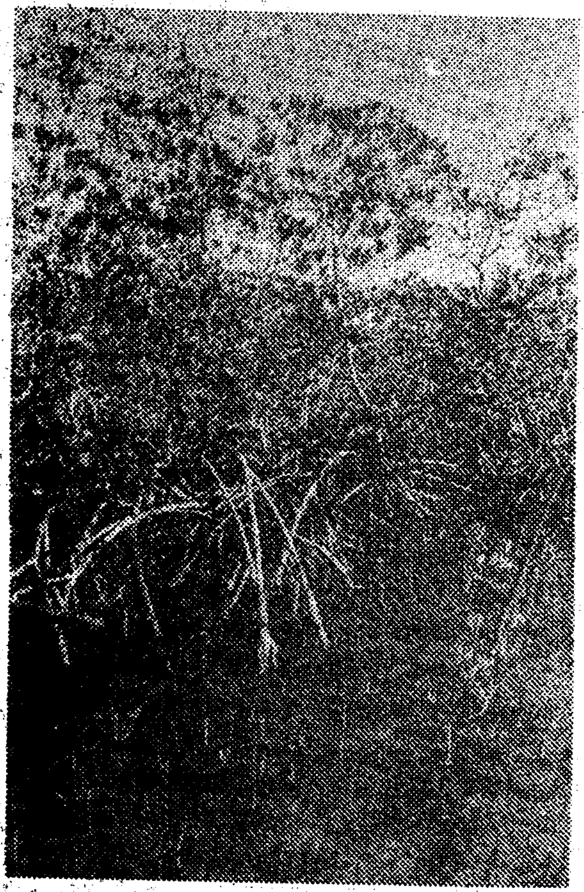


Fig. 2. Mangove trees in Cuba, showing pneumatophores and seedlings in the foreground.

Salt marshes

In higher latitudes, the mangrove ecosystems disappear because the trees cannot tolerate even minor frosts. They are replaced on the coastal strip by much lower growing ecosystems: salt marshes. Like the mangrove swamps, the salt marshes are within the tidal influence of the sea and are inundated with salt water every high tide. As you can see from Fig.3, they consist of a patch work of low vegetation separated by tidal creeks. Salt marshes tend to develop in sheltered intertidal regions where wave action is not too strong.

Salt marsh vegetation is dominated by grasses such as *Spartina* and rushes *Juncus* spp. The lower lying pools, where the salt concentration is higher have different vegetation including glasswort *(Salicornia europaea)*, a very succulent plant which is eaten as a (rather salty) vegetable in Europe. Salt concentration can vary considerably depending on several factors including the structure of the marsh, how often it is flooded by tides and the amount of rainfall. If rainfall is high, areas of the marsh are washed free of some of the salt and are colonised by other plant species such as sea lavender *(Limonium* spp.) and arrow grass *(Triglochin* spp.)

Fig. 3. A salt marsh in Udale Bay, Cromarty Firth, Black Isle, Scotland

Salt marsh soils are high in phosphates but low in nitrogen, which may limit plant growth. They can also be toxic to plants if sulphur from sea water collects in marsh soils as iron pyrites and hydrogen sulphide. When the soils dry out, sulphuric acid may form which lowers soil pH. In these marshes up to 70% of the net primary productivity is due to chemosynthetic bacteria which utilise the sulphur (Howarth *et al.* 1983). Mats of cyanobacteria on the mud are important as fixers of light energy. Salt marshes have high primary productivity, but much of the organic matter produced gets washed out of the marsh with the retreating tides.

1.6.5 FLOOD LAND ECOSYSTEMS

The second group of wetland ecosystems are those which obtain their water from rivers. These wetlands are often extremely seasonal. They flood deeply with water when the river overflows its banks. This may happen during a rainy season, or when winter snows melt in the catchment area. Floodlands tend to occur in lowland, flat-bottomed valleys through which a large river meanders. Such areas can be very large on the flood plains of great rivers. These large lowland rivers are associated with a number of features illustrated in Fig. 4. Normally, the mature river will meander across a wide, flat plain which was created by sediment deposited in the past by the river. The channel in which the river flows builds up at the side into sandy banks called levees. It is only when the water reaches the top of these banks and overflows that the valley is flooded. The flood plain often has small permanent wetland areas which form when the river takes a new path on the valley floor, leaving behind an oxbow lake. These lakes slowly fill in with silt to form boggy areas. Often a flood plain will have several oxbow lakes in various stages of infill.

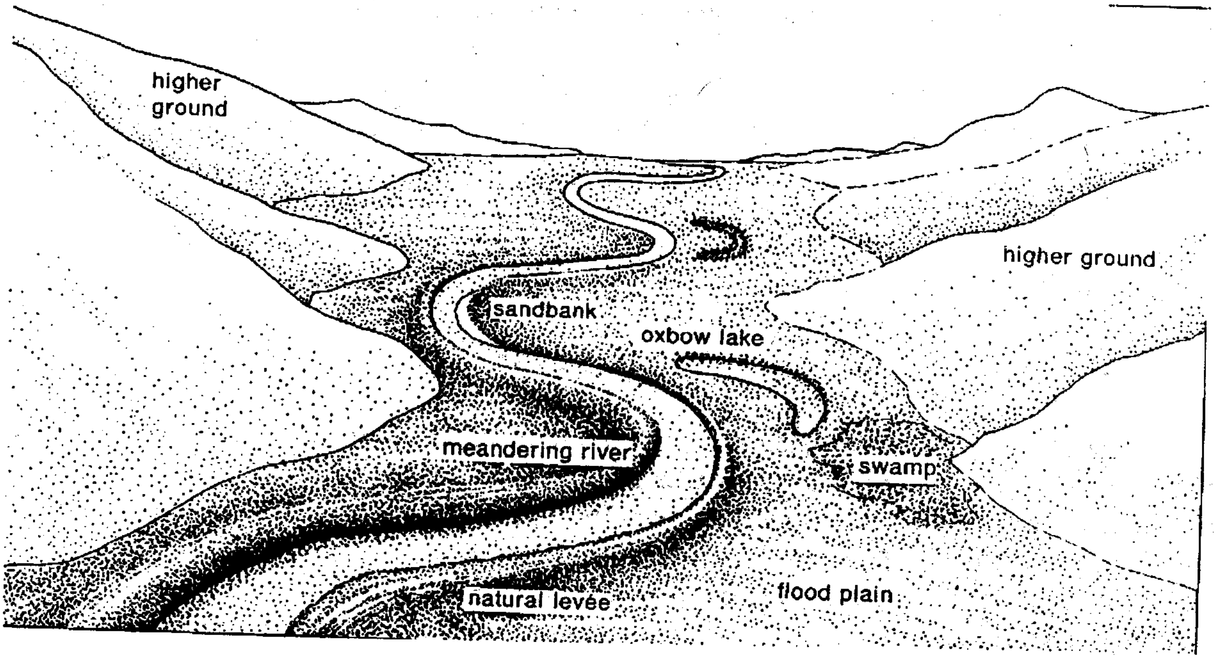


Fig. 4. A mature river valley. The large meandering river floods periodically to create the flood plain and as meanders are cut off from the main river flow they form oxbow lakes.

When the river floods the valley, it carries with it clays, silt and mineral nutrients which are deposited on the flood plain. This is because as the water slows down it loses its capacity to carry particles. The largest particles settle out of the water to form the sandy levees. The smaller silt and clay particles are carried further by the floods and settle out only when the water stops flowing. This frequent addition of new material makes flooded valley soils nutrient rich. During the period of flooding, anaerobic conditions are created in the soil. This temporary condition seems to be the limiting factor which determines which communities grow on the site.

The topography of the valley floor in relation to the river affects the number and duration of floods. Areas closest to the river tend to flood most often and those further away and on higher ground may only flood in very wet years. The species composition in the ecosystem changes with distance from the river.

The natural vegetation in temperate flood plains is mixed deciduous forest. In temperate North American, for example, five associations of forest species can be identified. The most extreme is in areas flooded all year round. These have a small number of specialised swamp trees like the swamp cypress *(Taxodium distichum)* and tupelo *(Nyssa aquatica)*. In areas flooded for more than half the year, the swamp species are joined by specialist oaks *(Quercus* spp.) and ashes *(Fraxinus* spp.). With less than 50% flooding the swamp species disappear and a larger variety of oaks, elms

(*Ulmus* spp.) and many other genera grow in their place (Larson *et al.*, 1981). These mixed woodlands have a rich fauna of birds, amphibians, reptiles and mammals.

In many parts of the world floodlands have been cleared of their natural vegetation. The frequent flooding constantly enriches the soils and the proximity of the river makes it ideal for irrigation. These areas are very valuable for cultivation and many such areas, like the Nile valley in Egypt, have been farmed for thousands of years. In temperate zones, flood plains make excellent water meadows of rich grazing land, although the wet environment can harbour diseases and parasites which may infect grazing animals.

1.6.6 SWAMP AND MARSH ECOSYSTEMS

The ecosystems in this category are found in areas of impeded drainage, where water runs off the surrounding land and collects, or where groundwater lies close to the surface. In some cases, rivers and streams may also feed into the area. The land is flooded all year round except in very dry years, unlike most of the flood-lands described. Swamp and marsh ecosystems are very variable in size and form, depth of soil and plant community structure. In general, they can be divided into two major types: **swamps** in which trees are the dominant vegetation; and **marshes** which have large open areas of grasses and reeds.

Swamp wetlands are dominated by trees similar to those found in the very wettest areas of flooded river valleys. Some of the most famous swamp areas occur in Florida (USA), where the very low-lying land is often flooded. Dominant tree species here include the swamp cypress and water tupelo. Fig. 5 shows a close-up of swamp in South Carolina. You can see that the floor of the forest is under water. The tall stately trees form a very impressive structure; those in the photograph are swamp cypresses with fanned out butresses at the bases of their trunks. The knobs you can see projecting out of the water are not rotted off tree stumps, but knee roots. Several species in the swamp have such knee roots. They project above the surface of the water and are usually one or more metres high. These pneumatophores may act just like the ones in the mangrove swamps in Fig. 5, as aerators for the roots which are permanently under water. Carbon dioxide has been shown to leave these knee roots, though it has not been proved that oxygen is taken in (Mitsch & Grosselink, 1986).

Fig. 5. Close-up of the bases of swamp cypress trees (Taxodium spp.) in South Carolina. USA showing knee roots.

Unlike the mangrove trees, which produce seedlings able to survive and become established in the inundated muds, swamp trees produce seeds which only germinate and grow in dry conditions. This means that regeneration of the swamp trees can only occur after the swamp has temporarily dried out. This is the key feature which determines the existence of a swamp ecosystem or lake ecosystem. If the swamp never dries out but remains with standing water, then the trees will never regenerate and the swamp will become a lake. However, swamp trees are very long lived, so drying out need only happen every hundred years or so for the swamp forest to regenerate.

Marshes are wetland ecosystems which are dominated by grasses (Poaceae), sedges (Cyperaceae) and reeds (Junaceae) rather than trees. The movement of groundwater, runoff and the addition of stream water usually make marshes nutrient rich with a fairly high pH. Marshes are common in temperate zones. In the northern hemisphere, the same genera are usually dominant in both North America and Eurasia. These include *Typha, Scirpus, Phragmites, Cladium* and *Juncus*. Each genus tends to dominate in a particular habitat where the marsh conditions suit it best. The species which live in marshes often have tough or very sharp-edged leaves *(Cladium* and *Phragmites* were used to roof houses because they were long lasting). These tough leaves may have evolved to deter large herbivores, such as swamp rhinoceros *(Teleoceras* and *Elasmotherium* spp.) and straight tusked elephant *(Loxodonta antiqua)* in the Pliocene and Pleistocene (Tomkins, pers. com.). Since these animals have become extinct, their absence has left the tough grass species relatively untouched.

Most leaf matter falls to the wet marsh surface and is attacked by decomposers which form the base of the rest of the food web. The leaf litter often builds up into a peaty layer. This is especially so in fenland, although the thickness of fen peat is never as great as seen in bogs. There is more on the inter-relationship between lakes, marshes and bogs.

1.6.7 BOG ECOSYSTEMS

The fourth category of wetlands is true bogland. It receives water only from rainfall, not from streams, rivers or groundwater. This sole source of water greatly affects the nutrient content of boglands. Rainwater has very little nutrient content, unlike river- and groundwater, and as it drains through the soil profile it tends to leach out any remaining nutrients. The dominant species in bogs are mosses in the genus ***Sphagnum*** (Fig. 6). Many different ***Sphagnum*** species are found in bogs, each with slightly different water requirements. The mosses grow upwards and their lowermost leaves decay and join the peat building up beneath.

Wherever rainfall is high and temperatures cool, so that water loss by evapo-transpiration is less than water gain from rain, ***Sphagnum*** bog tends to develop. The main areas where bogs occur are in the temperate and boreal regions. The bog may slowly grow up to form a hugh dome of peat called a **raised bog**. Raised bogs are usually confined by some feature of topography such as a hollow formed by an infilled lake. If rainfall is high, above about 1000 mm a year, **blanket bog** can develop even on shallow slopes. The peat in blanket bog can build up to several metres thick. This peat is vulnerable to erosion as it is easily washed away once the surface vegetation has been damaged by trampling, grazing or pollution. The peat is washed away leaving deep gullies which gradually widen as more peat washes into them. Fig. 7 shows eroded blanket peat in the Pennines. England. The high rainfall aids this process and often several metres of peat are eroded away to reveal the underlying gritstone. The high rainfall leaches nutrients from the bog. The pH is also very low, often about 3-4, caused by humic acids and sulphuric acid formed when organic sulphur is oxidised. Few plant species other than *Sphagnum* mosses can grow in these conditions. Those which do well have often evolved methods of increasing their nutrient intake. Some are carnivorous plants which lure insects into traps, or have sticky leaves that catch flies. Such plants include sundews *(Drosera* spp.) and butterworts *(Pinguicula* spp.) with sticky leaves, and pitcher plants *(Sarracenia* spp.) which have a modified leaf shaped like a tube with slippery sides and digestive juices in the bottom. There are sticky-leaved *Drosera* plants growing on the *Sphagnum* in Fig. 6. Other plants are more orthodox and gain extra nutrients from nitrogen-fixing bacteria in root nodules. An example is the bog myrtle *(Myrica gale).*

Fig. 6. The surface of a *Sphagnum* bog. The tops of the *Sphagnum* can be seen in the extreme foreground; the insectivorous sundews are *Drosera anglica.*

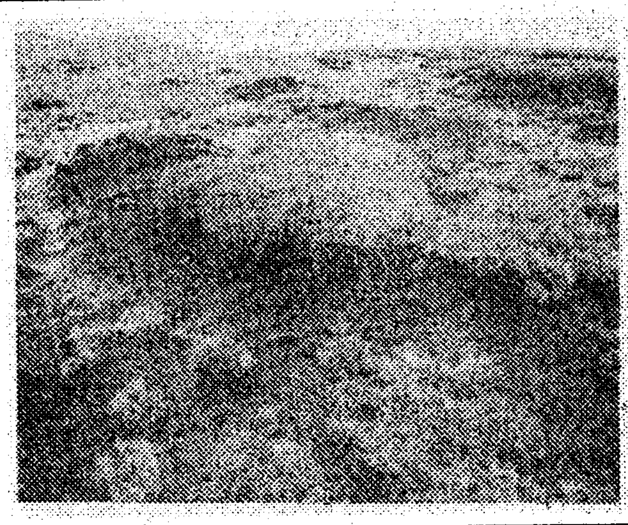


Fig. 7. Eroded blanket bog in the Yokshire Pennines.

The whole bog community is slow growing and short. Primary productivity is low, with only small populations of herbivores such as insects, hares and bog lemmings and a few predators such as spiders and owls. The larger herbivores and predators like deer, caribou and bears roam over a much wider area, although they may enter bogs from time to time (Mitsch & Grosselink. 1986).

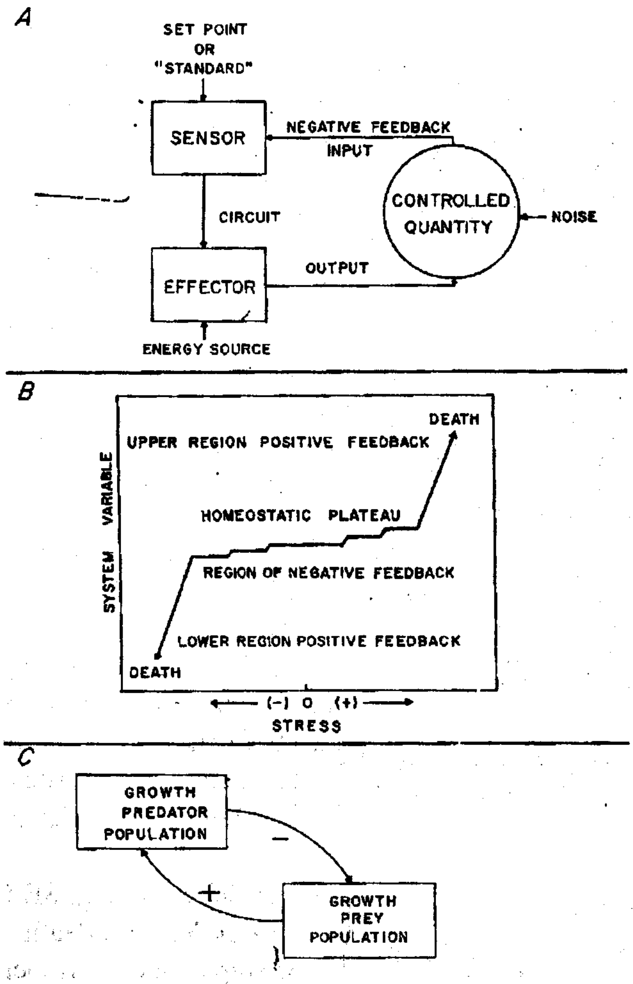
1.6.8 FEED BACK LOOP

Ecosystems are capable of self-maintenance and self-regulation as are their component populations and organisms. Thus, *cybernetics* (fr. *kybernetes* = pilot or governor), the science of controls, has important application in ecology especially since man increasingly tends to disrupt natural controls or attempts to substitute artificial mechanisms for natural ones. Homeostasis (homeo=same; stasis=standing) is the term generally applied to the tendency for biological systems to resist change and to remain in a state of equilibrium.

Explanation and Examples

The very elementary principles of cybernetics are modeled in Fig. 8. In simplest form a control system consists of two black boxes and a controlled quantity interconnected by output and input circuits or signals (Fig. 8). In the familiar household heat control system the thermostat is

Fig. 8. Elements of cybernetics. **A** – A simple control system, analogous to a household thermostat, in which some of the output is used as negative feedback to maintain some kind of equilibrium in a controlled quantity. **B**. The concept of the homeostatic plateau within which relative constancy is maintained by negative feedback despite tendency of test to cause deviations. Beyond limits of homeo-statis positive feedback results in rapid destruction of the system. (After Hardin, 1963). **C**. The interaction of positive (+) and negative (-) feedback in a predator-prey "feedback loop" system. A period of evolutionary adjustments is usually required before, such a system actually becomes stable. Newly associated predators and prey tend to oscillate violently.



the sensor (or "error detector" as it can also be called), the furnace the effector (which receives its energy from the fuel), and the room temperature the controlled quantity. Control depends on *feedback*, which occurs when output (or part of it) feeds back as input. When this feedback input is positive (like compound interest, which is allowed to become part of the principal), the quantity grows. Positive feedback is "deviation-accelerating" and, of course, necessary for growth and survival of organisms. However, to achieve control – as for example, to prevent overheating a room or cancerous overgrowth of a population – there must also be *negative feedback*, or "deviation-counteracting" input, as shown in Fig. 8B. Mechanical feedback mechanisms are often called servomechanisms by engineers; biologists use the phrase homeostatic mechanisms to refer to living systems. Cybernetics embraces both inanimate and animate controls. The interaction of positive and negative feedback and the limits of homeostatic control are diagramed in Fig. 8C. As critics of human society are pointing out with increasing frequency, the positive feedback involves in he expansion of knowledge, power, and productivity threatens the quality of human life and environment unless adequate negative feedbac... itrols can be found. The science of controls, or cybernetics, thus becomes one of the most important subjects to be studied, understood, and practiced.

The existence of homeostatic mechanisms at different levels of biological organization was mentioned in the previous chapter. Homeostasis at the organism level is a well-known concept in physiology as outlined, for example, by Walter B. Cannon in his readable little book entitled *The Wisdom of the Body* (1932). We find that equilibrium between organisms and environment may also be maintained by factors which resist change in the system as a whole. Much has been written about this "balance of nature" but only with the recent development of good methods for measuring rates of function of whole systems has a beginning been made in the understanding of the mechanisms involved.

Some populations are regulated by density, which "feeds back" by way of behavioral mechanisms to reduce or increase the reproductive rate (the "effector") and thus maintain the population size (the "controlled quantity") within set limits. Other populations do not seem to be capable of self-limitation but are controlled by outside factors (this may include man, but more about this alter). Control mechanisms operating at the ecosystem level include those which regulate the storage and release of nutrients and the production and decomposition of organic substances. The interplay of material cycles and energy flows in large ecosystems generates a self-correcting homeostasis with no outside control or set-point required. The possible role of "ectocrine" substances in coordinating units of the ecosystem has been mentioned. In subsequent sections and chapters, we shall have frequent occasion to discuss these mechanisms and to present specific data demonstrating that the whole is often not as variable as the part.

It is important to note, as shown in Fig. 8B that homeostatic mechanisms have limits beyond which unrestricted positive feedback leads to death. Note also that we have shown the "homeostatic plateau" as a series of levels or steps. As stress increases, the system, although controlled, may not be able to return to the exact same level as before. **Really good homeostatic control comes only after a period of evolutionary adjustment**. New ecosystems (such as a new type of agriculture) or new host-parasite assemblages tend to oscillate more violently and to be less able to resist outside perturbation as compared with mature systems in which the components have had a chance to make mutual adjustments to each other.

The idea of the ecosystem and the realization that mankind is a part of, not apart from, complex "biogeochemical" cycles with increasing power to modify the cycles are concepts basic to modern ecology and are also points of view of extreme importance in human affairs generally. Conservation of natural resources, a most important practical application of ecology, must be built around these viewpoints. Thus, if understanding of ecological systems and moral responsibility among mankind can keep pace with man's power to effect changes, the present-day concept of "unlimited exploitation of resources" will give way to "unlimited ingenuity in perpetuating a cyclic abundance of resources."

1.6.9 SUMMARY

We can summarize what has been presented in this chapter.

1. An ecosystem, or biocoenose, is composed of a community and the physical environment it occupies.

2. Soil is an important part of terrestrial ecosystems.

3. Soils are composed of mineral particles, including sand and clay, and organic matter, including plant litter and insect droppings.

4. Soil usually has a layered structure caused by the build-up of organic matter on the surface and the effects of water movements which leach the soil and deposit nutrients, humus and clay particles within it.

5. Animals such as worms and termites are important in soil as they mix up the different horizons; in soils where worms are absent the horizons are very pronounced (podzols).

6. Soils are affected by climate (rainfall and temperature) and, to some extent, by the evegetation growing on them. As a result, soils are distributed on a latitudinal pattern corresponding approximately to vegetation zones.

7. Wetland ecosystems include mangrove swamps, salt marshes, flooded river valleys, swamps, marshes and bogs.

8. The environment of a wetland habitat depends on the source of its water; sea water is saline, river water is sediment rich, drainage water is nutrient rich and rainfall is nutrient poor.

9. Mangrove swamps and salt marshes are dominated by the influence of tides and by the high salt content of the soil and water.

10. Bogs are mainly fed by rainfall and are therefore nutrient poor. Many bog plants augment their nutrient intake by being insectivorous.

11. Aquatic ecosystems include the open sea, ponds, lakes and rivers.

12. Ponds are small and some are ephemeral, drying out occasionally in years of drought or regularly every dry season.

13. Lakes may be fertile (eutrophic) or nutrient poor (oligotrophic).

14. Lakes may become stratified in summer due to the heating of the surface waters. As debris sinks and decays, the bottom waters, especially in eutrophiclakes, can become anoxic and nutrient rich while the surface waters become nutrient poor.

The ecosystem is the central theme and most important concept of ecology. The two approaches to its study, the biological and the merological, must be integrated and translated into programs of action if man is to survive his self-generated environment crisis. It is man the geological agent, not so much as man the animal, that is too much under the influence of positive feedback, and therefore, must be subjected to negative feedback. Nature, with our intelligent help, can cope with man's physiological needs and wastes, but she has no homeostatic mechanisms to cope with bulldozers, concrete and the kind of agro-industrial air, water, and soil pollution that will be hard to contain as long as the human population itself remains out of control.

1.6.10 EXPECTED QUESTIONS

1. Discuss the various types of ecosystems with examples.
2. Write a short note on the following:
   a) Food Land ecosystems
   b) Bog ecosystems
   c) Marine wet land ecosystems

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Dr. K. VEERAIAH

LESSON 2.1

FUNDAMENTAL CONCEPTS RELATED TO ENERGY AND ENTROPY LAW

CONTENTS:

2.1.1 Introduction to what is ENERGY

2.1.2 Energy sources and USES

2.1.3 Current energy sources

2.1.4 Some energy units

2.1.5 Explanation about fundamental concepts related to energy

2.1.6 Energy Conservation

2.1.7 What is our energy future.

2.1.8 Introductoin to entropy law.

2.1.9 Units of entropy

2.1.10 Summary

2.1.11 Expected questions.

2.1.12 References.

2.1.1 Introduction:

Energy and matter are essential constituents of both the universe and living organisms. If matter is the material of which things are made, ENERGY is the capacity to do work. Energy can take many different forms. Heat, light, electricity, and chemical energy are common forms. The energy contained in moving objects is called KINETIC ENERGY. The energy that is stored but available for use is potential energy chemical energy stored in the food that we eat and the gasoline that we put into the car, is also potential energy that can be released to do useful work.

Heat describes the energy that can be transferred between objects of different temperature. When two objects of different temperature are placed in content, heat transfer to the cooler one until the two reach the same temperature. When a substance absorbs heat, its internal energy increases; the kinetic energy of its molecules increases, or it may change state: a solid may become liquid or a liquid becomes a gas. The behavior of the energy is described in the following laws. The first law of the thermodynamics states that energy may be transformed from one type into another but is never created nor destroyed. Light, for example, is a form of energy, for it can be transformed into work, heat or potential energy of food, deepening on the situation but none of it is destroyed. The second law of thermodynamics may be stated in several ways, including the following: No process involving an energy transformation will spontaneously occur unless there is a degradation of the energy transformation will spontaneously occur unless there is a degradation of the energy from a concentrated form into a dispersed into the cooler surroundings. The second law of thermodynamics may also be stated as follows: because some energy is always dispersed into unavailable heat energy, no spontaneous transformation of energy (light, for example) potential energy (protoplasm, for example) is 100% efficient.

Organisms, ecosystems and the entire biosphere posses the essential thermodynamic characteristic of being able to create and maintain a high state of internal orders or a condition of low entropy. If is achieved by a continual dissipation of energy of high utility (Light or food for example) to energy of low utility (heat, for example). In the ecosystem, order in terms of a complex biomass structure is maintained by the total community respiration which continually "pumps out disorder".

Energy is often measured in units heat (calories) or work (Joules). One Joul (J) is the work done when 1 kg is accelerated 1m per second per second

$1J = 1Kg. M^2/S^2$

one calorie is the amount of energy needed to heat one gram of pure water one degree celsius. A celsius can also be measured as 4.184 J.

2.1.2 ENERGY SOURCES AND USES:

Being able to utilize external energy to do useful work is one of the most unique characteristics of humans. Access to a source of high quality energy is essential for continuation of the current way of life. But what do these terms mean? Work is the application of force through a distance. Energy is the capacity to do work, power is the rate of flow of energy, or the rate at which work is done. The energy we use to move our muscles, to think, and to energy in our food. Food energy is generally measured in calories.

2.1.3 CURRENT ENERGY SOURCES:

Fossil fuels (petroleum, natural gas & coal) now provide about 79 percent of all commercial energy in the world. Biomass fuels such as wood, peat, charcoal, and manure contribute about 9.5% of commercial energy. Other renewable sources, solar, wind, geothermal and hydroelectricity makes up about 4.5 percent of our commercial power etc. In any registered place biomass supplies more than 90% of the energy used for heating and cooking. This is an important energy source for poor people but can be a serious cause of forest destruction.

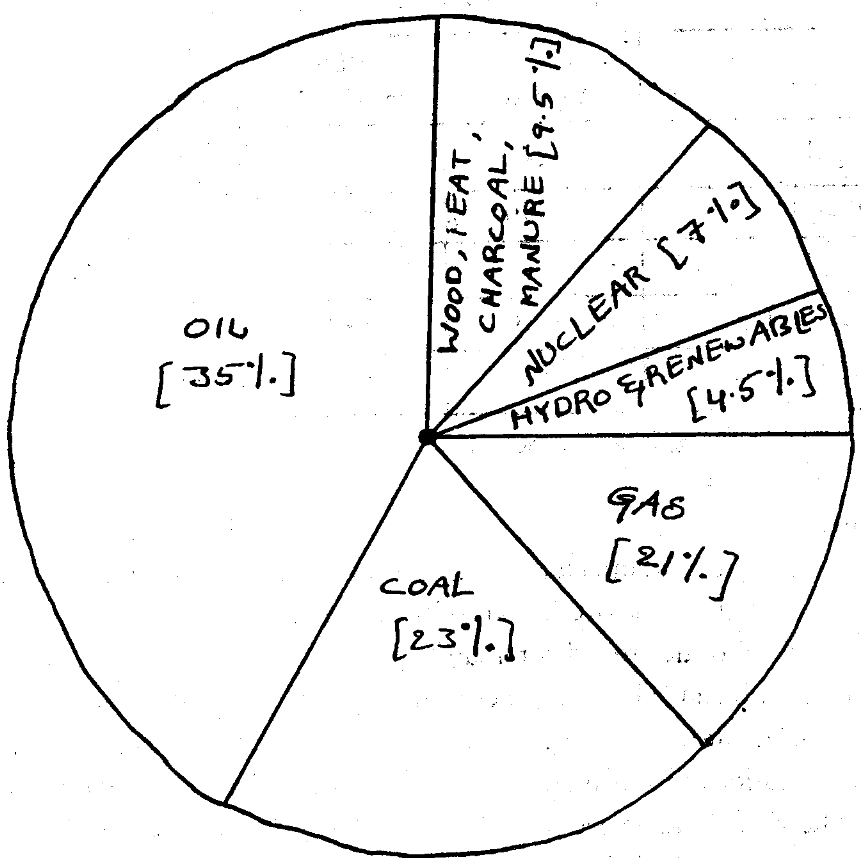


Fig. 2.1 The figure explains the worldwide commercial energy production.

2.1.4 SOME ENERGY UNITS:

1 JOULE (J) = The force excreted by a current of 1 ampper second following through a resistance of 1 ohm.

1 Walt (W) = one Joule per second

1 Kilowatt – hour (kwh) = 1 thousand (10^3) watts exerted for 1 hour

1 Megawatt (MW) = 1 million (10^6) watts

1 gigawatt (GW) = 1 billion (10^9) watts.

1 petajoule (PJ) = 1 quadrillion (10^{15}) Joules

1 British thermal unit (BTU) = energy to heat 1 1b of water 1^0F

1 PJ = 947 Billion Btu, or 278 million Kwh.

1 standard barrel (bbl) of oil = 42 gal (160 lit) or 5.8 million Btu

1 Metric ton of standard coal = 27.8 million Btu or 4.8 bbl oil

ENERGY SAVING POTENTIAL:

	MODEL AVERAGE	BEST ON MARKET	BEST PROTOTYPE	SAVINGS (%)
Automobiles (MI//gal)	24	78	107	71
Refrigerator (kwh/day)	190	68	11	94
Home (1,000 J/day) 4	2	1	75	
Gas furnace (milion/day)	210	140	110	48
Air conditioner (kwh/day)	10	5	3	70

SAVINGS = Average model + best prototype .. 1.0

2.1.5Explanation

It is readily apparent how the fundamental concepts of physics outlined in the above paragraph are related to ecology. The variety of manifestations of life are all accompanied by energy changes, even though no energy is created or destroyed (first law of thermodynamics). The energy that enters the earth's surface as light is balanced by the energy that leaves the earth's surface as invisible heat radiation. The essence of life is the progression of such changes as growth, self-duplication, and synthesis of complex relationships of matter. Without energy transfers, which accompany all such changes, there could be no life and no ecological systems. We, as human beings, should not forget that civilization is just one of the remarkable natural proliferations that are dependent on the continuous inflow of the concentrated energy of light radiation. Thus, the relationships between producer plants and consumer animals, between predator and prey, not to mention the numbers and kinds of organisms in a given environment, are all limited and controlled by the same basic laws which govern nonliving systems, such as electric motors or automobiles.

Some of the radiation falling on the earth, passes through the atmospheric film, and strikes forests, grasslands, lakes, oceans, cultivated fields, deserts, greenhouses, ice sheets, and many hundreds of other types of ecological systems which blanket the earth and compose the biosphere. When light is absorbed by some object which becomes warmer as a result, the light energy has been transformed into another kind of energy known as heat energy, which is composed of the vibrations and motions of the molecules that make up the object. The absorption of the sun's rays by land and water results in hot and cold areas, ultimately leading to the flow of air which may drive windmills and perform work such as the pumping of water against the force of gravity. Thus, in this case, light energy passes to heat energy of the land to kinetic energy of moving air which accomplishes work of raising water. The energy is not destroyed by lifting of the water, but becomes potential energy, because the latent energy inherent in having the water at an elevation can be turned back into some other type of energy by allowing the water to fall back down the well. As indicated earlier food resulting from photosynthetic activity of green plants contains potential energy which changes to other types when food is utilized by organisms. Since the amount of one type of energy is always equivalent to a particular quantity of another type into which it is transformed, and may be calculated one from the other. For example, knowing the amount of light energy absorbed and knowing the conversion factor, we may determine the amount of heat energy which has been added.

The second law of thermodynamics deals with the transfer of energy toward an ever loss available and more dispersed state. As far as the solar system is concerned, the dispersed state with respect to energy is one in which all energy is in the form of evenly distributed heat energy. That is, if left to itself, all energy where it undergoes a change of form which will be eventually tend to be transformed into the from of heat energy distributed at uniform temperature. This tendency has often been spoken of as the running down of the solar system. Whether this tendency for energy to be leveled applies to the universe as a whole is not yet known.

At the present time the earth is far from being in a state of stability with respect to energy because there are vast potential energy and temperature differences which are maintained by the continual influx of light energy form the sun. However, it is the process of going toward the stable state that is responsible for the succession of energy changes that constitute natural phenomena on the earth as we know them. It is like a man on a treadmill; he never reaches the top of the hill, but his efforts to dos so result in well-defined processes. Thus when the sun energy strikes the earth, it tends to be degraded into heat energy. Only a very small portion of the light energy absorbed by green plants is transformed into potential or food energy; most of it goes into heat, which then passes out of the plant, the ecosystem, and the biosphere. All the rest of the biological world obtains its potential chemical energy from organic substances produced by plant photosynthesis or microorganism chemosynthesis an animal, for example, takes in chemical potential energy of food and converts a large part into heat to enable a small part of the energy to be reestablished as the chemical potential energy of new protoplasm. At each step in the transfer of energy from one organism to another a large part of the energy is degraded into heat.

The second law of thermodynamics which deals with the dispersal of energy is related to the stability principle. According to this concept any natural enclosed system with energy flowing through it, whether the earth itself or a smaller unit, such as a lake, tends to change until a stable adjustment, with self-regulating mechanisms, is developed. Self-regulating mechanisms are mechanisms which being about a return to constancy if a system is caused to change from the stable state by a momentary outside influence. When a stable adjustment is reached, energy transfers tend to progress in a one-way fashion and at characteristic steady rates, according to the stability principle.

According H.T. Odum (1967), building on the concepts of Lotka and Schrodinger places the thermodynamic principles in the ecological context in the following manner;

Antithermal maintenance is the number one priority in any complex system of the real world. As Schrodinger has shown, the continual work of pumping out "disorder" is necessary if one wishes to maintain internal order in the presence of thermal vibrations in any system above absolute zero temperature. In the ecosystem the ratio of total community respiration to the total community biomass (R/B) can be considered as the maintenance to structure ratio, or as a thermodynamic order function. This "Schrodinger ratio" is an ecological turnover, a concept introduced in earlier If R and B are expressed in calories (energy units) and divided by absolute temperature, the R/B ratio becomes the ratio of entropy increase of maintenance (and related work) to the entropy of ordered structure. The larger the biomass, the treated the maintenance cost; but if the size of the biomass units (individual organisms, for example) is large (such as vegetation in a forest), the Antithermal maintenance per unit of biomass structure is decreased. One of the theoretical questions now under debate is whether nature maximizes the ratio of structure to maintenance metabolism or whether it is energy flow itself that is maximized.

It is interesting to note that the word economics and ecology have the same root, *oikos,* which refers to "house." It can be said that economics deals with financial housekeeping and ecology deals with environmental housekeeping. While energy can be thought of as the "currency" of ecology, energy and money are not the same because they flow in opposite directions (i.e., exchange), and money circulates while energy does not. The behavior of energy in ecosystems can be conveniently termed the energy flow because, as we have seen, energy transformations are "one-way" in contrast to the cyclic behavior of materials.

2.1.5 ENERGY CONSERVATION:

one of the best way to avoid energy shortages and to relieve environmental and health effects of our current energy technologies is simply to use less. Conservation offers many benefits both to society and to the environment.

1. **USING ENERGY MORE EFFICIENTLY:** Much of the energy that is consumed is wasted. This statement is not a simple admonishment to turnoff lights and turndown furnace thermostats in winter; it is technological challenge. Our ways of using energy are so inefficient that most potential energy in fuel is lost as waste heat, becoming a form of environmental pollution. More efficient and less energy-intensive industry, transportation, and domestic particle could save large amounts of energy. Many improvements in domestic energy efficiency have occurred in the past decade. Today's average new home uses one half the fuel required in a house built in 1974, but much more can be done. Household energy losses can be reduced by one-half to three – fourths by using better insulation, installing double or triple glazed windows, purchasing thermally efficient curtains or window coverings, and sealing cracks and loose joints.

2.1.7WHAT IS OUR ENERGY FUTURE:

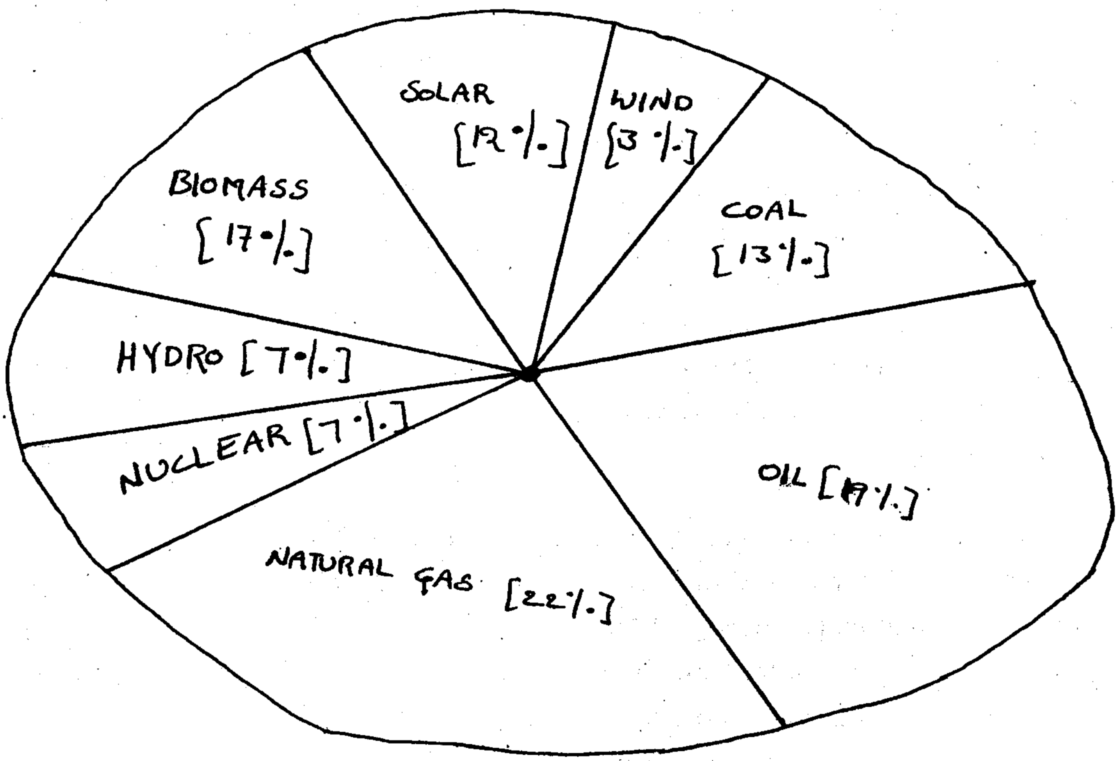


Fig. 2.2 Idealized ecological scenario for cumulative world energy consumption 2000-2100.

None of the renewable energy sources discussed likely to completely replace fossil fuels and nucleus powers in the near future. They could, however, make a substantial collective contribution toward providing us with the conveniences as we crave in a sustainable collective contribution toward providing us with the conveniences we crave in a sustainable, environmentally friendly manner. They could also make us energy independent and balance our international payment deficit.

Environmentalists point to the dangers of air pollution, global climate change, and other environmental problems associated with burning of fossil fuels. On other hand, prefer conservation measures such as forcing auto -makers to increase average fuel efficiency of cars and light trucks and providing heating bill assistance for law-income households.

In light of what you're read in this chapter about current and potential sources, what sort of energy policy would you suggest if you were invited to advice government officials? How much conservation is it realistic or fair to ask people to adopt? What is a reasonable percentage of our energy that might come from the renewable sources in 20 or 50 years? If you want more towards the 'ecological scenario' described above by the world energy council, how would you go about implementing that plan? What government actions do you think would be most effective in accomplishing these goals?

2.1.8ENTROPY LAW:

Introduction: For many years scientists believed that only exothermic changes resulting in a lowering of internal energy or enthalpy could occur spontaneously.

But melting of ice is an endothermic process and yet occurs spontaneously. On a warm day, ice melts by itself. The evaporation of water is another example of a spontaneous endothermic process. Thus arose the need of investing another driving force that affects the spontaneity. This is known as the entropy change, as, ΔS.

SPONTANEITY and RANDOMNESS: Careful examination shows that in each of process viz., melting of ice and evaporation of water, there is an increase in randomness or disorder of the system. The water molecules in ice are arranged in a highly organized crystal pattern which permits little movement. As the ice melts, the water molecules become disorganized and can move very freely. The movement of molecules becomes free still when the water evaporates into space as now they can roam about throughout the entire atmosphere. In other words, the randomness of the water molecules increases as ice melts into water or water evaporates into space.

INCREASE IN RANDOMNESS FAVOVRS A SPONTANEOUS CHANGE.

A change that brings about randomness is more likely to occur than one that brings about order. Let us suppose we have a suit of playing cards arranged numerically, we can see that sequence of cards in certainly highly organized. Now, if we throw the cards into the air, collect them and restock them, we will almost surely find that they have been placed at random.

This is expected because when the cards are tossed, there are many ways for them to be disordered, while there is only one way for them to come together again in their original sequence. Thus on the basis of pure chance a disordered sequence is for more probable than the ordered one with which it was started. The same law of chance applies to any physical or chemical process.

Entropy is defined as "It is a thermodynamic state that it is a measure of the randomness or disorder of the molecules of the system".

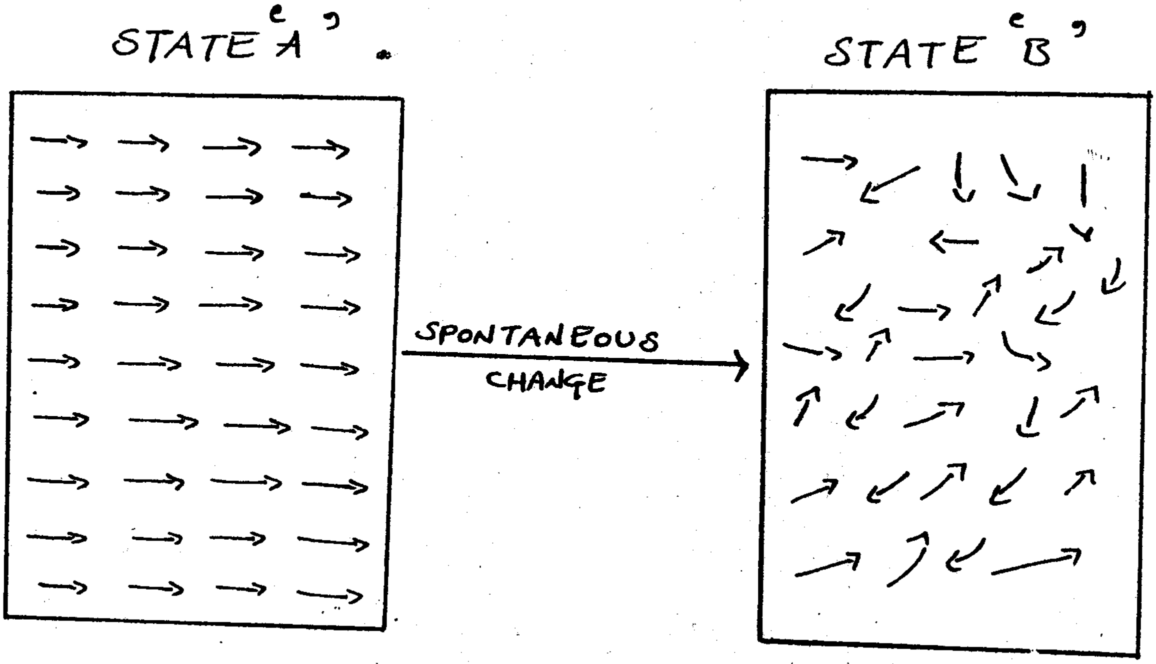
The symbol of entropy is 'S' while the change in disorder accompanying a process form start to completion is represented by ΔS. The entropy of a system is a state function and depends only on the initial and final states of the system. The change in entropy, as, for any process is given by the equation.

$AS = S_{final} - S_{Initial}$

When $S_{Final} > S_{initial}$ as is positive.

A process accompanied by an increase in entropy tends to be spontaneous.

Let us consider a molecular system in states A and B. In state A all the molecules are arranged in a highly ordered, while in state B the molecules are present at random and it is highly disordered.



Highly ordered low entropy & Less probable

Highly disorderd high entropy & More probable

Fig. 2.3

1. By the definition, the entropy of A is low and that of B high, thus an increase of entropy occurs in the change from A to B.
2. According to the law of chance, A is less probable and B is more probable. Therefore, the change from A to B is spontaneous.
3. From (1) and (2), it follows that the change from A to B which is accompanied by increase of entropy will tend to be spontaneous.

Hence in general, that change in a system which is accompanied by an increase in entropy, tends to be spontaneous.

The second law of thermodynamics states that whenever a spontaneous process takes place, it is accompanied by an increase in the total energy of the universe. More specifically, the term 'universe' is to mean the system & surroundings.

Thus $\Delta S_{univ} = \Delta S_{syst} + \Delta S_{run}$

The second law, as stated above, tells us that when an irreversible spontaneous process occurs, the entropy of the system and surroundings increases. In other words $\Delta S_{univ} > o$ when a reversible process occurs, the entropy of the system remains constant. $\Delta S_{univ} = O$, since the entire universe is undergoing spontaneous change, the second law can be most generally and concisely stated as:

"The ENTROPY of the system is constantly increasing. The entropy of a substance varies directly with the temperature. The lower the temperature, the lower the entropy. For example, water above 100^0 at one atmosphere exists as a gas and has higher entropy. The water molecules are free to room about in the entire continues. When the system is cooled, the water vapour condenses to form a liquid. Now the water molecules are confined below the liquid level but still can move about somewhat freely, thus the entropy of the system has decreased. On further cooling, water molecules join together to form ice crystal. The water molecules in the crystal are highly ordered and entropy of the system is very low. If we cool the solid crystal still further, the vibration of molecules held in the crystal lattice gets slower and they have very little freedom of movement and hence very small entropy. At absolute zero all molecular vibration ceases and water molecules are in perfect" order. Now the entropy of the system will be zero.

At absolute zero, the entropy of a pure crystal is also zero.
That is, S=O at T =OK

Numerical definition of entropy:

We have discussed the physical definition of entropy, but classical thermodynamics doesn't require a physical explanation of the concept of entropy. All that we need is an operational definition so that we can calculate the entropy change of the system and the surroundings.

In 1850 Celsius introduced a numerical definition of entropy. According to him entropy of a system, is a constant quantity when there is no communication of heat. When heat flows into a system, the entropy increases by q/t. heat flouring out of a system produces a corresponding decrease. Thus entropy could be precisely defined as:

For a reversible change taking place at a fixed temperature the change in entropy (ΔS) is equal to heat energy absorbed or evolved divided by the temperature (T).

That is $\Delta S = q / t$

If the heat absorbed then ΔS is positive and there will be increase in entropy. If heat is evolved, ΔS is negative and there is a decrease in entropy.

2.1.9 UNITS OF ENTROPY.

As stated above, entropy is equal to heat energy divided by absolute temp. Therefore, it is measured in entropy units which are calories per degree per mole i.e., cal $mol^{-1} K^{-1}$

In the SI system, the units are joules per mole per degree i.e., J $mol^{-1} K^{-1}$. These are represented by EU.

leu = 4.184 EU.

The absolute entropy of a substance at 25^0C (298K) and one atmosphere pressure, is called the standard entropy; S^0.

2.1.9 SUMMARY:

Energy is the capacity to do work. Today nearly 80 percent of all commercial energy is generated by fossil fuels, with about 35 percent coming from petroleum. Coal produces 23 percent, and natural gas accounts for 21 percent of our commercial supply. Petroleum and natural gas were not used in large quantities until the beginning of the twentieth century, but supplies are already running low.

Several sustainable energy sources could reduce or eliminate our dependence on fossil fuels and nuclear energy. Exciting new technologies have bean involved to use renewable energy sources. The greatest worry about nuclear power is the danger that accidents or terrorist attacks could release hazardous radioactive materials into the environment. The environmental damage caused by mining, shipping, processing and using fossil fuels may necessiate cutting back on our use of there energy sources.

2.1.10 XPECTED QUESTIONS:

1. What is energy and write an essay on its fundamental concepts?
2. Write a detailed account of entropy law?
3. What are the current energy sources and what can you do to same the energy?
4. Write short notes on energy conservation?

2.1.10.1 REFERENCES:

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LESSON 2.2

CONCEPT OF PRODUCTIVITY FOOD CHAINS FOOW WEBS THROPHIC STRUCTURE AND ECLOGICAL PYRAMIDS

CONTENTS

2.2.1 Introduction to concept of productivity
2.2.2 Productivity types
2.2.3 Productivity in phytoplankton
2.2.4 The organisms responsible for primary production
2.2.5 Primary production
2.2.6 Methods used to measure primary productivity
2.2.7 Food Chains
2.2.8 Significance of food chains
2.2.9 Food Web
2.2.10 Trophic structure and Ecological pyramids
2.2.11 Summary
2.2.12 Expected Questions
2.2.13 References

2.2.1 Introduction

The productivity of an ecosystem refers to the rate of productions i.e. the amount of organic matter accumulated in any unit time. A community's primary production, is the conservation of solar energy into chemical energy that was stored in living organisms. Since much energy is used in respiration, a more useful term is often net primary productivity, is the amount of biomass stored after respiration. Productivity depends on light levels, moisture and nutrient availability. In tropical forests, coral reefs and estuaries have high levels of productivity because they have abundant supplies of all the required resources. In deserts, lack of water limits photosynthesis. On the arctic tundra or in high mountains low temperatures inhibit plant growth. In the open ocean, lacks of nutrients reduce the ability of algae to make use of potential sunshine and water.

Even the most photosynthetically active ecosystems capture only a small percentage of the available sunlight and use it to make energy rich compounds. In a temperate climate oak – forest, leaves absorb only about half the available light on a midsummer day. Of this absorbed energy, 99% is urged to evaporate, in respiration and cooling. A large oak tree can transpire several thousand liters of water on a warm, dry, sunny day, while making only a few kilograms of sugars and other energy rich organic compounds.

2.2.2 Productivity types

1: Primary Productivity { Gross primary productivity / Net primary productivity }

2. Secondary productivity
3. Net productivity

1. Primary Productivity: It is associated with the producers which are autotrophic, most of which are photosynthetic and to a much lesser extent the chemosynthetic microorganisms. There are the green plants, higher macrophytes, as well as ower forms, the phytoplankton and some photosynthetic bacteria. PRIMARY PRODUCTIVITY IS DEFINED AS " THE RATE AT WHICH RADIANT ENERGY IS TRAPPED BY PHOTOSYNTHETIC & CHEMOSYNTHETIC ACTIVITY OF PRODUCERS". Primary productivity is further distinguished as:

a) **Gross Primary Productivity (GPP)**: It is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. This is also sometimes referred as total (gross) photosynthesis or total assimilation. It depends on the chlorophyll content. The rate of primary productivity is estimated interms of either chlorophyll content as 'chl/g dry weight/unit area' or photosynthetic number i.e., amount of CO_2 fixed/g chl/hour.

b) **Net Primary Productivity**: It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. This is thus the rate of increase of biomass and is also known as apparent photosynthesis or net assimilation. Thus, the net primary productivity refers to balance between gross photosynthesis and respiration and other plant losses as death etc.

Secondary Productivity: It refers to the consumers or heterotrophs. These are the rates of energy storage at consumers level. Since consumers only utilize food materials in their respiration, simply converting the food matters to different tissues by an overall process, secondary productivity is not divided into gross and net amounts. Thus some ecologists as ODUM (1971), prefer to use the term assimilation rather than 'production' at this level the consumer level. Secondary productivity actually remains mobile and does not live in situ like the primary productivity. Only about 10-20% of the primary production is converted into secondary production, the remaining 80 to 90% is lost by the consumers in the form of faeces.

Net Productivity: It refers to the rate of storage of organic matter not used by the heterotrophs i.e. equivalent to net primary production minus consumption by the heterotrophs during the unit period, as a season or year etc. It is thus the rate of increase of biomass of the primary producers which has been left ones by the consumers. Net productivity is generally expressed as production of $Cg/m^2/day$. Which may then be consolidated on month, season or year basis.

In more general terms, productivity of an ecosystem refers to its richness that and have a richer productive community/may have a larger quality of organisms than a less productive community, this is by no means always the case. Standing biomass or standing crop present at any given time should not be confused with productivity.

2.2.3. Productivity in Phytoplanktons

Thermodynamically the most desirable measure of primary production would be change in free energy but, at present at least, this can't be done easily enough to be practical use. A large numbers of determinations for comparative purposes are required for knowing the change in primary production. Since oxygenic photosynthesis is the predominating contributor to primary production and measuring changes in the amount of one of the substances involved e.g. oxygen or carbon helps to determine the change in primary production. With terrestrial plants a simple method of doing this is to determine the dry weight of material accumulated during the growing season. With suitable corrections for losses by respiration and predation this provides a reasonable estimate of primary production. A similar method is not possible with phytoplankton because generation times are much shorter than those of higher plants and biomass is usually consumed by predators at about the some rate as it is produced. In this situation only determinations of photosynthesis made over short periods, of hours rather than days, and in the absence of predators can give an accurate idea of the rate of primary production.

2.2.4 The organisms responsible for primary production

Usually, primary production is referred to the total phytoplankton 'measured interms of chlorophyll content' numbers or cell volume. Numbers give only a poor idea of photosynthetic capacity since the cells counted may range from flagellates only 1 μm or so in diameter to large diatoms, about 2 mm across. Cell volume is a better measure but cell surface is better still. Small cells have a high surface/ volume ratio. Which favors rapid exchange of materials between protoplasm and environment 'and' as expected, they are most active in photosynthesis. Phytoplankton is divided rather arbitrarily into net plankton, retained by the finest blotching silk with 64um apertures 'and nannoplankton which passes through such a net. It is usually found that 'after passing through the net' lake or sea water retains 50% or sometimes more of its photosynthetic capacity. Floristic studies on phytoplankton have until recently been concentrated on net plankton but it now appears that the smaller flagellates, diatoms, green and blue green algae which make up the nannoplankton and which have been relatively ignored by taxonomists are at least as important in primary productivity. Photosynthesis by nannoplankton was found to be greater than its biomass would suggest where as several species were found to contribute significantly to biomass but not to primary production.

2.2.5 Primary Production

The most important input of energy into the ecosystem is by photosynthesis. This is the synthesis of organic matter from water, carbon dioxide and mineral salts as carried out in sunlight by chlorophyll containing plants. It may be described by the equation.

$$Co_2 + H2O \rightarrow CH_2O + O_2 \quad (1)$$

In which (CH_2O) is an approximate emphericalIy formula for organic products, the potential chemical energy of which has been derived from radiant energy. Photosynthesis need not 'however, necessarily start from the inorganic form, CO_2. If a suitable organic source, such as acetate or glucose is available' cell material may be synthesized directly from this using energy supplied by the photosynthetic mechanism. Thus a substance already having f=high potential chemical energy is converted into other substances at the expense of radiate energy. This process 'photo assimilation' is well attested by laboratory experiments; it presumably occurs 'for example' in water polluted with sewage' but it is not clear to what extent it goes on under natural conditions. There is yet another variant of photosynthesis carried out by bacteria, which contains chlorophylls other than chlorophyll a, and by chlorophyll-a containing algae under special conditions 'which depends on the availability of particular inorganic or organic hydrogen diners and in which oxygen is not evolved. For example, green sulphur bacteria carry out photosynthesis according to this equation.

$CO_2 + 2H_2S \xrightarrow{hv} (CH_2O) + H_2O + 2S \longrightarrow$ (2)

The total energy fixed in photosynthesis world wide is one of the most important factors limiting life on earth. Until fairly recently the assumption was commonly made that the oceans 'because they are large in area by comparison with the land' support most of the photosynthesis in the world. Careful measurements of both photosynthesis and nutrients, especially nitrogen and phosphorus, available to support photosynthesis in the world careful measurements of both photosynthesis and nutrients, especially nitrogen and phosphorus, available to support photosynthesis of the world occurs in the oceans despite their large area. That photosynthesis occurs in upper 100m or so of the mixed surface layer and is most intensive in the costal zones where nutrients are available from runoff from the land and from upward mixing of nutrient rich water from the oceanic depths.

The convention that ecologists have developed for examining energy fixation by plant communities is summarized by two simple equations, one of that is applied to a single plant or a plant community.

NP = GP – Ra (3)
Where NP = Net production
GP = Gross production, which is a total photosynthesis
Ra = Respiration of the autotrophs.
NEP = GP – 9Ra+Rh (4)
Where NEP = Net ecosystem production, the net storage or loss of energy by a unit of landscape.
GP = Gross production
Ra = Respiration of the autotrophs
Rh = Respiration of heterotrophs.
Ra+Rh = Re: the respiration of the ecosystem as a whole.

The Community	Average Production	Maximum production
Bog	900	1500
Marshes, freshwater		
Typha, cattail	2700	3700
Carex, sedge	1000	1700
Phragmites, reed	2100	3000
Cyperus, papyrus	7500	15000
Freshwater tidal	1600	2100
Marshes, salt water tidal		
Spartina	2500	6000

Other grasses	1500	8500
Salicornia	3000	
Swamps, freshwater		
Bog, spruce	500	
Cedar, Cypress	4000	
Hardwood	1600	
Swamps, salt water		
Mangroove	3000	
Benthic micro types		
Freshwater, Lake	170	1560
Freshwater, spring	3000	3500
Marine	200	850

Annual production levels in benthic plant communities

2.2.6 METHODS USED TO MEASURE PRIMARY PRODUCTIVITY

The Harvest Method: In this method the plants grown on a particular area are harvested at ground level and their weight is taken. They are dried and again weighed. This is done at regular intervals 'the primary production is expressed interms of biomass or mass/unit area/unit time.

Carbondioxide Assimilation Method: Plants utilize carbon dioxide for photosynthesis. So the rate of photosynthesis can be calculated by calculating the amount of carbon dioxide utilizing plants per unit time. The incorporation of carbondioxide in photosynthesis can be determined by using infrared analyzer, with the help of this possible to measure carbondioxide enter or leave.

Oxygen Production Method: This method is used to measure primary production in aquatic ecosystem. In this method the amount of oxygen produced per unit time is taken as an index to measure the rate of photosynthesis. For this light and dark bottle technique is used. Samples of water containing the autotrophs are collected in a light bottle and in a dark bottle. The light bottle allows light to enter in and dark bottle does not allow light. The two bottles are suspended at the same depth from which the sample is collected. After a certain period of time the amount of oxygen present in the two bottles is calculated by titration using sodium thiosulphate. In dark bottle photosynthesis does not occur but respiration occurs.

In light bottle both respiration and photosynthesis occur. The rate of photosynthesis is calculated by calculating the amount of O_2 present in the two bottles. The light and dark bottle method, pioneered by GAARDER and GRAM in 1927. oxygen production may also be measured in certain aquatic ecosystems by the diurnal curve method.

Productivity determinations with radioactive materials:

This method is similar to oxygen production method. In this method a known quantity of C^{14} is introduced into the light and dark bottles along with the sample and the bottles are suspended for six hours. During this period C^{14} is incorporated into the protoplasm of the autotrophs. The autotrophs are filtered and dried, after drying the radioactivity is measured. The amount of radioactivity is proportionate to the amount carbohydrate produced. Radioactive isotopes other than C^{14} and P^{32} offer many possibilities which are yet to be investigated.

The Chlorophyll Method: The Possibilities of using the chlorophyll content of whole natural communities as a measure of productivity are now being actively investigated. GESSNER (1949) made the remarkable observation that the chlorophyll which actually develops on a per square mater basis tends to be similar in diverse communities.

Factors Affecting Productivity:

1) Quantity of incident radiation
2) Density of photosynthesizing material
3) availability of water
4) CO_2 and HCo_3
5) Temperature
6) Nutrients like P, N, Si etc.

In higher temperature   Higher respiration = Productivity is less

In terrestrial communities

GPP = 2.7x NPP

In aquatic communities (In ocean)

GPP = 1.5 x NPP.

2.2.7. Food Chains:

The transfer of energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as food chain.

At each transfer a large proportion of the potential energy is lost as heat, so the steps or links in a sequence is limited, usually to four or five. The shorter the food chin the greater the available energy which can be,converted into biomass. Food chains are not isolated sequences but are interconnected with one another. Traditionally food chains with the producers at the bottom, plant eaters the second trophic level, carnivores which eat the herbivores. The third level, secondary carnivores are at the fourth level. Sometimes the sun as the ultimate source of almost all food chains is placed at the bottom. Although decomposers play vital role in natural communities they are not usually included in food chains. Some organisms are omnivores eating the producers as well as the carnivores at their lower level in the food chain, such organisms may occupy more than one trophic level in the food chain. In any food chain energy flows from producers to primary consumers, from primary consumers to secondary consumers, form secondary consumers to teritiary consumers and so on. This simple chain of eating and being eaten away is known as food chain. **Food Chains are attempts to demonstrate the fate of individual organisms** in a particular habitat

Generalized food chain

↑

3rd level carnivore

↑

2nd level carnivore

↑

1st level carnivore

↑

Herbivore

↑

Producer

In general, two basic types of food chains are recognized, they are.

1. Grazing food chain
2. Detritus food chain

1. Grazing food chain:

Green plants → herbivore → carnivore this type of food chain starts from the living green plants goes to grazing herbivores and in to carnivores. Ecosystem with such type of food chains are directly depend on sun. Most of the ecosystems in nature follow this type of food chain. From energy stand point, these chains are very important.

Phytoplanktons → Zooplanktons → fish

Grasses → rabbit → fox

These two sequences are the examples of grazing food chain

Some examples to the Food Chain:

SCENEDÊSMUS BOLIGENS → Brachionus falcatus
(Phytoplankton) (Zooplankton)

↓

Homosapien ← *Wallago attu* ← *Amblypharyngodon* sps
(Man) (a large fish) (A small fish)

Sun

↓ 1000 calories

Autotrophs → 990 Calories loss to the environment

10 Calories plant ↓
matter available Herbivores → 9 calories loss to the environment
as a food

↓

1 calorie available as a food Carnivores

MODE OF ENERGY FLOW THROUGH A SIMPLE FOOD CHAIN

2. Detritus food Chain:

Detritus → bacteria →Detrivores→Predators.

This type of food chain goes from dead organic matter into microorganisms and then organisms feeding on detritus (detrivores) and their predators. Such ecosystems are thus less dependent on direct solar energy. Detritus food chain ends up in a manner similar to the grazing food chain 'but the way in which the two chains begin in quite different. In fact this type of food chain is simply a sub component of another ecosystem.

Abbreviated food chains:

Phytoplankton → krill → Blue whale

This type of food chain starts from eh phytoplankton 'phytoplankton in turn are eaten by krill' these intern may be eaten by Blue whale here we find only three trophic levels'. **Shorter the food chain greater the amount of availability of food energies.**

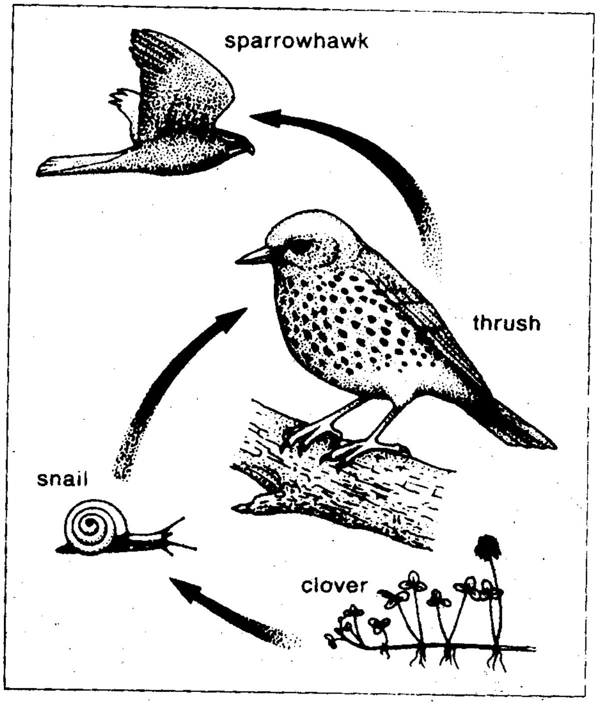


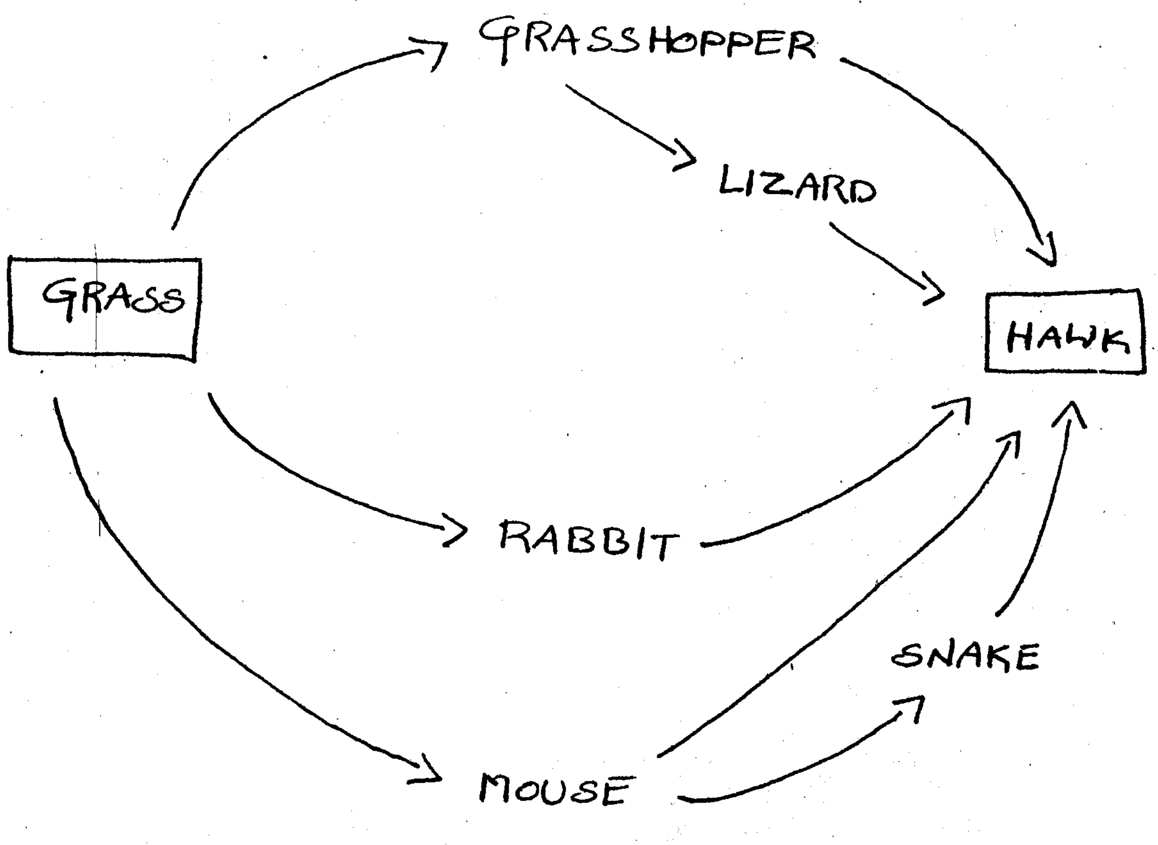
Fig. 2.4 A hypothetical food chain typical of a European mixed deciduous oak wood.

2.2.8 SIGNIFICANCE OF FOOD CHAIN :

The food chain studies help understand the feeding relationship and the interaction between organisms in any ecosystem. They also help us to appreciate the energy flow mechanism and matter circulation in ecosystem

2.2.9 Food Web:

A food web is really a collection or matrix of food chains. It shows the pattern of energy or nutrient flow throughout a community. Food chains in natural conditions never operate as isolated sequences, but are interconnected with each other forming some sort of interlocking pattern, which is referred to as food web.



EXAMPLES FOR FOOD-WEB'S

In such a food web in grassland, they may be seen as many as five food chains, which in sequences are:

1. Grass → Grasshopper → Hawk
2. Grass → Grasshopper → Lizard → Hawk
3. Grass → Rabbit → hawk
4. Grass → Mouse → Snake → Hawk.

The complexity of any food web depends upon the diversity of organisms in the system, it would accordingly depend upon two main points.

1) Lenth of food chain, diversity in the organisms based upon their food habits would determine the length of the food chain. More diverse the organisms in food habit, more longer would be food chain.

2) Alternatives at different points of consumers in the chain. More the alternatives, more would be the interlocking pattern.

Advantages of food web:

1. It is more realistic than food chain.
2. Omnivores can be shown in food web but not on a food chain.
3. It helps us to understand the actual pattern of energy flow in a community.

Disadvantages:

1. Food web cannot describe the relative importance of food chains.
2. Lack of information of individual group of organisms. Various techniques are used to determiner food webs are:

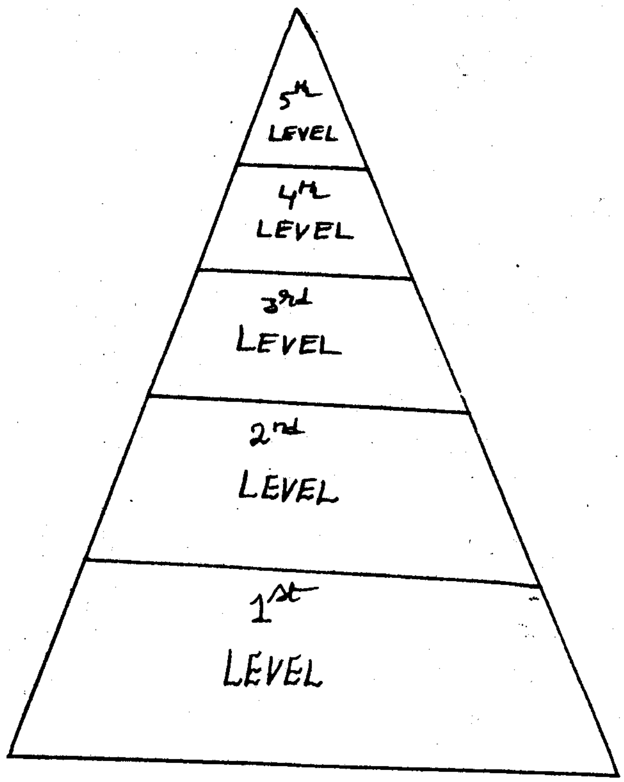
1. Visual observation
2. Analysis of fecal pellets
3. Analysis of stomach contents
4. Application of radio isotopes.

Generally 'food webs are not too complex. As more and more species are involved in a food web the connections increase.

Trophic Levels: Each food chain contains many steps like producers 'herbivores' primary carnivores and so on. Each step of the food chain is called. Trophic level. The number of trophic levels in a food chain is always restricted to 4 to 5, but very often the chains are very much complicated with many trophic levels.

Phytoplankton → Zooplankton → Fishes → Snakes
Tr. L_1 Tr. L_2 Tr. L_3 Tr. L_4

Trophic = Feeding



2.5. Tophic Levels

In the trophic structure several community groups or trophic levels are organized 'the species which are occupy by a particular trophic level are generally suppose to have similar food preferences. Thus the organisms whose food is obtained from plants by the same number of steps are said to belong to same trophic level. For eg the green plants (producers level) occupy first trophic level the herbivores occupy second trophic level, carnivores occupy third trophic level 'secondary carnivores occupy the fourth trophic level and the territory carnivores occupy the 5the level. This trophic classification is one of function is not of species i.e., a given species population may occupy one or more trophic level according to the energy assimilated.

2.2.10 Trophic Structure and Ecological Pyramids:

The interaction of the food chain phenomena and the size metabolism relationship results in communities having a definite trophic structure. Trophic structure may be measured and described either in terms of the standing crop per unit area or in terms of the energy fixed per unit area per unit time at successive trophic levels. Trophic structure and also trophic function may be shown graphically by means of ECOLOGICAL PYRAMIDS. Ecological pyramids are of three general types.

1. Pyramid of numbers in which no. of individual organisms depicted.
2. Pyramid of biomass based on the total dry weight 'caloric value or other measure of the total amount of. Living material.
3. Pyramid of energy in which the rate of energy flow/or productivity at successive trophic level is shown.

Pyramid of Numbers :They show the relationship between producers 'herbivores and carnivores at successive trophic levels in terms of their number. In a grassland the producers which are mainly the grasses' are always maximum in number. This number then shows a decrease towards apex 'herbivores like rabbit, mice etc are lesser than producers' the carnivores snakes and lizards lesser than herbivores. Finally top tertiary consumers are very less in number. Thus the pyramid become up right. Similarly in a pond the pyramid is upright. Here the producers which are mainly the phytoplankton as algae, bacteria are maximum in number. The herbivores which are smaller fish and rotifers are small number than producers and secondary consumers water bless in number than herbivores. Finally territory consumers the biggest fish are least in number.

In a forest ecosystem however, the pyramid of number is some what different in shape. However, in a parasitic food chain the pyramids are always inverted.

Actually the pyramid of numbers do not give a true picture of the food chain as they are not very functional. They do not indicate the relative effects of the geometric, food chain and size factors of the organisms.

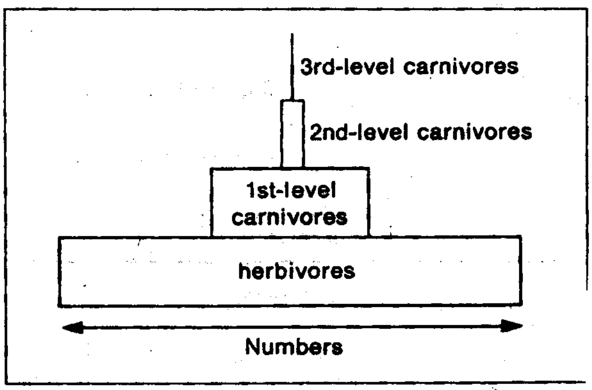


Fig. 2.6 Typical pyramid of number. Producers have been omitted, following Elton. The width of the boxes indicates the relative numbers of the organisms at each of the trophic levels. The most convenient horizontal scale is probably a logarithmic one. The highest carnivore(s). in this case the third-level carnivore, is/are sometimes refereed to as the 'top carnivore(s)'s.

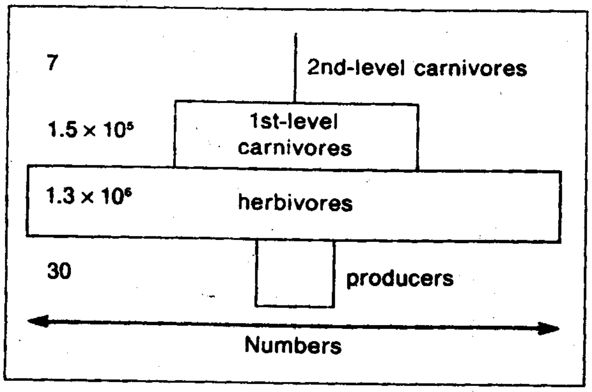


Fig. 2.7 10b Inverted pyramid of numbers in Wytham oak wood, Oxford. The horizontal scal mic. The numbers at the right-hand side refer to the numbers of the organisms at each trophic level per hectare. Only oaks were counted as producers. (Data from Varley, 1970.)

Pyramid of Biomass: They are more fundamental, as they instead of geometric factor, show the quantitative relationship of the standing crops.

In grassland and forest, there is generally a gradual decrease in biomass of organisms at successive levels from the producers to top carnivores. Thus pyramids are upright. However, in a pond as the producers are small organisms their biomass is least, and this value gradually shows an increase towards the apex of the pyramid, thus making the pyramid is inverted in shape.

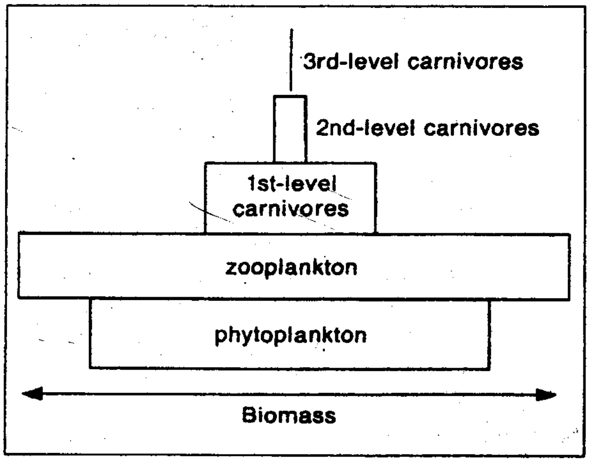
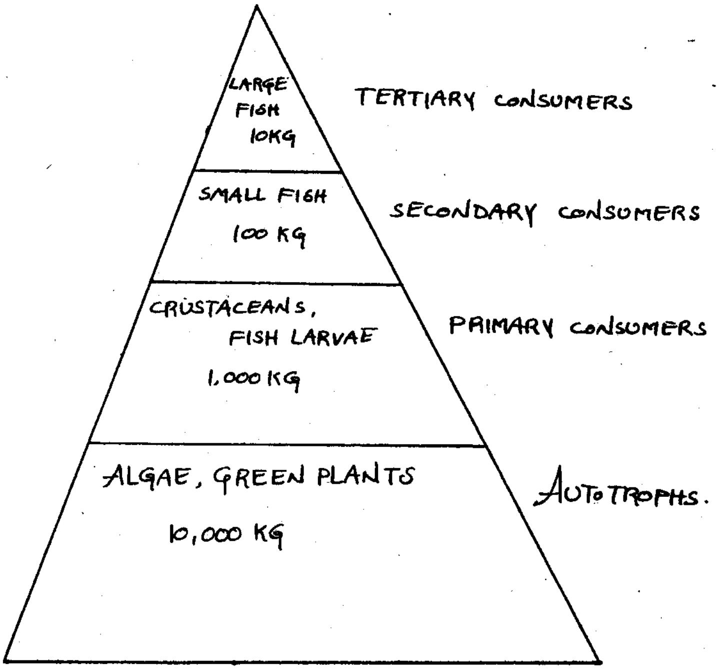


Figure 2.8 Inverted pyramid of biomass of zooplankton feeding on phytoplankton.



2.9. Pyramid of Biomass in a pond

Pyramid of Energy : Here, the rate of energy flow/or productivity at each successive trophic level is shown. In this case ther will be gradual decrease in the availability of energy from autotrophs to lighter trophic levels.

Pyramid of energy gives the best picture of the community function by highlighting the amount of energy available for successive higher trophic levels. Pyramid of energy can never be inverted. This follows directly from the first law of thermodynamics. The units of pyramid of energy are therefore energy/area/time.

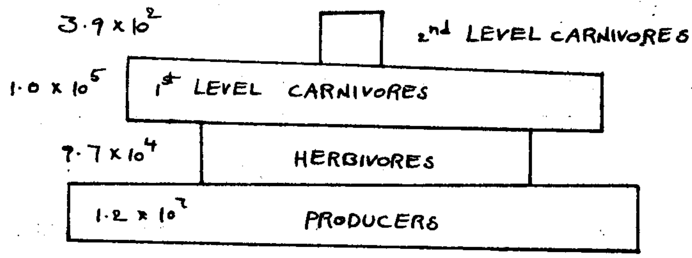


Fig. 2.10. Pyramid of Energy based on oak trees.

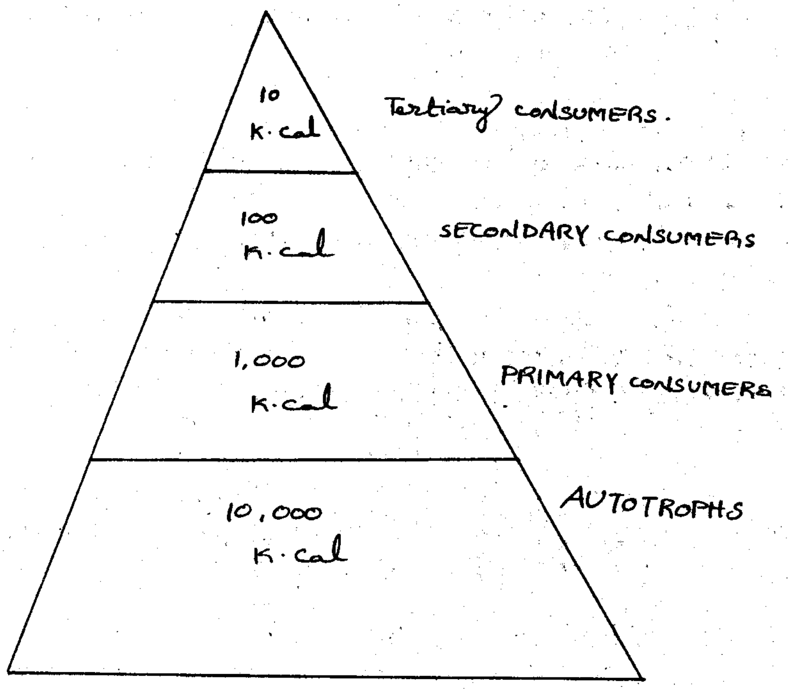


Fig. 2.11. Piramid of Energy

2.2.11Summary:

Productivity is nothing but the rate of production. Productivity is mainly of three types they are primary productivity, secondary productivity and net productivity. Net primary productivity is the amount of dry weight accumulated by autotrophs per unit area per unit time. Gorss primary productivity equals to net primary productivity plus respiration. Lack of nutrients limits primary production in most aquatic environments. Aquatic communities where the nutrient supply is good, as is the case for some algal beds, coral reefs and estuaries have primary productivities greater than any found on land. Production efficiencies vary from about 1-3% for endotherms to over 50% for some ectotherms.

Food chains can be used to demonstrate the biological fate of individual atoms. Food chains rarely have more than five levels, ecologists disagree as to why this is so.

A food web is the sum of the food chains in a community. Food webs do have the advantage that they are more realistic than food chains; for instance omnivores can be shown on a food web but not on a food chain.

Pyramids of numbers may quite often be inverted; pyramids of biomass only rarely. Pyramid of energy show the flow of energy up a food web. Pyramids of energy can never be inverted.

2.2.12 Expected questions:

1. Write detailed account on concept of productivity?
2. What is productivity and explain the estimation methods of primary productivity?
3. What is food chain? Give comparative account of grazing and detritus food chains/

4. Explain secondary production and what are the factors affecting the productivity?
5. Explain the following:

    1. Food Web
    2. Ecological Pyramids

6. What are the advantages and disadvantages of food web/ and add a note on significance of food chain?

2.2.13 References;

1. Basic Ecology –Odum.E.P (Saunders Publishing)
2. Ecology Principles And Applications – J.L. Chapman And M.J. Reis (Cambridge University Press)
3. Ecology And Environment – P.D. Sharma (Rastugl Publications)
4. Ecology – P.S. Verma And V.K. Agarwal (S. Chand Publications)
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Dr. K. Veeraiah, M.Sc., Ph.D.

LESSON 2.3

BIOGEOCHEMICAL CYCLES

CONTENTS

2.3.1 Introduction to Biogeochemical cycles
2.3.2 Carbon cycle
2.3.3 Nitrogen cycle.
2.3.4 Graphic representation to Nitrogen cycle.
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BIOGEOCHEMICAL CYCLES

2.3.1 Introduction:

The elements and compounds that sustain us are cycled endlessly through living things and through the environment. On a global scale 'this movement is referred to as biogeochemical cycling. Substances can move quickly or slowly; you might store carbon for hours or days 'while carbon is stored in the earth for million of years. When human activity alters flow rates or storage times in these natural cycles' overwhelming the environment's ability to process them these materials can become pollutants. Sulfur, nitrogen, carbondioxide and phosphorus are some of the more serious examples of these. Global scale movement of energy also play a role. Here we will explore some of the paths involved in cycling several important elements; water, carbon, nitrogen, sulfur and phosphorus.

Carbon, nitrogen minerals, water and other basic materials move constantly in cycles form the abiotic environment into and through living organisms, and back to the environment again. The actual atoms say of carbon and nitrogen that compose our bodies at this moment were present in the world long before we arrived in it. The cycling to which we refer is a repetitive sequence in which small molecules are built up into the large complex molecules of living organisms only to appear again in simple form as a result of the death and decomposition of organisms. These circular pathways of elementary materials are called BIOGEOCHEMICAL CYCLES, a term that emphasizes the participation of living organisms and the rocks, water, soil and air of the abiotic environment.

Perhaps as many as 40 of the 90- plus chemical elements participate in such cycles. Some are the well known elements that are needed in bulk amounts-carbon, nitrogen, hydrogen, oxygen. Some are trace elements which may enter living organisms in tiny amounts but are nonetheless essential to their survival. Each of these elements has a cycle of its own in which it follows a distinctive pathway at a characteristic flow rate. All of these cycles have greater or lesser capacities for self-regulation. This is important because human beings are altering these cycles in significant ways.

Organic and abiotic phases of Geochemical cycles:

Since an element is necessary for maintence of life, its movement through biotic communities can be viewed in the terms of food chain. The flow of chemical element through the food chain can be viewed as the organic phase of the biogeochemical cycle. Further, the biogeochemical cycles also include abiotic phases which are the functions of the chemistry of the elements in question. These abiotic phases are of critical importance to the ecosystem, as the major reservoirs for all nutrient elements are external to the food chains, and flow in the abiotic phases tends to be much lower than in the organic phase. The rapidity and direction of nutrient cycling through the abiotic phases determine not only the distribution of the element in the total environment, but also it availability of living systems. There are two classes of abiotic phases in biogeochemical cycles, a sedimentary phase which is part of all cycles and an atmospheric phase, which is possessed by some. In some cycles, such as nitrogen, the atmospheric phase is more important rather than the sedimentary phase.

2.3.2 CARBON CYCLE:

The great reservoir of monorganic carbon, and the source of almost all the carbon incorporated into living organisms, is the free CO_2 contained in the atmosphere and dissolved in the waters of the earth. The first quantitatively important step of the carbon cycle in the utilization of carbon from this reservoir is photosynthesis, largely by photosynthetic bacteria, algae and green plants. The carbon assimilated each year in this process is a little less than a tenth of the 700x 10^9 metric tons of CO_2 in the atmosphere which first becomes part of simple carbohydrates. These become ploys accharides, proteins lipids and other complex organic compounds. A few of these big molecules are broken down by respi9ratiory metabolism of the plants themselves, and some carbon is again refereed as CO_2. But most of them remain in the plant until it dies or eaten. When herbivorous, animals eat plants; they eliminate some of these organic compounds in the urine and faces as waste products. They digest the rest and then resemble them in their own tissues they, two, release some respiratory CO_2. When carnivorous animals eat herbivorous animals, more digestion and resynthesis takes place.

As long as it is a vital part of living organism, carbon occurs largely within organic molecules. But most of this organic carbon eventually reappears as CO_2 and returns to the inorganic realms of waters and air. Indeed, the CO_2 dissolved in the waters of the earth serves as an important reservoir of buffer in the carbon cycle. A bit of the CO_2 arises as a direct product of respiratory metabolism in plants, animals and protests. The position of carbon eliminated by animals in their waste products is still in the form of fairly complex organic compounds, and therefore does not immediately become atmospheric CO_2 which could be reutilized in photosynthesis. Substantial amounts of carbon remain in the tissues of organisms when they die.

If the carbon in animal wastes and dead bodies were not reconverted into CO_2, all life would have ended long ago. It has been estimated that atmospheric CO_2 would be exhausted in a year were not the atmosphere continually recharged with CO_2. The microbes attack, digest and decompose the organic materials of dead plants and animals and of waste products, reducing them to the simpler and energy-poor compounds with which the various cycles can begin again.

Other ways in which organic compounds can be broken down include fire, a rapid type of combustion and oxidation and decomposition, s lamer types. When wood burns, the carbon if its cellulose and other constituents is rapidly converted to CO_2.

Substantial amounts of carbon may be withdrawn from this cycle for long period of time. Some of this carbon is stored in living organisms, especially trees. But much larger amount is locked up in the huge deposits of limestone, which is mainly $CaCO_3$. Much but not all limestone is result of the activities of organisms. In the sea, plankton and other organisms incorporate $Ca^{2+}$and HCO^-3 ions into their calcium carbonate shells. Coral reefs are the result of this process. Huge amounts of carbon are also taken out of circulation for varying periods as fossil fuels petroleum, coal & gas. In time, most of this will be returned to the atmosphere. Recognition of these phenomena led to the discovery of another facet of the carbon cycle.

A carbon silicate cycle, a bio-geo chemical cycle that operates on a time scale in excess of 500,000 years. In this cycle, the atmospheric CO_2 dissolves in rain water and forms the carbonic acid. As rainwater weathers and erodes rocks containing calcium and silicates, $Ca^{2+}$and HCO^-3 ions are released into the ground water, eventually finding their way into rivers and oceans. There these ions are used by organisms to build $CaCO_3$ shells. The shells are eventually deposited as sediments on the sea floor and when the sea floor spreads, the sediments slip under the continental land masses. There heat and pressure cause $CaCO_3$ to react slowly with silica or quarter (SiO_2) with the reformation of silicate rocks and the release of CO_2, which reenters atmosphere via midocean ridges or volcanic eruptions. Because of the leisurely paces of this cycles vast quantities of limestone now lie deep in the earth, where its carbon will remain unavailable for a long time.

The Green house effect:

The burning of fuel by humans has increased the CO_2 reservoir in the atmosphere by about 25% in the last 140 years – from 280 ppm or less to about 350 ppm. Today more than 1.1 tons of carbon (as Co_2) is released every year for every human being on earth. Americans contribute stone per person per year. It is believed that this release rate will quadruple by the year 2100.

The causes concern because atmospheric CO_2, which is not readily decomposed by sunlight, plays a major role in regulating the temperature of the earth's surface and thus it climate. It does this by acting as a one-way screen. It is transparent to solar radiation at visible wavelengths, where most of the energy of sunlight is concentrated. However, molecules of CO_2 in the atmosphere absorb and re-emit some of the longer wavelengths of this energy, the infrared radiation that would otherwise be transmitted back into space the earth's surface. As a result, much of this energy is trapped in the atmosphere as heat.

This phenomenon is termed the green house effect because atmospheric CO_2 acts like the glass in a green house, transmitting visible light and reflecting infrared radiation. At present, the surface temperatures of the earth are about 35^{0}C higher than they would be if CO_2 and other gases were absent from the atmosphere.

Because of the tending of CO_2 to warm the earths air blanket, there is alarm ones the possible long range consequences of increasing atmospheric CO_2. The most troubling aspect of the green house effect is the global warming of 3-4°C predicted in the next century. Such an occurrence would likely raise the worldwide sea level by approximately 70 cm. Of the west Antarctic ice sheet and the ice masses in the Arctic Ocean begin to melt off, an additional 100 cm rise in the sea level would follow, with disastrous consequences for the world's costal regions.

If human activities continue to increase atmospheric CO_2, the results could be ecologically destabilizing. An increase in the average world temperature would enlarge the area of acid lands and diminish agricultural production.

2.3.3 Nitrogen Cycle:

Water contains only hydrogen, and oxygen. Carbohydrates and fats contain only carbon, hydrogen and oxygen. All other molecules of biological importance contain nitrogen. For instance, proteins, nucleic acids and chlorophyll all contain nitrogen. Nitrogen makes up almost 13% of our dry abundant (Rankama and Sahama 1950).

Despite the importance of nitrogen to living systems, it is still not possible to present a detailed a quantitative account of the nitrogen cycle. Nitrogen is an essential constituent of different biologically significant organic molecules such as amino acids and proteins, pigments, nucleic acids and vitamins. It is also the major constituent of the atmosphere, comprising about 79 percent of it. The paradox is that in its gaseous state, N_2 is abundant but is unavailable to most life. Before it can be utilized it must be converted to some chemically usable form.

To be used biologically, the free molecular nitrogen has to be fixed and fixation requires and inputs of energy tin the firs step molecular nitrogen, N_2 has to be split into two atoms: $N_2 \rightarrow 2N$, the free nitrogen atoms then must be combined with hydrogen and to form ammonia, with the release of some energy

$$2N+3H_2 \rightarrow 2NH_3.$$

The global nitrogen cycle with estimates of the annual rates of flow between the various compartments. It is worth emphasizing that the annual movement of nitrogen around the cycle is dwarfed by the amount of nitrogen present in the atmosphere and in rocks. The atmosphere contains approximately $4x10^2$ g and rocks approximately $2x10^{23}$ g. In terrestrial systems the great majority of nitrogen (97%) is found in soil organic mater, litter and soil inorganic nitrogen; only 3% is found in plants and animals (ROSSWALL 1983).

From an ecological perspective it is most convenient to break the nitrogen cycle down into a number of stages. They are.

1. AMMONIFICATION
2. NITRIFICATION
3. NITROGEN FIXATION
4. DENITRIFICATION

AMMONIFICATION:

When organisms excrete nitrogenous waste or die, the nitrogen is converted to ammonium ions by the action of Saprotrophic fungi and bacteria. This process is known as ammonification. The saprotrophs micros use the ammonia to synthesize their own proteins and other nitrogen containing organic compounds. Inevitably, though, some of the ammonia leaks into the surrounding soil and so become available to other bacteria and to plants.

NITRIFICATION;

In warm, moist soils with a pH near to 7, ammonium ions (NH_4+) are oxidized within a few days of their formation or their addition as a fertilizes. This oxidation benefits the bacteria performing the reactions by releasing energy which the bacteria can use for the synthesis of ATP. Nitrification takes place in two stages. First ammonium (NH_4+) is converted to nitrite (NO^-_2) and then nitrite is converted to nitrate (NO^-_3). These reactions are known as nitrification and can only be carried out by certain interfacing bacteria.

In the first stage of nitrification, ammonia is oxidized to nitrite by bacteria of the genera nitrosamines, involves the addition of oxygen to ammonia, giving rise to hydroxylamine (NH_2OH). This is then further oxidized to nitrite.

In the second stage of nitrification, nitrite is oxidized to nitrate by bacteria of the genera nitrobacteria, nitrospira and micrococcus. The reaction proceeds by the addition of water followed by the removal of hydrogen. The association between nitrosomonas and nitrobacter has been described as one of commensalisms (Goodday 1988). The two species exist in the same soil environment without much mutual influence except that nitrobacter depends upon nitrosomonas for its nitrite. Up take of nitrogen by plants: most plants absorb the majority of their nitrogen as nitrite. However, many plants also absorb ammonium. In acid soils, conversion of ammonia to nitrite is slow and in forests on acidic soils, many trees absorb most of their nitrogen as ammonium. (Salisbury and Ross, 1985)

Nitrogen Fixation

Nitrogen fixation is the reduction of atmospheric nitrogen (N_2) to the ammonium ion (NH_4+). It is of great importance to organisms. Together with lightning it is the natural way in which organisms. Together with lightning it is the natural way in which organisms gain access to the huge reserves of nitrogen in the atmosphere. Nitrogen fixation can only be carried out by certain species of bacteria and cyanobacteria. Some of these species are free living occurring in soil or in water. Others exist in symbiotic relationships with higher plants.

The most well known of the nitrogen fixing bacteria are in the genus Rhizobium. These bacteria form symbiotic association in the root nodules of many plants in the family Leguminosae, which includes such important crop such as peas, groundnuts, beans and cloves. Until it recently thought that no members of the grass family, Graminae, could perform nitrogen fixation. However, new techniques introduced in the 1970's showed that many grasses have nitrogen fixing bacteria associated with their roots in a region called the rhizosphere. This is a transition zone between root and the soil. How important such N_2 fixation is to grasses, including the world's cereals, it is still under dispute. However it is clear that fixation rate in grasses are certainly less than for legumes and other species which posses root nodules.

The formation of root nodules has been extensively investigated in the leguminosae.. Species in the genus rhizobium persist saprotrophically in the soil until they infect a root hair or damaged epidermal cell. The plant responds to this infection by producing root nodules containing tetraploid host cells with the bacteria and some diploid cells without the bacteria of particular interest is the observation that root nodules contain leghaemoglobin. Leghaemoglobin functions in much the same way as our own haemoglobin: it transports oxygen. It is thought that leghaemogllobin. Allows the rate at which oxygen reaches the nitrogen-fixing bacteria to be controlled. Too much oxygen inactivates the enzyme that catalyses nitrogen fixation, possibly because nitrogen and oxygen resemble each other in size and shape, however, some oxygen is required for the bacteria to respire, as they are aerobic. The enzyme responsible for nitrogen fixation is called nitrogensase. Although its chemical structure is still completely not known it consist of two distrinct proteins, often called components I and II

Component I is an iron molybdenum (Fe-Mo) protein apparently containing two molybdenum and 28 iron atoms; component II is an iron (Fe) protein containing four iron atoms. More recently, a second form of nitrogenase has been found in which contains vanadium instead of molybdenum. This vanadium mtrogenase closely resembles the molybdenum nitrogenase.

Dentirification :

Denitrification involves the reduction of the nitrate ion (No_3^-) to nitrogen dioxide (No_2), dinitrogen oxide (N_2o), nitrogen monoxide (NO) or nitrogen (N_2) by certain anaerobic bacteria which have the ability to use the nitrate ion as an electron acceptor in respiration. Aerobic organisms, of course, use oxygen as their electorn acceptor in respiration, making water. Under anerobic conditions, however, oxygen is unavailable. Some species of bacteria in few genera including pseudomonas and clostridium, can make nitrite from nitrate under water logged conditions when oxygen tends to; be in short supply. A few species, including thiobacillus denitrificans, go further than this and reduce nitrate (NO_3^-) to dimolecular nitrogen (N_2) (Hamilton 1988). It is also new known that plants lose small amounts of nitrogen to the atmosphere as gaseous ammonia, dinitrogen oxide, nitrogen dioxide and nitrogen monoxide, especially when well fertilized with nitrogen.

2.3.4 NITROGEN CYCLE

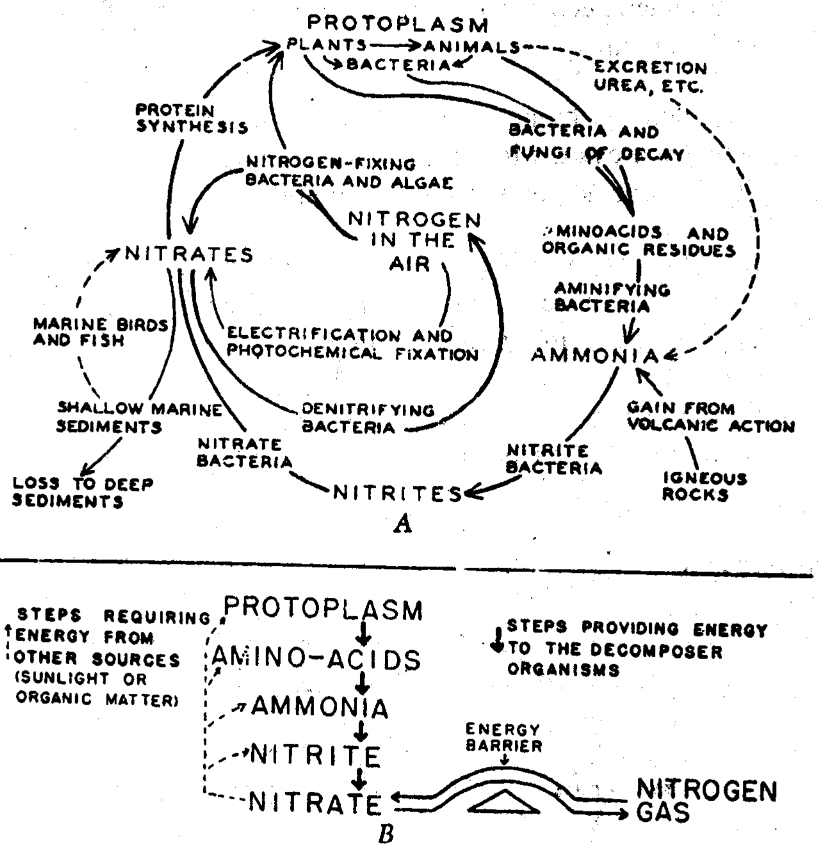

Fig. 2.12 Two ways of picturing the nitrogen biogeochemical cycle, an example of a relatively perfect, self-regulating cycle with a large gaseous reservoir. In *A* the circulation of nitrogen between organisms and environment is depicted along with microorganisms which are responsible for key steps. In *B* the same basic steps are arranged in an ascending-descending series, with the high energy forms on top to distinguish steps which require energy from those which release energy.

2.3.5 Phosphorus cycle:

Phosphorus cycle has no atmospheric phase. It occurs naturally in environment as phosphate (PO_4^-, or one of its analognes, HPO_4^- or $H_2PO_4^-$), either as soluble inorganic phosphate ions, as soluble organic phosphate (i.e., as a part of soluble organic molecule) or as particulate phosphate (i.e., as a part of an insoluble inorganic or organic molecules) or as mineral phosphate (i.e., as a part of mineral grain as found in a rock or sediment). The ultimate source of phosphate in the ecosystem is crystalline rocks. As there are eroded and weathered, phosphate is made available to living organisms, generally as ionic phosphate. This is introduced into autotrophic plants through their roots, where it is incorporated into living tissues. From autotrophs, it is passed along the grazing food chain in the same fashion as nitrogen and sulphur, with excess phosphate being excreted in the faceces. An extreme example of faecal phosphate is the tremendous guano deposits built up by birds on the desert west co art of South America. Phosphates can also be released : s particulate matter from forest and grassland fires.

In the detritus food chain, as large organic molecules containing phosphate are degraded, the phosphate is liberated as inorganic ionic phosphate. In this form it can be immediately taken up by autotrophs, or it can be incorporated into a sediment particle, either in the soil of a terrestrial ecosystem or in a sediment of a n aquatic ecosystem. The sedimentary phase of phosphorus cycle remains comparatively slow than the organic phase.

Besides phosphorus, there are biogeochemical cycles for all the other nutrients used by living organisms, as well as some that are not. Most of them has complete cycles in sedimentary phase. The availability depends on their solubility in water and availability of water as solvent.

Thus, the geochemical cycles of different chemical substances are closed, the atoms are used over and over again. To keep the cycles going does not require new matter but it does not require energy, for the energy cycle is not a closed one. Further, the patterns of flow, both of energy and of chemical substances, are of great significance,. The simpler patterns involve energy, as the sources of energy are external to the ecosystem, and flow is unidirectional through it. Chemical substances, on the other hand, are finite and have their origin inside the ecosystem, thus, they must continuously cycle with in the system.

2.3.6 Phosphorous cycle :

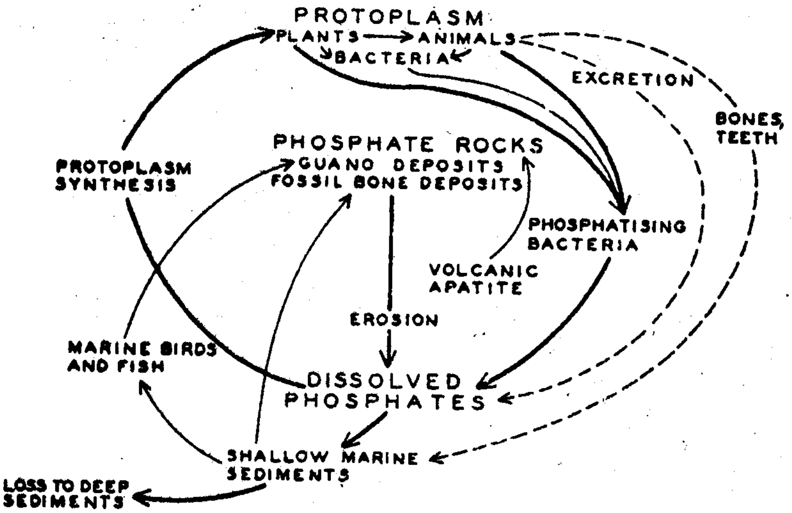

Fig. 2.13 The phosphorus cycle. Phosphorus is a rare element compared with nitrogen. Its ratio to nitrogen in natural waters is about 1 to 23 (Hutchinson, 1944a). Chemical erosion in the United States has been estimated at 34 metric tons per square kilometer per year. Fifty-year cultivation of virgin soils of the Middle West reduced the P_2O_5 content by 36 per cent (Clarke, 1924). As shown in the diagram, the evidence indicates that return of phosphorus to the land has not been keeping up with the loss to the ocean.

2.3.7 Sulphur cycle :

Sulphur, like nitrogen, is an essential part of protein and amino acids and is characteristic of organic compounds. It exists in a number of states elemental sulphur, S, sulphides, sulphur monoxide, sulphite and sulphates. Of these three are important in nature elemental sulphur, sulphides and sulphates.

The sulphur cycle is both sedimentary and gaseous phase. The sedimentary phase of sulphur cycle is long termed and in it sulphur is tied up in organic and inorganic deposits. From these deposits, it is released by weathering and decomposition, and is carried to terrestrial and aquatic ecosystems in a salt solution. Atmospheric phase of sulphur cycle is less pronounced and it permits circulation on a global scale.

Sulphur enters the atmosphere from several sources the combustion of fossil fuels, volcanic eruption, the surface of the oceans and gases released by decomposition. Initially sulphur enters the atmosphere as hydrogen sulphide which quickly oxidizes into another volatile form, sulphur dioxide (SO_2). Atmospheric sulphur dioxide, soluble in mater, is carried back to earth in rainwater as weak sulphuric acid, H_2SO_4. What ever its source, sulphur in a soluble form, mostly as sulphates (SO_4=)is absorbed through plant roots, where it is incorporated into certain organic molecules, such as some aminoacids (e.g., cystine) and proteins. From the producers the sulphur in aminoacids is transferred to the consumer animals, with excess being excreted in the faces.

Excretion and death carry sulphur in living material back to the soil and to the bottoms of ponds, lakes, and seas where the organic material is acted upon by bacteria of detritus food chain. Within the detritus food chain, the sulphydral group (-SH0 of amino acids e.g., L-cystine) is separated from the rest of the molecule as hydrogen sulphide (H_2S) by most decomposing bacteria as a normal part of the degradation of proteins. In an aerobic environment, the hydrogen sulphide is oxidized to sulphates by bacteria specially adapted to perform this conversion.

$$H_2S + 2O_2 \rightarrow SO_4= +2H^+$$

The sulphates produced then produced then can be reused by the autotrophs. In anerobic environments, such as bottom of certain lakes, it is impossible to oxidize sulphide by this means, because the process of oxidation requires oxygen. But if infrared radiation is present in these environments, there are photosynthetic bacteria that can use it to manufacture carbohydrates and oxidize sulphide either to elemental sulphur or to sulphates:

$$6CO_2\ 12H_2S \text{ thr } \_ C_6H_{12}O_6 + 6H_2O+12S$$
$$6CO_2 + 12H_2O + 3H_2S + hr \rightarrow C6H_{12}O_6+6H_2O+3SO_4=+6H+$$

elemental sulphur can also be utilized by other bacteria to form sulphates. If oxygen is present, the reaction is quite rapid

$$25+3O_2+H_2O \rightarrow 2SO_4=+4H+$$

under the anaerobic conditions, elemental sulplhur can still be oxidized to sulphates by certain bacteria if nitrate is present.

$$6NO_3-+55+2CaCO_3 \rightarrow 3SO_4=+2CaSO_4+2Co_2+3N_2$$

none of these bacterial reactions is unidirectional; under certain conditions, sulphates can also be reduced either to sulphide or to elemental sulphur by bacteria. This series of reactions operating within the organic phase of the sulphur cycle provides a rather finally tuned mechanism for regulating the availability of sulphur to autotrophs.

The sulphur is removed from the organic phase in the form of elemental sulphur which is insoluble and accumulates in sediments. If iron is present in the sediments, it can combine with sulphide to form iron sulphides, all of which are highly insoluble.

Fe^{++} + S= _ FeS
Fe (ionic) + 25 (ionic) → FeS_2

FeS_2 is highly insoluble under neutral and alkaline conditions and is firmly held in mud and wet soil. Some ferrou8s sulphide is contained in sedimentary rocks overlying coal deposits. Exposed to the air in deep and surface mining, the ferrous sulphide oxidizes and in the presence of water produces ferrous sulphates & sulphuricacid

$2\ FeS_2 + 7O_2 + 2H_2O \rightarrow FeSO_4 + 2\ H_2SO_4$
$12\ FeSO_4 + 3O_2 + 6H_2O \rightarrow 4\ Fe_2\ (SO_4)_3 + 4\ Fe\ (OH_3)\downarrow$

In this manner sulphur in pyrite rocks, suddenly exposed to weathering by man, discharges heavy sulgs of sulphur, H_2SO_4, ferric sulphates and ferrous hydroxide into aquatic ecosystems. These compounds destroy aquatic life and cause acidic water.

2.3.8 sulphur cycle

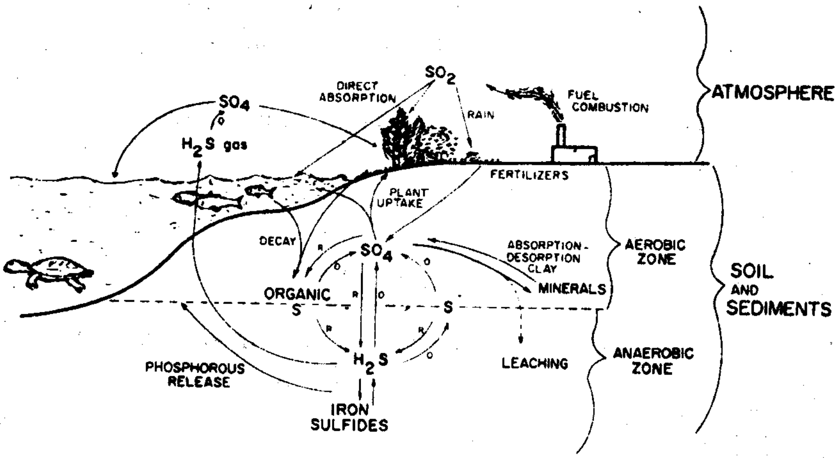

Fig. 2.14 The sulfur cycle linking air, water, and soil. The center "wheel-like" diagram shows oxidation (O) and reductions (R) that bring about key exchanges between the available sulfate (SO_4) pool and the reservoir iron sulfide pool deep in soils and sediments. Specialized microorganisms are largely responsible for the following transformations: $H_2S \rightarrow S \rightarrow SO_4$, colorless, green, and purple sulfur bacteria; $SO_4 \rightarrow H_2S$ (anaerobic sulfate reduction), desulfovibrio bacteria; $H_2S \rightarrow SO_4$ (aerobic sulfide oxidizers), thiobacilli bacteria; organic $S \rightarrow SO_4$ and H_2S, aerobic and anaerobic heterotrophic microorganisms, respectively. The metabolism of these various sulfur bacteria is described in Chapter 2. Primary production, of course, accounts for the incorporation of sulfate into organic matter, while animal excretion is a source of recycled sulfate (see Figure 4-11). Sulfur oxides (SO_2) released into the atmosphere on burning of fossil fuels, especially coal, are becoming increasingly bothersome components

2.3.9 Summary :

The elements and compounds that sustain us are cycled endlessly through living things and through the environment. On a global scale, this movement is referred to as biogeochemical cycling.

Carbon, nitrogen, minerals, water and other basic materials move constantly in cycles from the abiotic environment into and through living organisms, and back to the environment again.

The nitrogen cycle is a complex process involving the activities of several genera of bacteria. Mycorrhizal help plants to obtain phosphate from soil. An understanding of nutrient cycling helps to explain why the oceans are salty.

2.3.10 Expected Questions:

1. What are bio geo chemical cycles? Write a detailed account on carbon cycle?
2. Explain the nitrogen cycle?
3. Write a detailed account on phosphorus cycle?
4. Write notes on sulphur cycle?

2.3.11 References:

1. Basic Ecology – E.P. Odum
2. Ecology principles and applications J.L. Chapman and M.J. Reiss.
3. Ecology _ Verma & Agarwal
4. Ecology and Environment P.D. Sharma.

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LESSON 2.4
CONCEPT OF LIMITING FACTORS

2.4.1 INTRODUCTION
2.4.2 Liebig's law of minimum
2.4.3 Shelford's law of tolerance
2.4.4 Combined concept of limiting factors.
2.4.5 References.

CONCEPT OF LIMITING FACTORS

2.4.1 INTRODUCTION

Temperatures, moisture levels, nutrient supply, soil and water chemistry, living space and other environmental factors must be within appropriate levels for organisms to persist every living organism has limits to the environment, it can endure. In 1840, Liebig proposed that the single factor in shortest supply relative to demand is the critical determinant is species distribution. Ecologist Victor Shelford later expanded the same principle of limiting factors by stating that each environmental factor has both minimum and maximum levels, called tolerance limits, beyond which a particular species cannot survive or is unable to reproduce. Shelford postulated, the single factor closest to these survival limits, is the critical limiting factor that determines, where a particular organism can live.

At one time, ecologists accepted the critical limiting factor concept so completely that they called it Liebig's or Shelford's law and tried to identify unique factors limiting the growth of biota. For many species, however, the interaction of several factors working together, rather than a single limiting factor determines the distribution. The mussels and barnacles living in extremely harsh conditions but generally are sharply limited to an inter tidal zone, where they grow so thickly that they often completely corner the substrate. No single factor determines their distribution. Instead, a combination of temperature extremes, salt concentrations, competitors and food availability limits the number and location of these animals.

For other organisms, there may be a specific critical factor which determines the abundance and distribution of that species in a given area.

A striking example of cold intolerance as a critical factor is found in that giant saguaro Cactus which grows in the dry, hot Sonoran desert of southern Arizona and northern Mexico. Saguaros are extremely sensitive to low temperatures. A single exceptionally cold winter night with temperatures below freezing for 12 hours or more kills growing lips on the branches. Animal species, too, exhibit tolerance limits that often are more critical for the young than for the adults. The fish, cyprinodon for instance, occurs in small, isolated populations in warm springs in the northern desert. Adult fish can survive temperatures between O^0C and 42^0 C and are tolerant to an equally wide range of salt concentrations. The Eggs and Juvenile fish, however can only live between 20^0C and 36^0C, and are killed by high salt concentrations. Reproduction, the essential biological process therefore, is limited to a small part of the range of adult fish, for its abundance. Sometimes, the requirements and tolerances of species are useful indicators of specific environmental characteristics. The presence or absence of such species can tell us something about the community and ecosystem as a whole. Lichens and eastern white fine, for example re indicates of air pollution because they are extremely sensitive to sulfur dioxide and precipitation. Bull thistle is a weed that grows on distributed soil but is not eaten by cattle; therefore, an abundant population of bull thistle in a pasture is a good indicator of overgrazing. Similarly, anglers know that trout species require clean, well- oxygenated water, so the presence or absence of trout can be indicator of water quality.

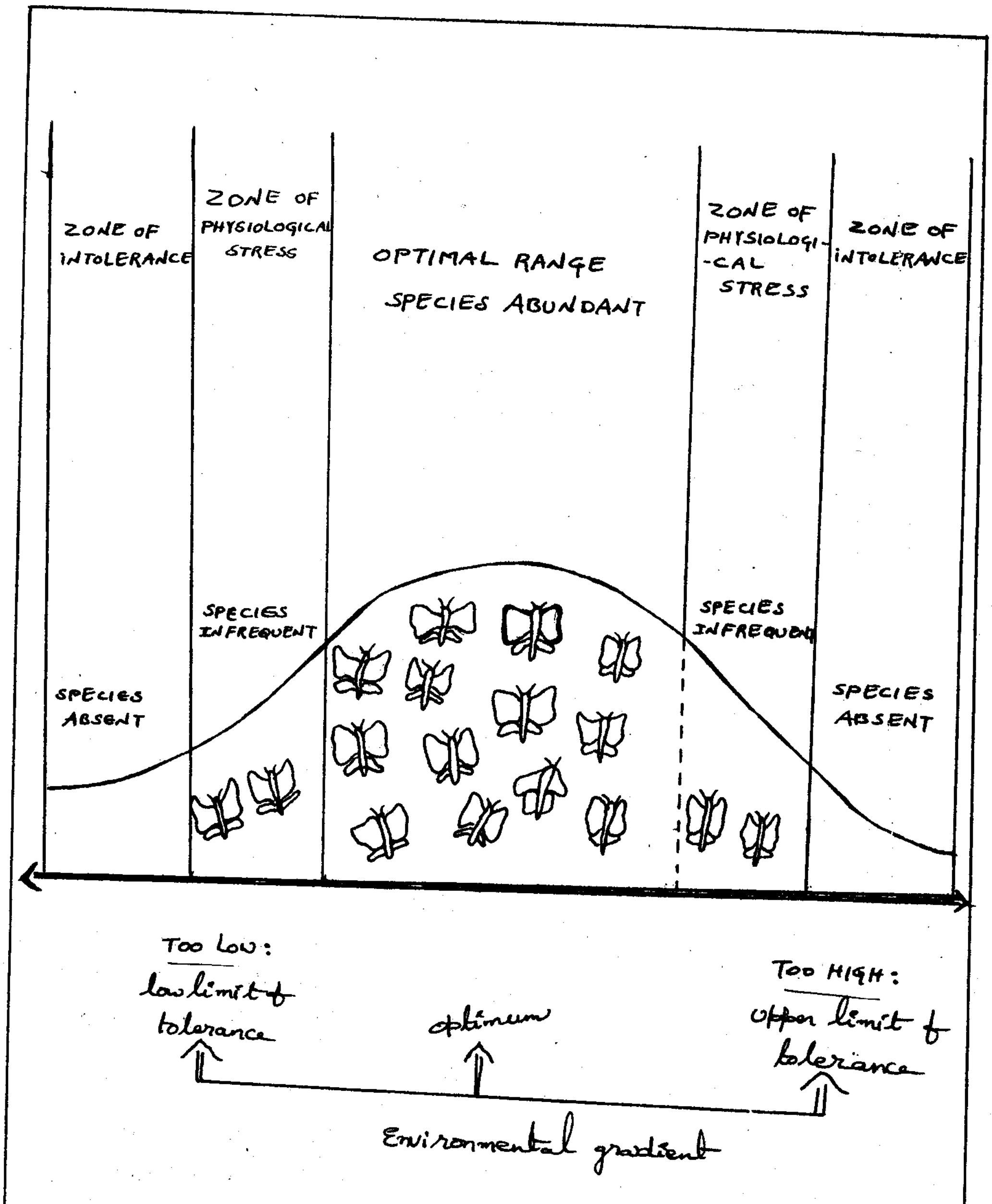

Fig. 2.15. The principle of tolerance limits states that for every environmental factor, an organism has both maximum and minimum levels beyond which it can survive.

2.4.2 LIEBIG'S LAW OF MINIMUM:

An organism is seldom, if ever, exposed solely to the effect of a single factor in its environment. On the contrary, an organism is subjected to the simultaneous action of all factors in its immediate surroundings. However, some factors exert more influence than do others, and the attempt to evaluate their relative roles had led to the development of the law of the minimum by the German biochemist JUSTUS LIEBIG IN 1840.

LIEBIG while investigating the relationship between the available amounts of essential elements and plant growth, discovered that crop yield was frequently limited by elements other than those utilized in the largest quantity. Freely, translated, a part of his statement on his experiential results is that "growth is dependent on the amount of food stuff that is present in minimum quality". This statement has come to be known as LIEBIG'S law of minimum. It is now usually incorporated with a law of limiting factors developed by British physiologist F.F. BLACKMAN who at the beginning of this century investigated the factors affecting the rate of photosynthesis. Amount of carbondioxide (CO_2) available, amount of H_2O available, intensity of solar radiation, amount of chlorophyll present, and the temperature of the Chloroplast. BLACKMAN discovered that the rate of photosynthesis is governed by the level of the factor that is operating at a limiting intensity. Further a work on limiting factors and substances has shown that a high level of one factor will modify the limiting effect of a second, a process described as factor interaction. The same principle of limiting factors applies well to animal functions.

The law of minimum has been restated by TAYLOR (1934) in broad ecological terms, as follows: "The functioning of an organism is controlled or limited by that essential environmental factor or combination of factors present in the least favorable amount. The factors may not be continuously effective but only at some critical period during the year or perhaps only during some critical year in a climate cycle".

The fact of the critical minimum becoming determinal to the survival of an organisms was recognized by JUSTUS LIEBIG who was a pioneer in the study of effect of various factors on the growth of plants. He found that the yield of crop plants was often limited not by nutrients needed in large quantities, of carbondioxide, water but by some raw materials as boron, for example, neeed in minute quantities, but every scarce in soil. His statement that the growth of a plant is dependent on the amount of foodstuff which is presented to it in minimum quantity has come be known as LIEBIG'S LAW OF MINIMUM.

Since LIEBIG'Stime much work is done in this area. This additional information could show that two subsidiary principles must be added to this concept to make it more useful in practice. These are

1. A constrain that the LIEBIG'S law is strictly applicable only under steady-state conditions i.e. when inflows balance outflows of energy and materials. For example, we must assume that CO_2

was the major limited factor in lake/pond, and thus productivity was in equilibrium with the rate of supply of CO_2 coming from the decay of organic matter. We assume that light, nitrogen, phosphorus etc.. were available in excess in this steady state equilibrium. If a storm brought more CO_2into the lake/ pond the rate of production would change, and be dependent upon other factors as well. While the rate is changing , there is no steady state and no minimum constituent.

2. The second important principle is FACTOR INTERACTION. High concentration or availability of some substance or the action of some factor other than the minimum one, may modify the rate of utilization of the latter. Sometimes organisms are able to substitute at least party, a chemically closely related substance for one that is deficient in environment. For instance, where strontium is abundant Mollusces are able to substitute this for calcium of partial extent in their shells. Some plants require less since when growing in the shade than when growing in full sunlight; therefore, a given amount of zinc in the soil would be less limiting to plants in shade than under the same conditions in sunlight.

2.4.3 SHELFORD'S LAW OF TOLERANCE:

Not only may too little of something be a limiting factor, as proposed by LIEBIG but also too much, as in case of such factors as heat, light and matter. Thus, organisms have an ecological minimum and maximum; range in between represents the limits of tolerance. The concept of the limiting effect of maximum as well as minimum was incorporated into the law of tolerance by V.E. SHELFORD in 1913. Especially useful are what can be termed 'stress tests', carried out in the lab or field, in which organisms are subjected to an experimental range of conditions. All physical requirements may be well with in the limits of tolerance for an organism, and the organism may still fail because of biological interrelations. Studies in the intact ecosystem must accompany experimental laboratory studies, which, of necessity, isolate individuals from their populations and communities.

Some subsidiary principles to the law of tolerance may be stated as follows.

1. Organisms may have a wide range of tolerance for one factor and a narrow range for another.

2. Organisms with wide range of tolerance for all factors likely to be most widely distributed.

3. When conditions are not optimum for a species with respect to one ecological factor, the limits of tolerance may be reduced for other ecological factors. For example, penman reports that when soil nitrogen is limiting the resistance of grass to drought is reduced. In other words, he found that more water was required to prevent wilting at low nitrogen levels than at high levels.

4. Frequently, it is discovered that organisms in nature are not actually living at the optimum range of a particular physical factor. In such cases, some other factor or factors are found to have greater importance. Certain tropical orchids, for example, actually grow better in full sunlight than in shade, provided they are kept cool. In nature, they grow only in the shade because they cannot tolerate the heat of direct sunlight. In many cases. Population interactions present organisms from taking advantage of optimum physical conditions.

5. Reproduction is usually a critical period when environmental factors are most likely to be limiting. The limits of tolerance for reproductive individuals, seeds, eggs, embryos, seedlings and larval are usually narrower than for none producing adult plants or animals. Thus and adult cypress tree will grow continually submerged in mater or on dry upland, but it cannot reproduce unless there is moist, unfolded ground for seedling development. Adult blue crabs and many other marine animals can tolerate brackish water or freshwater that has a high chloride content and thus are often found for some distance up rivers. The larvae however, cannot live in such maters; therefore the species cannot reproduce in the river environment and never become established permanently the geographical range of game birds is often determined by the impact of climate on eggs or young rather than on the adults.

The concept of limiting factors is valuable because it gives the ecologist an 'entering wedge' into the study of complex situations. Environmental relations of organisms are apt to be complex, but fortunately, all possible factors are not equally important in a given situation or for a given organism. Studying a particular situation, the ecologist can usually discover the probable weak links and focus attention, initially at lest, on those environmental conditions most likely to be critical or limiting. If an organism has a wide limit of tolerance for a relatively constant factor in moderate quantity in the environment, the factor is not likely to be limiting. Conversely, if an organism is known to have definite limits of tolerance for a factor that also is variable in the environment, then that factor merits careful study, since it might be limiting. For example, oxygen is so abundant, constant, and readily available in the terrestrial environment that it is rarely limiting to land organisms, except to parasites or those living in soil or at high altitudes. On the other hand, oxygen is relatively scarce and often extremely variable in mater and is thus often an important limiting factor to aquatic organisms, especially animals.

To sum up, primary alternation should be given to factors than are operationally significant' to the organism at sometime during its life cycle. The aim of environmental analysis, for example, preparing an environmental impact statement, is not to make long, uncritical lists of possible 'factors' but rather to achieve these more significant objectives.

1. To discover by observation, analysis and experiment, which factors are operationally significant and
2. To determine how these factors affect the individual population, or community, as the case may be. In this manner the effect of disturbances or proposed environmental alterations can be predicted with reasonable accuracy.

The actual range of tolerance in nature is almost always narrower than the potential range of activity. This might be indicated by nothing short term behavioral response in the laboratory, because the metabolic cost of physiological regulation at extreme conditions reduces the limits of tolerance under field conditions at both upper and lower limits. If a fish in a pond receiving heated water from an industry or power plant has to devote all or most of its metabolic energy to coping with the elevated temperature stress, it will have insufficient energy for food-getting and reproductive activities required for survival under non-laboratory conditions. Adaptation becomes more costly as extreme conditions are approached, and the organism becomes increasingly susceptible to other factors such as disease or predation

2.4.4 COMBINED CONCEPT OFLIMITING FACTORS

The presence and success of an organism or a group of organisms depends upon a complex of conditions. Any condition which approaches or exceeds the limits of tolerance is said to be a limiting condition or a limiting factor.

By combining the idea of minimum and the concept of limits of tolerance one can arrive at a move general and useful concept of limiting factors. Thus in nature organisms are controlled by

- Quantity and variability of materials for which there is a minimum requirement and physical factors which are critical and
- The limits to tolerance of the organisms themselves to these and other components of the environment.

The chief value of the concept of limiting factors lies in the fact that it gives the ecologist an entering wedge into the study of complex situations. For an organism, not all possible factors are of equal importance in a given situation. Some are weaker than others. We May discover these weak links and find those conditions to be critical or limiting. If an organism has a wide limit of tolerance in moderate quantity in the environment, that factor is not likely to be limiting. Conversely, if an organism is known to have limits of tolerance for a factor which also is variable in the environment them that factor merits careful study, since it might be limiting. For example, oxygen, is so abundant, constant and readily available in terrestrial environment that it is rarely limiting to land organisms, except to parasites or living ion soil at high attitudes. On the other hand O_2 is relatively scarce and often extremely variable in water and thus is often an important limiting factor to aquatic organisms, especially animals. Therefore the main attention should be given to factors that are operationally significant to the organisms at sometimes during it life cycle.

2.4.5 Summary

If a principle is to become firmly established and to prove useful in practice, it must be eventually subject to quantitative aswell as qualitative analysis. The present concept of limiting factors were thus proved. As mentioned, the chief value of the concept of limiting factors lies in the fact that it gives the ecologist, an "Entering wedge" into the study of complex situations.

Environmental relations of organisms are apt to be complex, so that it is fortunate that not all possible factors are of equal importance in a given situation or for a given organism.

To occur and thrive in the given situation, an organism must have essential materials which are necessary for growth and Reproduction. These basic requirements vary with species and with the situation. Under "steady - state" conditions the essential materials available in amounts most closely approaching the critical minimum needed will tend to be limiting one. This "law of the minimum is less applicable under "transient - stage" conditions whenthe amounts and hence the effect of many constituents are Rapidly changing - as provoked by "Liebig".

The presence and success of an organism depend upon the completeness of a complex conditions. Absence or failure of an organism can be controlled by the Qualitative or Quantitative deficiency or excess with respect to any one of several factors which may approach the limits of tolerance of that organism, as proved by "shelford".

2.4.6 Expected Questions :

1. Explain the Liebig's law of the minimum? Give examples?
2. Explain the Shelford's law of Tolerance? Prove with examples?
3. What is the concept of limiting factors, write the necessary examples too?
4. What are limiting factors, explain?

2.4.7 Reference Book:

1. Basic Ecology - Odum.E.P. (Saunders Publishing)
2. Ecology Principles and Application - J.L. Chapman and M.J. Reis (Cambridge University Press)
3. Ecology and Environment - P.D. Sharma (Rastugl Publications)
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5. Principles of environmental Science Inquiry and Applications (Tata- Mc-Grawhill Publishing Limited) By-William P.Cunningham Mary Ann cunningham.

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LESSON: 3.1

BIOTIC INTERACTIONS
INTERSPECIFIC COMPETITION AND CO-EXISTANCE

3.1.1 INTRODUCTION
3.1.2 CONTENT
3.1.3 STATEMENT
3.1.4 DESCRIPTION
3.1.5 EXAMPLES FOR COMPETITION AND CO-EXISTANCE
3.16 SUMMARY
3.1.7 EXPECTED QUESTIONS
3.1.8 REFERENCES

INTRODUCTION:

Organisms are subjected to the living and non-living environmental factors. Every organism must share its world either with the members of its own species or with the members of other species. Animals have interactions with other animals and plants. The organisms experience the influence of other organisms, through competition, predation and herbivory. The effects of such organisms form the biotic part of the environment.

In nature, no plant or animal could survive by itself because it is dependent, on other organisms for food, shelter and certain requirements. Animals have relations with other animals, plants with other plants, some animals are dependent upon plants in their environment or vice-versa. Thus interdependency exist between species which results in their successful survival in nature. The relationship or interactions between species is classified as,

"Intra specific relationship". – Relation between the same species.

"Inter specific relationship" – Relation between the different species. The relationship or such biotic interaction may be beneficial to both parasites, harmful to both the parasites, either beneficial or harmful to one and neutral in respect to the other. Biotic community is nothing but the "local assemblage of species" and the interactions between organisms, is called biotic interactions. According to the nature of ecological relations between the interacting species, the type and the nature of interactions may be negative or positive, and is of different types. Some of them are as given below,

Interspecific competition and co-existence

3.1.2 Content:

If two species compete for, and are limited by, a single resource, then theory indicates that one or other will be eliminated. If, however, they compete for a range of resources, it is possible that they will partition the resources between them, and that both will survive. Theoretical models of resource competition suggest that two similar species will usually evolve so as to take different resources. If this results in the two species becoming morphologically more different, the process is referred to as character displacement.: note, however, that character displacement can occur for reasons other than resource competition for example, selection for mating isolation.

The presence of other organisms may limit the distribution of some species through "competition". Such competition is usually confined to closely related species which eats the same types of food and alive in the same sorts of places. The first indication of possible competition is usually the observation that the geographical distributions of two closely related species do not overlap. A second indication may be the observation that when species a is absent, species b lives in a wider range of habitats. The principle difficulty in dealing with these situations is that competition is only one of several hypotheses that will account for these facts.

STATEMENT: 3.1.3

Competition in the broadest sense refers to the interaction of two organisms striving for the same thing. Interspecific competition is any interaction between two or more species populations, which adversely affects their growth and survival. The tendency for competition to bring about an ecological separation of closely related or otherwise, similar, species is known as 'The competitive exclusion principle'.

3.1.4 DESCRIPTION

A great deal has been written about interspecific competition by ecologists, geneticists, and evolutionists too. In most cases, the word "competition" is used with reference to situations in which negative influences are due to shortage of resources used by both species.

The competitive interaction often involves space, food or nutrients, light waste materials, susceptibility to carnivores, disease and so both, and may other types of mutual interactions. The results of competition are of greatest interest and have been much studied as one of the mechanisms of natural selection. Interspecific Competition can result in equilibrium adjustments by two species, or it can result in one species population replacing another or forcing it to occupy another space or to use another food, what ever is the basis of competitive action. It is often observed that closely related organisms having similar habits or life forms often don't occur in the same places, they are different food, are active at different times, or are otherwise occupying somewhat different niches.

The explanation for the widely observed ecological separation of closely related (or otherwise similar) species has come to be known as 'competitive exclusion principle' (Hardin, 1960) or Gauses principle.

The result of the interaction is at the species with the greatest initiatory effect on the other will eliminate it from the space, although as slobodkin has shown the two species might theoretically coexist if the competition coefficients were very small in relation to the ratios of saturation densities to understand the competition we need not only consider conditions and population attributes that lead to competitive exclusion, but also situations, under which similar species coexist, since large numbers of species do share common resources in the open systems of nature.

One of the most thorough going and long term experimental studies of interspecific competition is that carried out in the laboratory of Dr. Thomas park of university of Chicago. Park, his students, and associated workers work with flour beetles, especially these belonging to genus Trilobium, small beetles can complete their entire life history in a very simple and homogenous habitat, namely, a jar of flour or wheat bran. The medium in this case is both food and habitat for larval and adults. If fresh medium is added at regular intervals a population of beetles can be maintained for a long time.

The investigators found that, when two different species of Trilobium are placed here in this little homogeneous universe, invariably one species is eliminated sooner or later, while the other continues to thrive. One species always wins or two species of Trilobium cannot service in his particular ecosystem, which, by definition contains only one niche for flow beetles. The eventual out come depends on climate rather on number of individuals.

The competitive ability and required parameters differ drastically from even species to species, so as the care in Trilobium to.

From the Trilobium model, it is easy to constant conditions that could result in co-existence instead of exclusion. If the culture system was "opened" and the individuals of the dominant species were to immigrate / be remove as by predator at a considerable rates the competitive interaction might be so reduced, that both the species could coexist. One can think of much other circumstance that would have favour for coexistence.

Some of the most interesting experiments in plant competition are those reported by J.L.Harper and et.al. at the university college of north Wales.

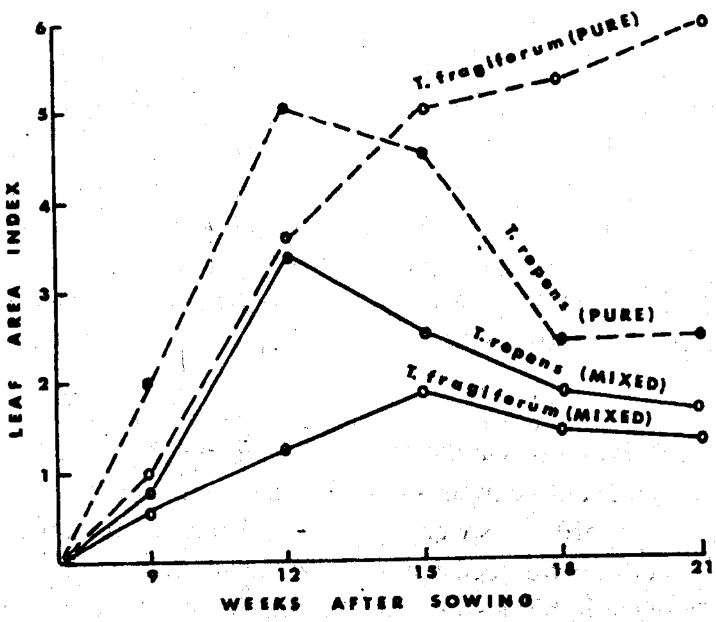

Fig. 3.1

The case for coexistence in populations of clover (Trifolium = T) with mixing, evenly interfere between two they show reduced density. The difference in growth form allows two species of clover to co-existence in the same environment i.e., same light, temperature, soil, etc. of the two species, Trifolium represents grows faster and reaches peek in leaf density sooner. However, I. fragiferum has longer petioles and higher leaves and is able to overtop the faster growing species, especially after I.repens has passed its peak, and thus avoids being shaded out. In mixed stands, therefore each species inhibits the other, but they both are able to complete their life cycle and produce seed, even though each coexists at a reduced density. In this case, the two species, even though competing strongly for light, were able to coexist because of difference in morphology and the timing of growth maxima.

Harper (1961) concludes that two species of plants can persist together if the populations are independently controlled by one or more of the following mechanisms,

Different nutritional requirements. Legume and non legume, for example
different causes of mortality for ex: differential sensitivity to grazing
Sensitivity to different toxins.
Sensitivity to same controlling factor, i.e., light, water and so forth, at different times.

3.1.5 Examples for competition: and co-existence:

Two closely related protozoa's, paramecium caudatum and *P.aurelia* when in separate culture, exhibited typical sigmoid population on growth and maintained a constant population level, in cultured medium that was maintained constant with a fixed density of food items.

The food bacteria did not themselves multiply in media and thus could be added at frequent intervals to keep food density constant.

When both the protozoans were placed in the same culture, however, *P.aurelia* alone survived after 16 days. In this case neither organisms attacked other or secreted harmful substances. *P.aurelia* populations simply had a more rapid growth rate i.e. higher instructive with intrinsic rate of increase, and thus "out-competed". *P.caudatum* for the limited amount of food under the existing conditions.

On the other hand *P.caudatum* and *P.bursaria* were both able to survive and reach a stable equilibrium in the same culture medium because although they were competing for the same food, *P.bursaria* occupied a different part of culture where it could feed on bacteria without competing with P.caudatum. Thus, the habitat feature of niche of these two species proved to be sufficiently different, even though their food was identical.

In nature, where competition would not likely be as severe, or as long continued, as in the small laboratory cultures, the two species would have less difficulty co-existing in the some habitat. Another example of how habitat diversification can reduce competition so as to allow co existence instead of exclusion is described by Crombie. He found that, Trilobium exterminates Oryzaephilus, which is another genus of flow beetle, when both live together in an hour, because Trilobium is more active in destroying immature stages of other species. However, if the glass tubes are placed in the flour into which immature stages of oryzaephilus may escape then both populations survive. Thus, when a simple "one-niche" environment is changed to a "two-niche" environment, competition is reduced sufficiently for the support of two species. This is also as example of the "Direct interference" type of competition.

Interspecific competition in plants in the field has been much studied and is generally believed to be an important factor in bringing about a succession species.

'Keever' describes an interesting situation in which a species of "tall-weed" that occupies first year fallow fields in almost pure stands was gradually replaced in these fields by another species previously unknown in the region. The two species, although belonging to different genera, have very similar life history with reference to time of flowering, seeding; and forms of life thus were brought into 'intense-competition'.

Griggs prepared a 'competitive ladder' that competition between individuals of the same species is one of the most important density dependent factors in nature, and the same can be said of 'Interspecific-competition' competition and co existence appears to be extremely important in determining the distribution of closely related species, and Gauses rule – "no two species in the same niche" – seems to hold as for laboratory and for field also, although much of the evidence is circumstantial.

Competitive interaction can cause morphological change through natural selection that welcomes the ecological separation. For example, in the middle Europe six species of titmice (small birds of the genus Parus) coexist, segregated partly by habitat and party by feeding areas and size of prey, which is reflected in small differences in length and width of the bill. In North America, it is rare for more than two species to be found in the same locality, even though seven species are present on the continent as a whale.

'Lack' suggests that" the American species of tits are at an earlier stage in their evolution, than the European and their difference in beak, body size, and feeding behavior are adaptations to their respective habitats, and are not yet adaptations for permitting the co-existence and diversity in the same habitat".

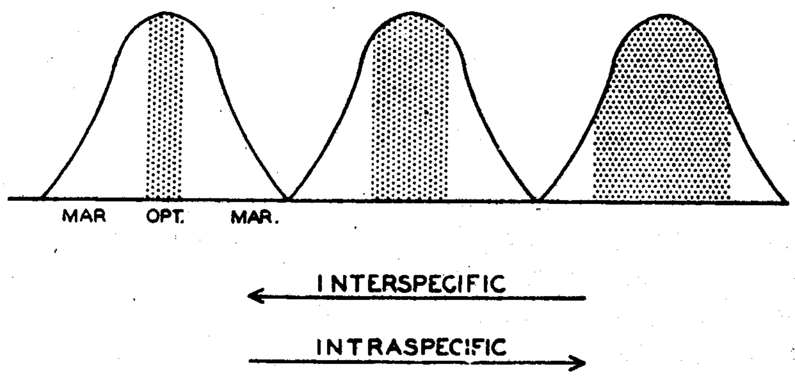

Fig. 3.2 The effect of competition on the habitat distribution of birds. When intraspecific competit dominates, the species spreads out and occupies less favorable (marginal) areas; where interspecific competit is intense the species tends to be restricted to a narrower range comprising the optimum conditions. (Modified fr Svardson, 1949.)

The effect of competition on the habitat distribution of birds when intraspecific competition dominates, the species spreads out and occupies less favorable (marginal) areas; where interspecific competition is intense and the species tends to be restricted to a narrow range comprising the optimum conditions.

The curves in above diagram, indicates range of habitat which can be tolerated by the species, with optimum and marginal conditions indicated;

When interspecific competition is less severe, then intraspecific competition generally brings about a wider habitat choice. Islands are good places to observe tendency for wider habitat selection to occur when potential competitions fail to colonize. For example, meadow vales (Microtus) often occupy forest habitats on islands where their forest competitor, the re-backed vole (Clethrionomyns), is absent.

According to 'Crowell', cardinal was more abundant and occupied more marginal habitat in Bermuda where many of its mainland competitors are absent. There are many cases, which seems at first to be exceptions to the Gause's rule but which, one on careful study, prove otherwise. A good example of this is the case of two similar fish-eating birds of Britain, the cormonant (Phalacrocorax carlo) and the shag (Phalacrocorax aristotelis) studied by "Lack". These two species, commonly feed in the same waters and nest on same cliffs, yet close study showed that actual nest sites were different and, food was basically different. Thus the shag feeds in the upper waters on the free-swimming fish and eels, where as cormonant is more of a bottom feeder, taking flatfish (flounders) and bottom invertebrates (shrimp, etc)

Just because, closely related species were sharply separated in nature does not, of course mean that competition is actually operating continuously to keep them separated; the two species my have evolved different requirements or preferences which effectively keep them out of competition.

On the nutshell or at a glance, a single example each from plant and animal kingdom will be undoubtedly sufficient to elucidate. In Europe, one species of Rhododendron, namely "R.hirsutum", is found on calcareous soils while another R.ferrugineum is found on acid soils. The requirements of 2 species are such that neither can alive at all in the opposite type of soil so that there is never any actual competition between them.

"Teal" has made an experimental study of habitat selection of species of fiddler crabs (uca) which are usually separated in their occurrence in salt marshes. One species, U.pugilator, is found on pen sandy flats, while another, U.pungnax, is found on muddy substrates covered with marsh grass. Teal found that one species would tend not to invade the habitat of other even in the absence of other, because each species would dig, or burrows only in its preferred substrate. The absence of the active competition of course does not mean that competition in the part is to be ruled out as a factor in bringing about the isolating behavior

We may do well to close the discussion of examples by adopting the three tentative modes proposed by .Philip, as a basis for the feature observation, analysis and experimentation too:

Imperfect competition: Interspecific effects are less than intraspecific effects.

Interspecific competition is a limiting factor, but not the extent of complete elimination of one species.

2. Perfect competition: One species in invariably eliminated from the niche by a gradual process as crowding occurs

This was according to unmodified Gause or "Lokta-Volterra"

Hyperperfect competition: Depressing affects are great and immediately effective

This is as in production of antibiotics.

3.1.6 Summary:

Theoretically modes of competition, Indicate that in case of competition between two similar species, one species may be displaced or both may reach a stable equilibrium mixture. The possibility of displacement has given rise to the competition exclusion principle, which states that complete competition cannot coexist. In simple laboratory populations one species often become extinct but some times coexists with another species. Natural communities show many examples of similar species, which are coexisting, and this must be reconciled with the principle of competitive exclusion. One approach to solve this paradox is to suggest that competition is rare in nature, and hence displacement is not expected. Another approach is to suggest that competition has occurred and interrelations we now see are the outcome of competition, displacement, and subsequent evolution in the past. Both views agree that competition is not common in present day populations, but this may not be true.

Experimental work with agricultural crops and range plants suggests that competitive interactions, are very great in the field populations, transferring the results of the laboratory work on competition to field populations have proved difficult.

Interspecific competition poses problems stated by the competitive exclusion principal, resource partitioning probably the most widely spread factor explaining coexistence of competitions.
Predators that explaining two competing species could play role in allowing coexistence. Regardless of the particular mechanism, the essential requirement, for coexistence is that species from be sufficiently different in some way to prevent either species from reaching a high enough density to drive the other extinct.

3.1.7 expected questions:

1. What are biotic interactions? Explain with examples?
2. What is interspecific competition, describe with examples?
3. Explain co-existence in biotic environment by making a note on interspecific competition?
4. Describe with proper examples, to prove inter specific competition as a negative interaction on population?
5. Evolutionary significance with reference to the competition?

3.1.8. Reference Book:

1. Basic Ecology - Odum.E.P. (Saunders Publishing)
2. Ecology Principles and Application - J.L. Chapman and M.J. Reis (Cambridge University Press)
3. "Ecology' by "I. Dodson, stanley I". - 1998
4. 'Ecology' The experimental analysis of distribution & abundance' - by "Charles J. Krebs".
5. Principles of environmental Science Inquiry and Applications (Tata- Mc-Grawhill Publishing Limited) By-William P.Cunningham Mary Ann cunningham.

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LESSON : 3.2

PREDATION; HERBIVORY; PARASITISM; ALLELOPATHY

3.2.1 Introduction

3.2.2 Predation and parasitism

3.2.2.1 Statement

3.2.2.2 Explanation

3.2.2.3 Other Glitters

3.2.3 Herbiovry

3.2.3.1 Content

3.2.4 Allelopathy

3.2.5 Summary

3.2.6 Expected Questions

3.2.7 References

3.2.1INTRODUCTION:

Predation, Herbivory, Parasitism, and Allelopathy were come under negative interactions, which are operating, on population.

Predators diversely affect the population size of their prey, but the affect of herbivory on the population dynamics of vegetation is less apparent. If an organism eat seeds or seedlings, so killing plants, this directly affects the total plant population size. Herbivore can have a positive effect on some plant populations by providing more opportunity for new individuals to establish. Predators, despite their obvious effect on prey numbers, may not always have a long-term effect on population regulation.

A parasite is an organism, which lives on or in an other organisms. The organism on which the parasite lives is called the host. A heavy infection of parasites, called the parasitic load, may eventually cause the death of the host, directly or indirectly, by weakening it so that it succumbs to a predator or disease. But how does a parasite differ from a predator or Herbivore? The definition of a parasite given above could fit members of both these groups. A parasite is recognized as being much smaller than its host, so that often many parasites can live on single host. Parasites usually reproduce much faster than their host and so have a much faster rate of population increase. However, as with many other definition in ecology, there is a boundary area between these three groups where it is difficult to decide which category to use.

For example, European cuckoos (Cuculus canorus) are much larger than their host bids, yet the baby cuckoo in the nest of meadow pipit is considered as a parasite. On the other hand a colony of monkeys eating the fruit or leaves of a tree are much smaller than their yet are considered to be Herbivore, not parasites.

3.2.2Predation : and Parasitism:

The local distribution of some species seems to be limited by predation.

3.2.2.1 Statement:

As already indicated, predation and parasitism are examples of interactions between two populations which results in negative effects on the growth and survival of one of the populations. A cardinal principle is that the negative effects tend to be quantitatively small where the interacting populations have had a common evolutionary history in a relatively stable ecosystem. In other words, natural selection tends to lead to reduction in detrimental effects or to the elimination of the interaction, altogether, since continued severe depression of prey or host population by the predator or parasite population can only lead to the extinction of one or both populations. Consequently, severe interaction is most frequently observed when the interaction is of recent origin (when two populations first become associated) or when there have been large-scale or sudden changes (perhaps temporary) in the ecosystem (as might be produced by the man). This leads to what we might call". "The principle of the instant pathogen", which explains why man's frequent unplanned or ill planned introductions or manipulations so often leads to epidemics.

3.2.2.2 Explanation: or content:

It is difficult to approach the subject of parasitism and predation objectively. The best way to be objective is to consider predation and parasitism from the population rather than from the individual stand point. Predators and parasites certainly kill and injure individuals, and they depress in some measure at least the growth rate of populations or reduce the total population size. But, predators and parasites play role in keeping herbivorous insects at low density but they may be ineffective when the host population erupts or escapes from density dependent control. Deer populations often cited as an example, of populations that tend to erupt when predator pressure is reduced. The most violent eruptions occur when a species is introduced into a new area where there are both unexplained resources and lack of negative interactions; excluding the cattle and fire, which otherwise, may have also played a part. The population explosion of rabbits introduced into Australia is, of course a well known example among the literally thousands of cases of severe oscillations directly caused by man.

We now come to the most important generalization of all, viz, The negative interaction become less negative with time if the ecosystem is sufficiently stable and spatially diverse to allow reciprocal adaptations. Violent oscillations occur when a host, the house fly, and a parasite wasp are first placed together in a limited culture system when individuals selected from cultures that had managed to survive the violent oscillations for two years were then reestablished in the new cultures, it was evident that an ecological homeostasis had evolved in which both populations had "powdered down", so to speak, and were now able to coexist in a much more stable equilibrium.

In the real world of a man, and nature time and circumstances may not favour such reciprocal adaptation by new associations, so that there is always the danger that the negative reaction may be irreversible in that it leads to the extinction of the host. The story of chestnut blight in America is a case in which the question of adaptation or extinction hangs in the balance, and there is little man can do but observed.

Originally, the American chestnut was important member of forests of Appalachian region of eastern, north America. It had its share of parasites, and predators. Likewise, the oriental chestnut trees in china – a different but related species – had their share of parasites, and so on, including the fungus Endothia parasitica, which attacks the bark of stems. In 1904, the fungus was accidentally introduced into the united states. The American chestnut proved to be un resistant to this new parasite, by 1952, all the large chestnuts had been killed and the similar examples, shows,

(1) when and where parasites and predators have long been associated with their respective hosts and prey, the effect is moderate, natural, or even beneficial from the longterm view, and
(2) newly acquired parasites or predators are the most damaging. Although predation and parasitism are similar from the ecological stand point, the extremes in the series, the large predator and the small internal parasite, do exhibit important differences other than size.

Parasite or pathogenic organisms usually have a higher biotic potential than do predators they are often more specialized in structure, metabolism, host specificity, and life history, as is necessitated by their special environment and the problem of dispersal from one host to another.

Of special interest are organisms which are intermediate between predators and parasites, for example, the so-called 'parasitic insects', which have the ability of consuming prey and predator and yet they have high biotic potential of parasite, and host specification and used in control of insect pests. The statement that is both challenge and warm warning i.e., one species harvest systems, as well as monoculture systems, are inherently unstable, because when stressed they are vulnerable to competitions disease, parasitism, predation, or other negative interactions. Optimum yield, may be less than the maximum when the cost of maintaining "order" in inherently unstable system is considered.

3.2.2.3. Other glitters:

The following sequence of studies illustrates how interactions between competitions and predators and of course parasites, affect density and diversity, with special reference to "man the predator".

1. **Larkin (1963)** — showed the altered equilibrium.

2. **Slabodkin (1964)** — showed the experimental removal i.e., predation by the experimenter) of Hydra in two-species laboratory cultures prevented density from reaching exclusion levels, thus enabling two species to coexist where only one could do so in absence of predation.

3. **Paine (1966)** — found that experimental removal of predators on inter tidal rocks i.e. where space is limited. Greatly reduced the diversity of the herbivores i.e. algae grazers, because of interspecific competition intensified to the point of exclusion; he predicted that in the continued absence of predators the number of species would eventually be reduced to one, as in the tribolium model.

4. **Smith (1966)** – describes how a succession of species – specific explanation combined with introductions and eutrophication have resulted in successive rises and fans of commercial fish in lake Michigan. First there was the lake trout that supported a stable fishery for half a century, but this was virtually eliminated by the combined assault if over harvest, attack by the introduced parasitic lamprey and eutrophication. Then in rapid succession lake herring, lake whitefish, chubs, and the exotic alewife exhibited population growth and decline as each inturn was exploited and gave way under the pressure of a competitor, predator, parasite.

Recently, Coho salmon have been introduced and are thriving on a die of alewifes, much to the delight of the sports fisherman one can predict that this bonanza will soon run its course unless harvest and pollution can come under better control.

3.2.3 : Herbivory :

3.2.3.1 : Content :

Herbivory can have a positive effect on some plant populations by providing more opportunity for new individuals to establish, for example, if rabbits are excluded from grassland, the ungrazed vegetation grows taller and there is an overall reduction in the number of individual plants and in the diversity of species. A very rich, heavily grazed grassland full of flowering plants changed to one dominated by species of grass with very few herbs. Rabbits evidently eat grasses in preference to herbs, so that when rabbits are present, the herbs can flower, set seed and increase. Once rabbits are excluded, the grass crowds out the other species.

Consumers affect primary production by removing plant biomass and recycling nutrients. Plant production in turn supports herbivore production interactions of producers and the carnivores are highly variable in time and space and rarely approach steady state. Shifts in top predators cause trophic cascades that pass through food webs and change the primary production. Despite the negative effects of herbivores on plants, herbivore biomass increases as primary production increases. " The relationship of plant production to herbivory is important because, it affects the production and abundance of animals, including people".

Herbivory rates are faster in aquatic ecosystems than terrestrial ecosystems, for a given rate of production. Herbivore biomass and herbivory rates increase with primary production with similar slopes in both terrestrial and aquatic ecosystems. However aquatic herbivores remove about 51% of primary production three times the amount removed by terrestrial herbivores.

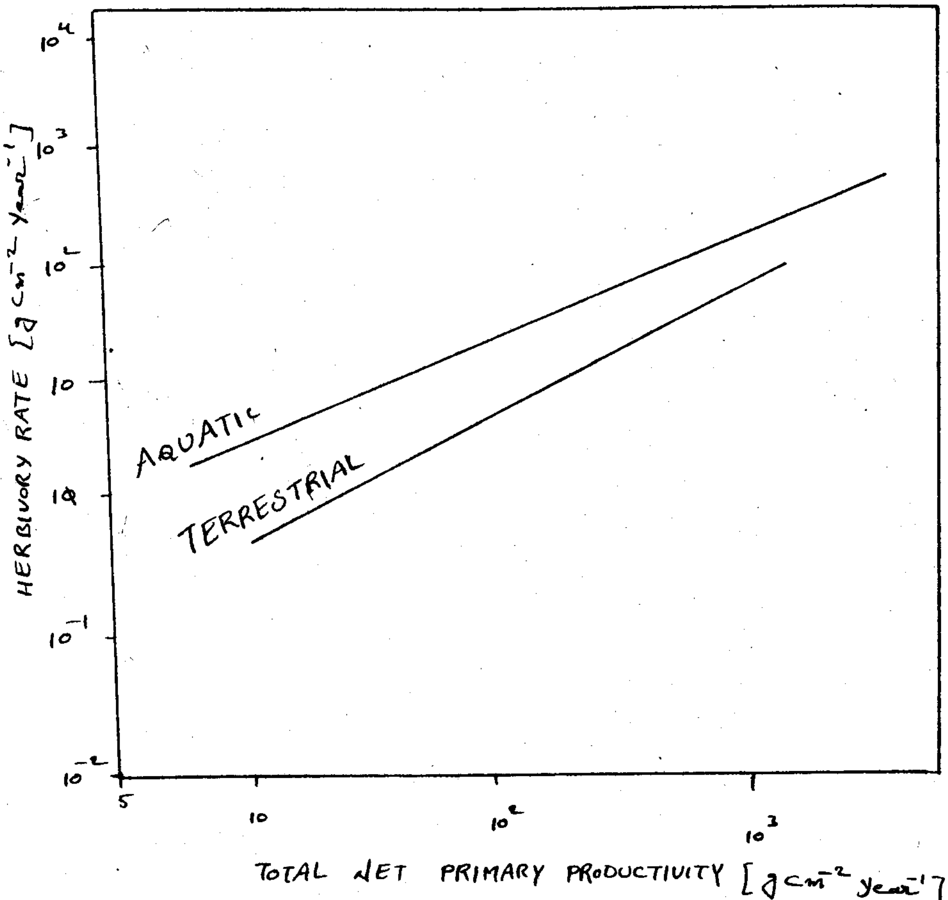


fig. 2.3 Annual rate of herbivory versus annual net primary productivity rate in aquatic and terrestrial ecosystems.

Differences in herbivory rate help explain the constant contrasting ratio of herbivore to producer biomass in aquatic and terrestrial systems. In Terrestrial ecosystems, primary producers attain higher biomass than Herbivores. Herbivore biomass is constrained by low herbivory and consequently low secondary production.

In Aquatic ecosystems, herbivory is faster, secondary production is higher and consequently herbivores attain higher biomass than producers. How can consumer biomass exceed plant biomass in aquatic ecosystem ?

The Aquatic plant biomass has a fast growth rate [replacing] its biomass several times per year, or even several times per week, so the relatively high consumer biomass is maintained by rapid growth and grazing of a relatively small plant biomass.

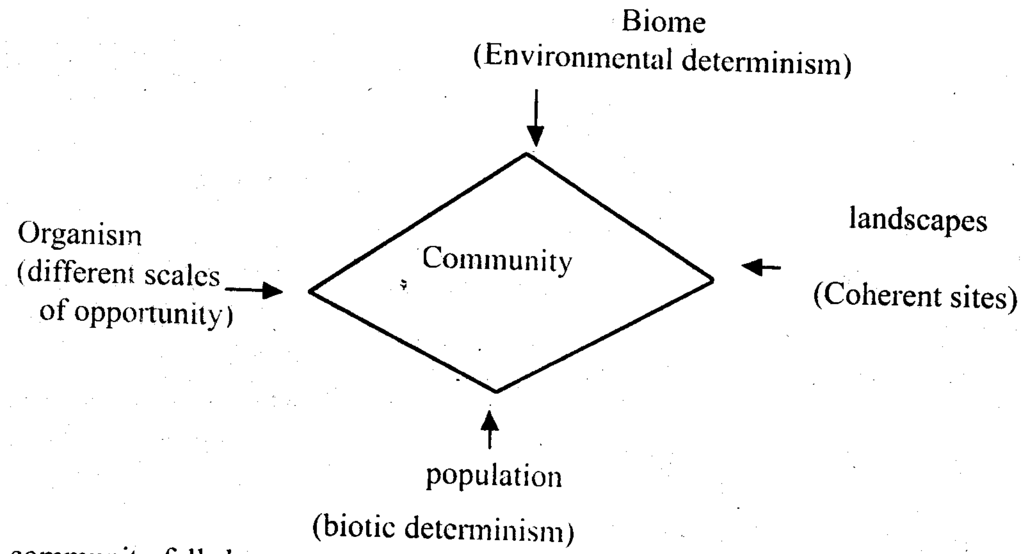
Are trophic cascades more common in Aquatic than terrestrial ecosystem.?

The high relative biomass of consumers relative to producers in aquatic ecosystem suggests this could be the case on the other hands diet choices by consumers may be more important than their relative biomass. In lakes, consumers with broad diets, such as the water flea Daphnia and largemouth bass, are crucial for Trophic cascades. In Terrestrial ecosystems analogs of Daphnia are large herbivores like deer, caribou and wildebeest, and the analogs of bass are wide ranging opportunistic predators like lions and wolves.

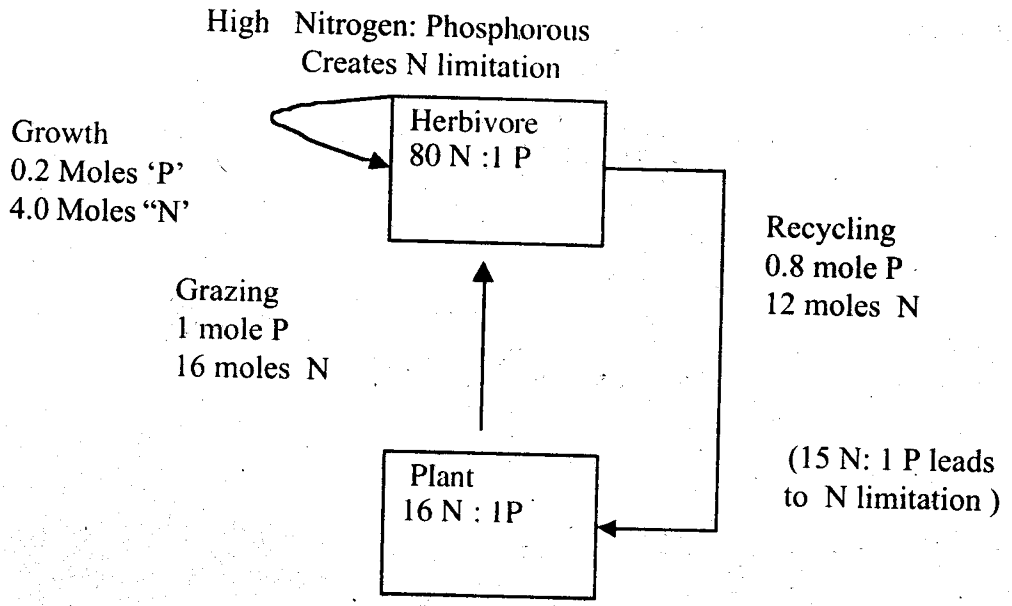
Will the return of the wolves to the northern united states cause a 'trophic cascade' through deer to affect plant diversity and production ?

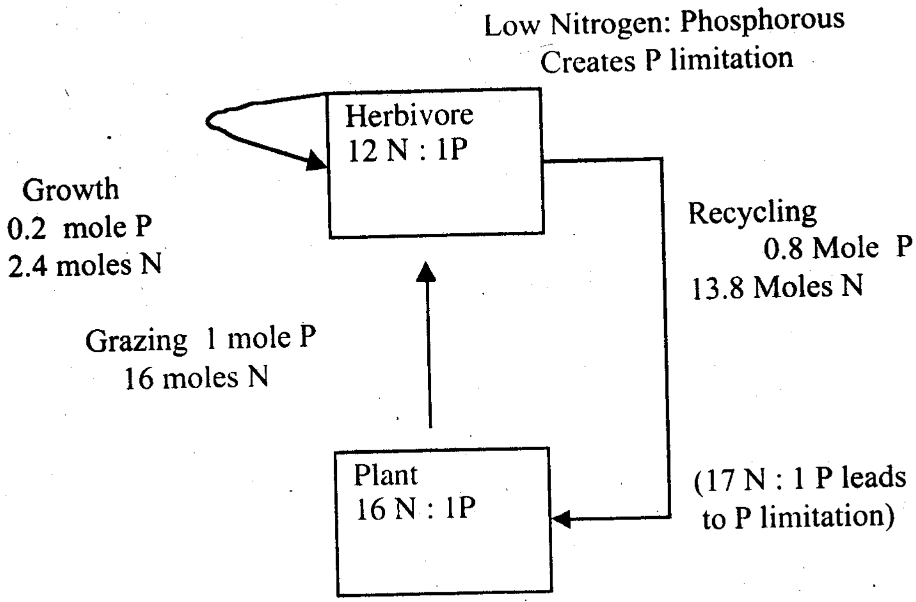
Ecologists may have the opportunity to answer this question someday at some time, let us wait!

Accombdation of different specices landscapes:



community falls between conceptions of biome and population.





Constrants in nutrient limitation of plants produced by herbivores with different requirements of for N& P and raito is 16: 1, the herbivore ingerts an amount of plant material equivalent ot 1 mole p and 16 moles N, and 20% of ingested P is assimilated. The herbivorewith high N:prequire assimilates 0.2 moles P and $ moles N, and therefore excretes 0.8 moles P and 12 moles N. the excreted N:P ratio of 15:1 would cause the plant to be N-limited if the herbivore has its only source of nutrients. The herbivore with a low N:P requirement also assimilates 0.2 moles of P, but needs only 1.4 moles of N. it therefore excretes 0.8 mole of P & 13.8 moles of N. the excreted N:P ratio of 17:1 would cause the plant to be p-limited if the herbivore was only source of nutrients.

Thus the Herbivores are the "Primary Macroconsumers," feeds directly on the plants or plant remains and are of two types, viz, zooplankton (Animal plankton) and Benthos (botton forms), paralleling the two types of producers. And is called Herbivory because of its feeding directly on plants.

3.2.4 : Allelopathy : [Alleon :of each other ; pathy : suffering]

3.2.4.1 Content:

Some organisms, plants in particular, may be limited in distribution by "poisons" "antitiotics" or "allelopathic" agents. The action of the pencillin among the micro organisms is a classical case

According to 'Muller', 1966 : The term Allelopathy (= harmful to the other) has been proposed for chemical inhibition by plants. The term "Antibiosis', is commonly used for such interaction.

A cardinal principle is that the negative effects tend to be quantitatively small where the interacting populations have had a common evolutionary history in relatively stable ecosystem.

According to "Ryther", 1954 : Chlorella, a common algae produces a bactericide that not only kills bacteria but also retards the growth of Daphnia, which feed on chlorella.

According to "Whittaker"(1970): In his review of botanical inhibitors, concluded : "Higher plants synthesize substantial quantities of substances repellent or inhibitory to the organisms."

'Alleleopathic effects have a significant influence on the rate and the species sequence of plant succession and on species comparision of stable communities. Chemical interactions affect species diversity of natural communities in both the directions; strong dominance and intense allelopathic effects contribute to low species diversity of some communities, where as variety of chemical accommodations are the part of the basis of the high species diversity of others'. Antibiosis, of course is not restricted to higher plants numerous examinations among the micro organisms are know; as illustrated by penicillin; the bacterial inhibitor produced by bread mold and now widely used in medicine.

Interest in toxic secretion of plants arose from a consideration of "Soil sickness". It was observed in the nineteetnh century that has one pice of ground was continuously cropped to one plant the yields decreased and could not be improved by additional fetilizer. As early as 1832, De candolle, suggested that the deleterious affect of continuous one-crop agriculture might be due to toxic secretions from roots. For example, according to the pickering 1917, with grass and apple trees:

Apple seedlings were grown with three different sources of water: a primary source, a secondary source passing through grass and soil only. The growth of young apple tree was apparently intribited by something production by Grass and carried by the water.

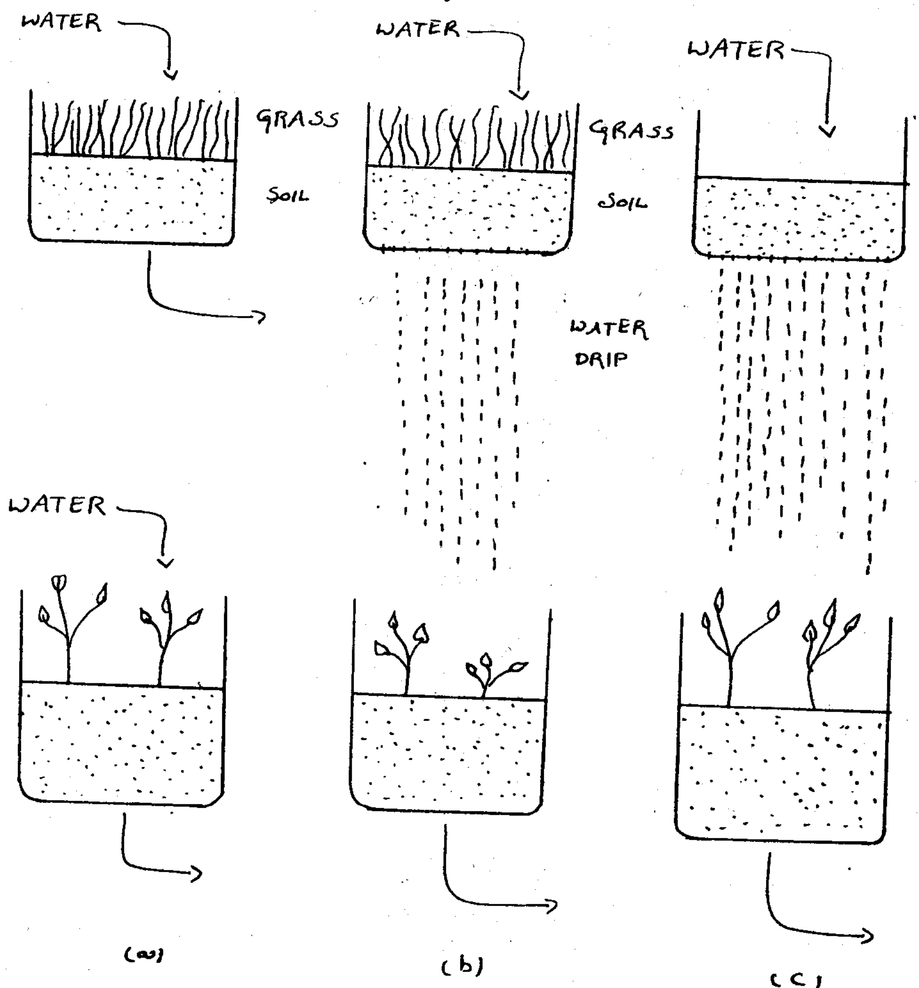


Fig. 2.4 : Experiments that demonstrating the detrimental effects of grass on apple tree seedlings. Grass and tree seedlings are grown in separate flats in green houre, water is provided either independently (a) to both grass and trees ; or as a single source to the grass and soil ; (b) or soil alone; (c) water drip provides moisture for the apple seedlings in (b) , and (c) :; Apple tree seedlings do'not' grow properly when the water has passed through "grass" first (b).

In the early 1900's several Agronomists commented on the effect of black walnut trees (Juglans nigra) on near by grass and Alfalfa plants. Massey deserved that the zone of dead Alfalfa around a walnut treee extended over an area of 2 to 3 times greater than that covered by the tree canopy and suggested that this zone was determined by the outer limits of walnut roots. The rods were suspected of secreting a toxin to which some plants, for example Alfalfa (lucerine) and tomatoes were susceptible; other plants for example, corn (Maize) and beets, showed no ill effects.

Schneiderhan (1927), showed that Black walnut trees injured and killed apple trees upto soft away. The average limit of toxic zone, was greater than the area covered by walnut copy,i.e. 50ft from walnut trunk, but larger walnut trees did not necessarily have much larger toxic zones.

Davis (1928) extracted from the roots and hulls of black walnut a crystalline substance called "Juglone", 5-hydroxy alpha-nopthaquinore and showed that this chemical would kill tomato and alfalfa plants. Others like Kentucky blue grass become more abundant than usual near walnut trees. (Brooks).

Not all walnut species, secrete toxic chemicals. The closely related species, English walnut (Juglans regia) and the California walnuts (J.hindrii and Juglans California) apparently donot senete growth intibitors.

Agriculturalists have recognized the action of "Smother crops" as weed supressors. These smother crops include barley, rye, sorghum, millet, sweet clover, alfalfa, soybeans, and sunflowers. The intibition of weed growth was assumed to be due to competition for water, light or nutrients. Barley, for eg: is rated as good smother crop and has a extensive root growth.

Overland'(1966), showed that barley (Hordeum vulgare) inhibited the germination and growth of several weeds, even in the absence of competition for nutrients or water.

Growth experiments with barley and chickweed (Stellaria media) gave the following results:

Average dry weight per plant (g) after 2 months of growth

	Barley	chickweed	No. of chickweed flowers
Controls (each grown) alone	4.15	3.20	100+
1 barley : 1 chickweed mixture	4.85	1.43	10

Extracts of living roots were more inhibitory than extracts of dead roots. The active inhibitory agent was found to be an alkaloid, but its specific chemical nature is not known.

Thus the adverse effect of barley is partly due to the secretion by their roots of chemicals that reduce growth and germination of near by weeds.

Many fruit trees will grow poorly if planted in soil that has previously grown the same kind of fruit tree. This has given rise to a variety of agricultural problem, which is illustrated by the "peach – replant" problem Borner reviews the soil-sickness problem in higher plants and cites many cases in which crop residues in some way affect subsequent crops. The causal mechanism for these effects is not understood.

Eg: In 1922, at Davis, California, peach and apple orchards were planted; in 1942 these trees were removed, and the whole area was planted in Faye Elberta peach trees in the spring of 1943. with in one year, it was clear that the peach trees succeeding apples were growing better than the peach trees succeeding peaches.

'Went' suggested, that two factors might be involved in the reduce of certain annuals:

(1) Organic detritus might be lacking and
(2) Toxic chemicals might be present.

'Gray ' & 'Bonner' (1948) demonstrated that encelia farinasa leaves contained a chemical that would inhibit the growth of tomato plants growing in sand in the laboratory. Water extracts of the leaves of this plant was also inhibitory, and Gray and Bonner were able to isolate the toxic substance, " 3- acetyl – 6 – methoxybenzaldehyde", the effect was less striking on tomato plants grown in rich garden soil, perhaps soil microorganisms destroyed the chemical inhibitor.

3.2.5 Summary:

Many plants and animals are limited in their local distribution by the presence of other organisms their food plants, predators, diseases and competitors too. Experimental transfers of organisms can test for this factor, and cages or other protective devices can be used to determine the critical interactions.

Predators can affect the local distribution of their prey, and studies on inter tidal organisms have illustrated this influence. The converse can also occur, in which prey's distribution determines the distribution of its predators, but this is not common. In some cases an animal is dependent on a single food source and may have its distributions limited by the distribution of the food few such such cares have been described.

Some organisms poison the environment for other species, and local distributions may be affected by these chemical poisons, or allelopathic agents. The action of penicillin is a classical example chemical interactions have been described in variety of crop plants and in native vegetation.

Thus predation and parasitism and allelopathy are as already indicated are examples of interactions between two populations or species which results in the negative effects on the growth and survival of one of the populations.

Herbivory can have a positive effect on some plant populations the herbivores are the primary macro consumers feeds directly on the plants or plant remains and are of two types viz zooplankton and Benthos.

3.2.6 Expected Questions:

1. What are the negative interactions which are operating on a population ? exlain
2. What is predation explain with examples along with parasitism ?
3. what is Allelopathy ? Describe briefly with examples ?
4. Explain the Herbivory and also mention its importance on the ecosystem ?
5. Can the negative interactions leads to evolution ? if so explain ?
   If not mention with examples too?

3.2.7 References:

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LESSON 3.3

POSITIVE INTERACTIONS COMMENSALISM, COOPERATION, MUTUALISM:

Contents

3.3.1 **Introduction**
3.3.2 **Statement**
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3.3.4.2 **Examples for without continuos context**
3.3.4.3 **Examples for obligate symbiosis.**
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3.3.4.5 **Mutualism without continuos contacts.**
3.3.5 **Cooperation.**
3.3.6 **Summary**
3.3.7 **Expected questions.**
3.3.8 **References.**

Positive interactions **Commensalism cooperation mutualism**

3.3.1Introduction

The biotic environment is experienced by an individual as interactions with other organisms. These include individuals of the same species and individuals of many other species. Throughout its life an individual will come into context with many other organisms. Within any community there will be a complex interplay of relationships both within and between species.

Such sort of interactions or relationships may be leads to positive or negative. The negative interactions were described in previous sections, viz., competition, predation, parasitism, etc. The positive interactions viz., **Commensalism, cooperation, mutualism** goes like this.

3.3.2statement

Associations between two species populations, which result in positive effects, are exceedingly widespread and probably as important as competition & parasitism and as so forth, in determining the nature of populations and communities. Positive interactions may be conveniently considered in an evolutionary series, as follows.

Commensalism – one population benefited

Cooperation - Both populations benefited
Mutualism - both populations benefited and have become completely dependent on each other.

Enrich and Raven first introduced the term co-evolution, in 1964, a paper on the relationship between butterflies and the host food plants of the larval stage. They were concern in particular with the patterns of interaction between two major groups of organisms with a close and evident ecological relationship. Within the paper they also introduced the term community evolution.

3.3.3 Description

Evolutionary interactions found among different kinds of organisms where exchange of genetical information among the kinds is assumed to be minimal or absent. The most restricted use of the term co-evolution should be used aptly, in interactions particularly positive. According to Darwin, every organism has to participate in the competition either directly or indirectly i.e. by natural selection, which has a directed attention to the competitive aspects of nature. The widespread acceptance of Darwin's idea of survival of the fittest as an important means of bringing about natural selection. By all these means, cooperation between species in nature has perhaps been underestimated. Atleast positive interactions have not been subjected to as much quantitative study as have negative interactions.

As in a balanced equation, it seems reasonable to assume that negative and positive relations between populations eventually tend to be balance one another, if the ecosystem is achieve any kind of stability.

3.3.3.1 Content

Commensalism represents a simple type of positive interaction and perhaps represented as first step toward the development of beneficial relations. Association between two organisms in which are benefits and other neither gains nor loses "**commensalism**" the relationship between members of different species in which only one of the partners is benefited and the other is not harmed. Usually the partner, which is benefited gets shelter, transport and food and in this process the other partner is not at all harmed or when different species associate in such a way that only one of the species is benefited but neither is harmed, it means "eating at the same table" when two or more animals live together, and if there is no physiological dependence between them, they are referred to as commensals and Relationship between such organisms is called Commmensalism. Commmensalism is rare among vertebrates but common in invertebrates Commensalism is of two types. Commensalism with continuos contact. It especially common between sessile plants and animals on hand, and motile organisms on the other hand. The ocean is generally a good place to observe Commensalism practically every warm borrows, shell fish , or sponge contains various ' Uninvited guests', organisms whish require the shelter of the host but do neither good nor harm is return if : small delicate crab in mantle cavity of oysters, are called 'commensal crabs'. Many of the commensals are not host specific and some not like so. The late W.C. 'Allee', worked extensively on the subject on the species, which care, in association both the species get gained something. He had observed the true practically in nature and so showed practically too, documented.
Eg.: Crabs and Coelenterates.

The Coelenterates grow on the backs of crabs, providing camouflage and protection, with stinging cues of coelenterates. In turn, the coelenterates are transported about and obtain particles of food when the crab captures and eats another animals

In this instance the crabs not able to depend absolutely on the coelenterate, nor vice versa. A further step in cooperation results when each population becomes completely dependent on other. Such cases have been called 'Mutualism'/ 'obligate symbiosis'.

A relationship between two different species in which both the partners are benefited is called Mutualism. Depending on the nature of association between the partners, The Mutualism, is classified as:

(a) Mutualism with continuos contact.
(b) Mutualism without continuos contacts.

In terms of population growth rate, Mutualism occurs when an increase in the density of either member of species pair increases the per capita population growth rate, of other species. Most research on Mutualism focuses on determining how the species benefit, each other and how the Mutualism could have evolved. The study area is young and still going through initial phases of describing the natural history of Mutulistic interactions. Often, quit different kinds of organisms are associated.

In fact, instances of Mutualism are most likely to develop between organisms with widely different requirements.

Eg: Most important interaction between Autotrophs and Heterotrophs.

Obligate Symbiosis between ungulates and Rumen bacteria.

Mutualism seems to replace parasitism as ecosystems evolve toward Maturity, and it seems to be especially important when some aspect of environment is limiting say for example, in fertile soil, to an extent that mutual cooperation has a strong selective advantage.

3.3.4.1 Commensalism' "with" continuos contact:

In this case, commensals remain more or less in permanent contact with their hosts.

1. Epiphytes, which are found growing, attached to branches of trees. Epiphytes – uses tree for attachment and manufacture their own food photosynthesis. These epiphytes are simply attached to outer surface of host ., and are called <u>ectocommensals.</u>

2. Certain green algae grows on the long grooved hairs of a sloth .Extensive growth of the algae gives green colour to the sloth which is advantageous to sloth to conceal itself between the green leaves of the tree.

3. Basicladida another green alga grows on the back of fresh water tortoises, which gives green colour to the host.

4. Sea barnacles are found attached to shells of molluscs, or to the body of whale. These barnacles get free transportation from place to place providing new feeding pounds. The barnacles' do not harm the host.

5. The bivalve ostrea frons is found attached on the roots of the red mangroves in shallow waters. The bivalve possess special hooks from its lower shell and cling to the body of the host.

6. Mollusks, barnacles, and tube worms are in close association with the marine king out, limulus polyphemus and living as ectocommensals without causing any harm to the host. Larger number of motile commensals are found living in the book gills." Certain commensals living inside the tissue or cavities of host "Endocommensals".

Examples 1: Bacteria like Escherichia coli is found living in the human.colon is a common Endocommensals.

3.3.4.2 Commmensalism without continuos context :

In this case, commensals remain only in temporary contact with each other or their context is only for a short period.

1. A sucker, which is modified dorsal fin in sucker fish, Echeneis is found attached to the upper side of a shark with sucker. Here commensal gets free transport and carried to new fcod grounds. The attachment is not permanent, and sucker fish releases the attachment af:er sometime an swims in search of food.

2. A marine crab, Polyonyx living in the 'U' shaped tube of chetopterus (Annelid), gets protection in the tube and does not harm the polychaete warm, the host.

3. A small tropical fish, the Fieraster lives with in the cloacal chamber of sea cucumber (Holathurian of echinodermata). It usually comes out of the cloacal chamber to feed in the neighborhood.

4. The pea crab, Pinnotheres lives as a commensal in the mouth cavity of certain sea mussels. The crab steals the food collected by mussel.

5. Many small fishes live among the stinging tentacles of physalia (a Portuguese man of war) without any harm from the host. These fishes get protection from the predators. Because of the stinging ceus present in the tentacles.

6. The pilot fishes move in-groups underneath the big sharks, so that they not only get protection and at the same time collect the food particles left over by the shark.

7. An Oystercrab is carried into the mantle cavity of one oyster along with the incurrent water as a planktonic larva. The larva remains inside the mouth and grows to adult stage.As the adult crab could not escape through narrow opening present between values of oyster, the crab becomes permanent prisoner, getting nourishment + protection from the oyster.

3.3.5 Obligate symbiosis or mutualism examples

1. Pollination and seed dispersal: The most familiar and possibly the most important mutualism in nature is between plants and animals that disperse the plants pollen and seeds. By co-operating the aid of insects and other animals, flowering plants have found an admirable solution to the problem of being sedentary. Animals carry pollen between flowers and disperse seeds to distant sites. The benefits to the animals that aid plants are numerous. Plants provide both nectar to attract pollinators and fleshy fruits to attract seed disperses, and may animal depends wholly on nectar or fruits that plants produce.

   Plant nectar provides only a dilute concentration of sugars forcing pollinators to visit many plants and there by disperse pollen to many recipients. Some plants take even advantage of pollinators without providing any benefits, for example, by with holding nectar or by attracting unsuspecting insects not with a reward, but instead with a chemical compound mimicking the insects sexpheromoes animals also take advantage of mutulistic advantage from plants. Some bees, rather than climb down the flower to collect nectar and there by get covered in pollens instead chew through the sides of flower to steal the nectar.

   Even though mutualism is predicted on both the species benefiting from their interactions, mutualism should not be confused with the altruism mutualism must be viewed from the perspective of natural selection with favors those characteristics in both the plants and animals leading to increased survival and fecundity. Mutualism arises only from the mutual self-interest of plants & animals acting through natural selection.

2. Digestion of cellulose: Many mutualistic reactions occur between microbes and animals that eat relatively undigested food. Cellulose, the compound that makes up the bulk of structural material in plants, is largely indigestible to almost all organisms except certain bacteria and protists.

   When a cow chews its cud, it is grinding up plant material so that cellulose grinding digesting microbes in its rumen has earlier access to the cellulose. Similarly, termites have an array of protists that join the termites' aum-cellulose digesting enzymes to decompose the wood that termites feed on. In this mutualism, the animal takes the advantage of the favorable environment of the animals' gut and the regular servings of food they receive.

3. Nitrogen fixation: another mutalism occurs between bacteria & plants, and involves the nitrogen fixation although nitrogen makes up 78% of atmosphere, plants can not use it in its gaseous form. In fact, many plants live in contact nitrogen shortages-nitrogen are the prime ingredients of most fertilizers. Several groups of bacteria & Cyanobacteria, (prokaryotes) have a requisite biochemistry to convert atmospheric nitrogen into nitrate or ammonium, forms of nitrogen that plants can use readily. With the obvious benefits, that nitrogen fixing for plants, several groups of plants have developed specialized structures for culturing nitrogen fixers. Legumes including peas, clover and beans develop nodules in their roots that provide the perfect environment for nitrogen fixing bacteria. The frequency of plant species having spe-

cialized structures to culture the nitrogen. This is particularly true in tropical areas, with heavily leached soils, where coopting the help of nitrogen fixers is critical to may tropical trees.

Mycorrhziral fungi: This is the mutualism between plants & fungi. Mosts of plants of higher ones have their root system surrounded by hyphae of specialized fungi, viz, mycorrhizal fungi. The fungi are particularly efficient in absorbing water and nutrients, (NPK), from soil. These nutrients are passed to the roots of the plants, and in some species the hyphae of the fungi actually penetrate the root cells. The association is basically of 3 types.

Ectotrophic mycorhiza: Mostly basidiomycetes.
Endotrophic mycorrhiza : Mostly phycomycetes.
Peritrophic mycorrhiza: Extramatrical do not penetrate epidermis of root.

In return, for water & nutrients, the plants provide the fungi with attest some of the carbohydrates they require. These mycorhizal associations are extremly important for trees and grasses. When no-native pines were introduced into both puerto rice and Australia in attempts to establish commercial plantations, the tree grow very slowly until receiving applications of soil containing the appropriate mycorrhizal fungal to helps the pines.

3.3.4.4 Materialism with contacts: (Physiological interdependence)

Examples: 1 lichens consists of matrix made up of fungi enclosing algal ceus. Lichen provides moisture, potection, minerals. Algae manufactures carbohydrates for its own and don lichen this is an evidance that, lichen can never grow in nature without algal assoication and vice versa.

2. Rhizobium bacterial and plants.

3. Animal and palnt –zoochlorellae (green algal), zooxanthellae (brown or yellow algae) live symbiotically in the outer tissues of some sponges, coelenterates, mollusks, and worms.

   A classical example, furnished by partnership of sea anemone, admisa pilata and the hermit crab Eupagurus prideause the nematocysts present in tentacles of sea anemone prevent the approach of predaceous fishes to feed upon anemone. In return, hermit crab provide free transportation of the anemone to new places for food access.

   A best known example of symbiosis is association between coelenterate chlorohdyra and green algae carteria, in endodermal cells of hydra, for O_2 by photosynthesis algae in return, the algae gets protection and also nitrogen substances from hydro for synthesis of its food material.

3.3.4.5 A Mutualism without continuos contact:

Examples:

1. Bird and grazing animal the cowbird in America, the oxpecker, the little white heron in Africa and cattle egret in India and other certain birds are often riding on the back of grazing animals where they obtain ready supply of food from ectoparasites like, ticks and mites. The grazing animals get rid off their pests.

2. The crocodile bird removes the leeches found between the teeth of crocodiles, which suck blood of crocodile. The bird gets the food aspect since they feed upon leeches and crocodiles getting rid off leeches.

3. The associations of Ants and Aphids. For honey dew. Aphids suck the sap of plants and they secrete this in the form of a nutritional fluid called honeydew. The ants are very found of honey-dew, hence they maintain the aphids which are well protected by the ants.

4. Pollination of flowers by bees, butterflies, etc.

5. Associations of ostriches and zebras for watching attack by predators by the keen right of ostriches and the greater sense of smell of zebras and are said to be derive mutual help and benefit.

3.3.5 Cooperation:

The interaction in which both the organisms gain by an association or interaction of some kind, in such care, we called it as *protocooperation* the late W.C. Allee studied and wrote extensively on this subject. He believed that the beginnings of cooperation between species are to be found throughout nature. He was able to document many of them, and to demonstrate the mutual advantages by experiments.

Example: Returning to the to the sea as an example, like commensalisms crabs and coelenterates often associate with mutual benefit. The coelenterates grow on the back the crabs or are some times planted there by crabs, providing camouflage and protection since the coelenterates have stinging cells as mentioned earlierly. In return, coelenterates are transported about and obtain particles of food, and when the crab captures and eats other animal. In this case the crab is not absolutely dependent on coelenterates nor vice-versa, as in mutualism

Thus this cooperation has its owns significance, but in many situations, animals compete for access to resources; in other situations we see cooperation instead. In the *Florida scrubjay* (*Aphelocoma coerulescens)* and a number of other words, some young individuals help at the nest of a relative rather than reproducting on their own.; *Female ground squirrels* work together to defend each other's young; *Lionesses* cooperate in bringing down large prey; vampire bats that foraged successfully share their blood meals with less succesful roostmates; honey bee workers give up their own reproductivity to contribute to the effort of their mother, the queen, to rear more her *offsprings*. Given that natural selection fovours individuals that behave to as to maximize their own fitness, i.e., to act in their own selfish best interests, how can such seemingly *altruistic behaviour* arise and be maintained in a population? The social insects are extreme examples of "Altruism" in the animal world, posing a dilemma that ***"Charles Darwin"*** recognized!

3.3.6 Summary:

Associations between two species populations can leads to positive interaction and is as important as negative interactions every species in the population, and every population in the entire community and community in the entire ecosystem has to get interacted, and should participate every organism or species has to live and should cooperate to the other species to done its job. "Every organism has to fall under a basic principle ***Live and let live,*** such sorts of thinking leads to

commensalism, cooperation and mutualism to get maximum and to give maximum or minimum basing on the situation.

All those positive interactions were mentioned with clear cut examples in the content of previous sections.

3.3.7 Expected questions

1. What are the positive interactions operating on population? Explain with necessary examples?
2. Explain commensalism and cooperation? Describe with examples?
3. What is mutualism, define and give significant features of mutualism along with mutualism?
4. Which type of positive interaction is most useful for species, explain with apt examples?

3.3.8References:

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LESSON: 3.4
CONCEPTS OF HABITAT ECOLOGICAL NICHE AND GUILD

3.1 : Introduction
3.2 : Content
3.3 : Ecological niche and guild
3.3.1 Introduction
3.3.2 Content
3.4 Expected Questions ?
3.5 References

Concepts of Habitat and Ecological Niche and Guild

3.1. Introduction:

These words are used extensively in ecology and has their own importance and is often have quite recognition too. The word Habitat is used significantly in ecology, when describing where an organism lives.

Unfortunately, it is difficult to give a precise definition of the term Habitat. The word is lattin one and literaily means it inhabits or 'it dwells'.

It was first used in 18[th] century floras or faunas to describe the natural place of the growth or occurrence of a species. These guides to the plants or animals of a region used always to be written in latin, hence the latin word, habitat.

When flora and fauna began to be written in a modern languages, the term 'habitats' remained untranslated and began to be used as a technical term.

It is easy to give the habitats of some species.

3.2: Content:

The habitat of an organism is the place, where it lives or the place, where one would got find it. For instance, the lowland gorilla (Gorilla gorilla)asits habitat lowland tropical secondary forest; the fungus Hericium abietis is found on conifenous logs and trees in the pacific north west of the USA.

Some species, though have several habitats. Those of the tiger (panthera tigris) include tropical rainforest, snow-covered coniferous and deciduous forests and mangrove swamps (sunquist, 1985).

Ecologists soon realised that for smaller organisms, especially if they lived in a very restricted area such as on a particular plant or animal on in a specific region of the coil, it was useful to be more precise about where they lived. Consequently the term Microhabitat was coined. Any one environment is divided up into many, possibly thousands of microhabitats.

The term habitat is generally understood to mean simply the place where an organism lives. Thus the habitats of some organisms are given as "Back swimmer", Notonecta is the shallow, vegetation choked areas (littoral zone) of ponds and lakes.

The habitat of Trillium plant is moisture shaded situation in a mature deciduous forest.

Different species in the Genus Notonecta or Trillium may occur in the same general habitat but exhibit small differences in location, in this event we can say that Microhabitat is different other species in this genera exhibit large habitat or macrohabitat, differences.

Habitat may also refer to the place where entire community was occupied. For example, the habitat of the "sand sage grassland community" is the series of ridges of sandy soil occurring the north sides of the rivers in the southern great plains region of the united states. Habitat in this consist mostly of physical or Abiotic complexes where as habitat as used with reference to Notonecta and Trillium, mentioned above includes living as well as Nonliving objects. Thus the habitat of an organism or group of organisms (population) include other organisms as well as the Abiotic environment. It is quite important to recognize these two possible uses of the term habitat in order to avoid confusion. By studying particular habitat we become acquainted with organisms and physical factors actually associated in a particular ecosystem. This helps mitigate the pitfalls the may follow excessive generaligation.

There are four major habitats in the biosphere, viz

—Marine
—Esturine
—Freshwater and
—Terrestrial.

Since most biologists, postulate the life began in ocean, it would be logical to study with the starting of marine habitat. But, it is best to start the study with the fresh water habitat, in actual practice. In the first place examples of fresh water habitats are available wherever man lives. Many freshwater habitats are freshy and small and therefore, are more readily accessible throughout with the use of relatively simple equipment. Finally, there are fewer kinds of organisms in small bodies of fresh water than in the oceans making it easier for the beginner to comprehend something of the nature of the natural community without an overburden of effort in learning to identify the organisms in a large number of classes and phyla. For these region reasons, the section study to be begin with freshwater environment.

Any one environment is divided up into many, possibly thousands of, microhabitats. The following diagram elucidates the range of microhabitats available to insect Herbivores and fungal parasites on a typical flowering plant.

"This diagram indicates the specific habitats of particular organisms on plants and has given with specificily only. Likewise, every organisms has its own habitat with habit, and can shows its perfect actions with caliber in that specific habitat only".

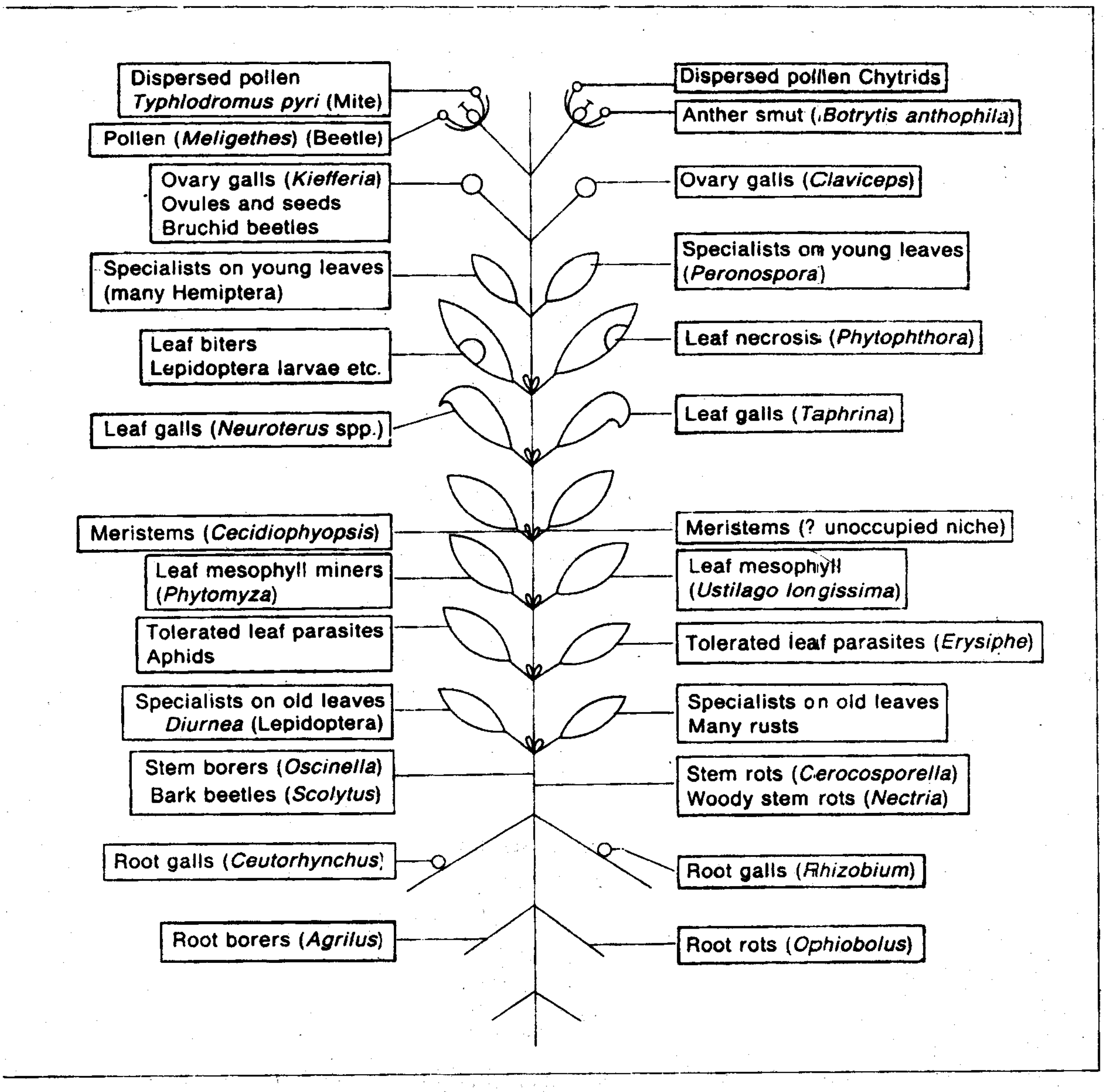

Fig.3.5 A generalized diagram of a typical flowering plant showing the microhabitats available to insect herbivores and fungal parasites. Examples are given of insect herbivores (left) and fungal parasites (right) which can attack particular parts of a plant with specific habitats. (After harper, 1977).

3.3: Ecological Niche and Guild.

3.3.1: Introduction:

The ecological niche is the conceptual cornerstone. This multi dimensional frame work defines all of what a species could do and all of the places where it could exist.

The concept of 'Ecological niche' is a foundation for thinking about how organisms are distributed and what controls their relative abundance the most congent presentation of that idea owes to G.E. Hutchinson in this description of niche as an "n-dimensional hyper volume".

What does this mean ?

Think of the niche as the equivalent of an ecological hologram for each kind of organism. Each environmental variable is like a land in the color of that spectrum that define some part of the halogram seen in three dimensions.

Using the niche as the general frame work emphasizes the importance of ecological master factors. Temperature effects, water balance constraints, and oxygen availability.

The niche concept is intimately involved with the competitive exclusion principle, and we must clarify this concept. The term niche was almost simultaneously defined to mean two different things.

"**Joawph Grinnell"** in 1917 was one of the most first to use the terms niche and viewd it as a subdivision of the habitat (udvardy 1959). Each niche was occupied by only one species.
"Elton" in 1927 independently defined the niche as the "rale" of the species in the community.
These vague concepts were incorporated into 'hutchinson's-redifinition' of the niche in 1958.
In ecology, it came to stand for the precise way in which a species fits into its environment . — "niche".

3.3.3 Content:

The term 'Ecological niche' is more inclusive term that includes not only the physical space occupied by an organisms, but also its functional rate in the community, and its position in the environmental gradients of temperature, moisture pH, soil and other conditions of existence. These three aspects of ecological niche can be conveniently designated as, viz.,

Spatial or habitat niche,
Trophic Niche, and
Multidimensional or Hyper volume Niche.

Consequently, the ecological niche can be conveniently designated and depends not only where it lives on what it does i.e., transform energy, behavior, response to physical and behavioral biotic environment; and how it is constrained by other species.
By analogy, it may be said that
Habitat – "organisms addresse"
Niche —"profession" — in biological sense

Since a description of the complete ecological niche for a species would include an infinite set of biological characteristics and physical paramenters, the concept is most useful and quantitatively most applicable, in terms of difference between species or the some species at two or more locations in one or a few major operationally significant features. The distinction between niche and habitat is an important one in ecology. The word niche originally meant a shallow, ornamental racess formed in the wall of a of building, usually for the purpose of containing a statue or other decorative object. 'Habitat orly referes to"location" of organism, where as'niche' gives a compete description of " how the organism relates to its physical and biological environment"., which requires a great deal of field work to determine the niche of an organism in detail. According to J.Grinnell 1917 and 1928, niche means "To stand for the concept of ultimate distributional unit within which each species is held by its structural and instinctive limitations" no two species in the same general territory can occupy for long identically the same ecological niche". Thus, Grinnell thought of the niche mostly in terms of the microhabitat, or what we would now calling 'The spatial niche.'

According to C.Elton in England, who was one of the firsts to begin using the term "Niche"(as mentioned earlier) in the sense of "functional status of an organism in its community". Since, this person placed the emphasis on energy relations, his version of the concept might be considered as Trophic niche.

According to G.E.Hutchinson, suggested that niche could be visualized as multidimensional space or hyper volume within which the environment permits an individual or species to survive, indefinitely. His new, which can designate as the multidimensional or Hyper volume niche, is comenable to measurement and mathematical manipulation.

Hutchinson, had also made a distinction between the fundamental niche and Realized niche. Fundamental niche — The maximum abstractly inhabited hypervolume when species is not constrained by competition with others. Where as

Realized niche.

— a smaller hypervolume occupied under the biatic constraints.

According to 'Mactrthur' niche and phenotyhpe (genetical term) are most useful in determining the differences between 'individuals' and 'species'. Thus, niches of similar species associated together in the same habitat can be compared with 'precision' when the comparison involves only a few operationally significant measurements.

Mac Arthur gone on to compare the niches of four species of American warblers (parulidae) which all breed in the same Macro habit, a spruce forest, but forage and alert in different parts of spruce tree. These four or five species, very similar in size and beak length, are all mainly insectivores, and all belong to the same genus; Dendrocia. The average beaklength differ only by few millimeters in terms of percentage.

Mean beak lengths of 5 species of warblers studied by Mac Arthur (1958)

Species	**mean beak lenth(mm)**
Dendroica Coronata	12.47
D.Virens	12.58

D.tigrina	12.82
D.fusca	12.97
D.castamea	13.04

Max Arthur chose to study these species precisely because, earlier ecologists studying them had been unable to find it out any differences in their requirements.

The warblers feed on firs (Abies and spruces (picea). Most of the trees in which the birds fed were 50-60 feet tall. He classified the trees into 6 vertical zones, each approximately 10 feet in height. He then divided each branch into three horizontal zones.,viz,

a)bare/lichen — covered bare
b)middlezone of oldneedles
c)Terminalzone of needles and buds (<1.5 y old)

The number of seconds each bird spent in each of the 16 possible zones was recorded
It is apparent from that the five warblers occupy feeding nciches, of course
Which, to a considerable extent are distinct. Furthermore, he noted that even when feeding in the same zone of a tree, the species appear to use different feeding "techniques. Not only this, the five warblers also showed some differentiation in their" nest positions" within the trees. Observations by Mac Arthur on the "winter feeding behaviour" of the birds also showed differences between the species.

Conclusion of this aspect:_ According to law of Ecology
"each species has its own unique niche ['Grinnell',1924] max Arthur suggests that three niche arrangements might be detected by examining species abundance distributions, namely the contignous

Nonoverlapping and Random pattern

Just noted, a Discrete pattern and over lapping pattern
Groups exhibiting intense interspecific competition and Territorial behaviour such as forest birds tend to conform to the nonover lapping niche hypothesis. " Whittaker" represented a graph which finds that curves approximating the simple geometric series are found in some plant communities, in rigorous environments, but the plant populations in most nature communities overlap in use of space and resources. Land plants as well as many animals apparently coexist under conditions of partial rather than direct competition. Some of the adaptations that promote niche differentiation without competition exclusion form habitat are considered evening tribolium-Trifolium model.(as mentioned earlier).

Examples: 1. niche segregation in Millepeds (Diplopoda) in the Microhabitat on the forest floor of maple-oak forest. All the species, live in the same general habitat, namely the forest floor of maple oak forest in Illinois, and all belong to the same basic trophic level, that is they are detritus feeders.

Each species predominates in a different microhabitat, presumedly, each species is using a some what different energy source since the stage of decomposition and microflora will change in the gradient from the center of log to the position underneath the leaf litter.

2.**Notonecta and corixa** – two Aquatic bugs which are similar, which can be collected from the same sample from a small vegetation choked pond but which occupy very different trophic niches. The backswimmer (Notonecta) is an active predator that swims about grasping and eating other animals in its general size range. In contrast, the water boatman (Corixa) eventhough it looks very much like the backswimmer, plays a very different role in the community since it feeds largely on decaying vegetation.

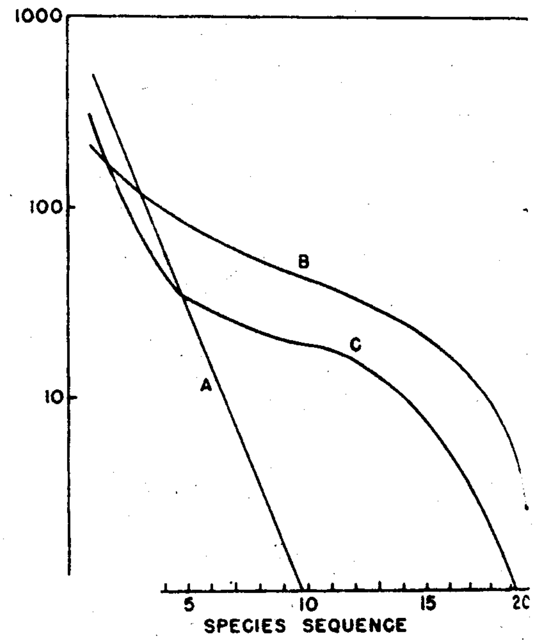

Fig.3.6 :

Dominance — diversity curves for a hypothetical example of 1000 individuals in 20 species form a community.

Number of individuous in the species coordinate are ploted against species number in seqauence from the most abundant to the least abundant (absissa)

A — Geometric series.
B — Non overlapping random niche hypothesis.
C – Intermediate sigmoid pattern..

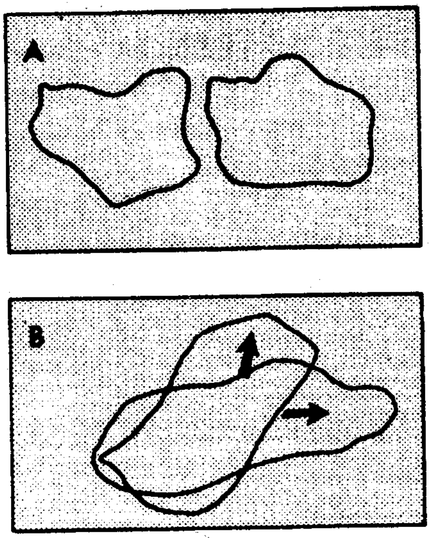

Fig.3.7 Schematic representation of the hypervolume concept of the ecological niche. The background dots represent environmental factors (temperature, food sources, minerals, other organisms) projected onto a plane. The irregular polygons enclose sets of factors that are operationally significant for a species population. In *A* two species occupy nonoverlapping niches, while in *B* niches of two species overlap to such an extent that severe competition for shared resources may result in elimination of one species or a divergence of niches as indicated by the arrows. (Redrawn from Bruce Wallace and A. M. Srb. *Adaptation*. Prentice-Hall, Englewood Cliffs, New Jersey.

3.4 Summary

I individuals are introduced into areas not occupied by thespecies and are able to survive, grow and reproduce in their new habitat, the distribution of species must be restricted either by lack of dispersal or by behavioral reactions. The behaviour of individuals in selecting their habitat may thus restrict the distribution fo some species of animals. Habitats than it usually occupies. Birds have also been studied from this point of view; outthought little expert mental work has been done so for to find out why birds select some habitats for breeding and avoid others. Habitat is the physical location of a specificity for the species, where as niche is the physical location as well as physiological relations with the surroundings and there accurate study comes under ecological niche, and in that, species with similar ecological resource requirements which have the similar role in community comes under the concept of guild.

3.5 Expected questions

1. Concept of habitat? Explain briefly?
2. Concepts of Ecological niche and guild? Explain?
3. What is the functional role of niche, Explain with proper elucidations?
4. Differentiate the niche with habitat?

3.6 References

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LESSON 4.1
POPULATION DYNAMICS

Contents

4.1.1 Introduction
4.1.2 Objectives
4.1.3 Properties of population growth
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4.1.1 INTRODUCTION

The concept of a community in the study of ecology is one of the most important principles in ecological thought. It emphasizes the fact that diverse organisms usually live together in an orderly manner. It is considered as a functional and an organized unit with characteristic trophic relations, patterns of energy flow and exhibit a compositional unity.

Population is a collective group of organisms of the same species occupying a particular area exhibiting certain characters unique to that group. The changing numbers in the population and the factors that control population growth are considered under population dynamics.

All living organisms generally live in groups. These organisms interact with the other members of their species at various times during their lifetime and also with the environment. A population is defined as a group of organisms of the same species, which live together in one geographical area, during a given time period. Within a population all individuals capable of reproduction, have the opportunity to reproduce with other mature members of the group.

In the following account an attempt is made to explain the basic principles underlying the growth of the population the environmental factors controlling its growth, characteristic features of the population, interrelation with the other members with in the populations and those in the community.

4.1.2 OBJECTIVES

The purpose of this unit is to

- To define a population of organisms
- Describe the population growth form
- Explain the factors that influence population growth
- Explain the interactions among the members to understand the concept of energy flow in the ecosystem.

4.1.3. Properties of a Population group

Each population shows certain characteristics, which are unique to that group. As a group alone they exhibit these characteristics and include density expressed as number of individuals in the population at a given time, natality referred as birth rate ands mortality referred to as death rate of the population. Populations also possess certain genetic traits such as adaptiveness, reproductive fitness and persistence, chiefly related to its ecology. Population attributes can be considered under two categories:

a. Those related to numerical relationships and the structure of the population

and.

b. The genetic properties such as adaptiveness, reproductive fitness and persistence

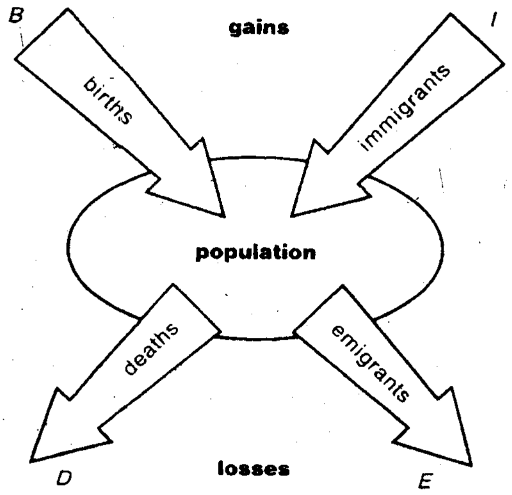

Fig. 4.1 The changes which take place in numbers of a population. Gains of population numbers are due to births (B) and immigration (I) : Losses are due to deaths (D) and emigration (E).

Population density is the size of the population in relation to a unit space. It expresses the number of individuals or the biomass of the population per unit area or volume. This is referred to as' Crude Density', the number or biomass per unit total space and 'Specific or Ecological Density' the number or biomass of the populations per unit of habitat space or as number of individual animals of a given species per hectare of area. It also expresses the standing crop per unit area, to know whether a population is changing indices of relative abundance is more informative. One of the difficulties faced in the expression of density is that the living organisms are not uniformly distributed, but show clumped distribution in certain areas while they are spaced in others. Hence care must be taken in the choice of size and number of samples used for the study of density. Many different techniques are used for estimating the population density

a. total count of the population in an area which has certain operational difficulties

b. quadrat sampling involving counting or recording the weights of individuals in plots or transects of appropriate size and number to get an estimate of the population density in the area sampled

c. marking and recapture methods for mobile organisms where in data on the marking and recapture are utilized in estimation of the population size

d. removal sampling, in which the number of organisms are removed from an area in successive sampling is plotted on y-axis of a graph and the number previously removed on the x-axis and the population size is estimated.

e. plot less methods in estimating the sessile organisms such as trees, where in from a series of random points the distance to the nearest individual is measured in each of the four quadrants, the density per unit area is estimated from the mean distance. This method is referred to as the quarter method.

4.1.4 BASIC CONCEPTS OF RATES

. Populations always change in numbers, i.e. the population shows increase or decreases in size and are said to be dynamic. Populations often fluctuate in size considerably depending on the season. Populations increase in number when young individuals are born in the area or new individuals join the existing group, from other populations (immigration). Populations loose individuals when they die (death) or when they leave an area to join another population (emigration). Change in numbers of individuals in population can be diagrammatically represented as in fig1. It is important to know how a population is changing. Many important population characteristics are concerned with the rates of change. A rate of change is estimated by dividing the change in size(numbers) by the time period during which it took place. The growth rate of the population is the number of individuals added to the population over a time period. The average rate of population growth is calculated by the standard notation $\Delta N/\Delta t$ where N is the population size and t= time. The instantaneous rate of growth the notation is dN / dT A population growth curve is obtained by plotting the time on the horizontal axis, x-axis or abscissa and the number of individuals in population on the vertical axis, y-axis or ordinate Fig represents the growth curve of a population of insects. Certain types of processes affecting the population give characteristic type of population curves. In terms of growth curve the slope of the line at any point is the growth rate.

4.1.5.1 Natality:

Natality expresses the inherent ability of a population to increase. It is equivalent to the birth rate, it expresses the production of new individuals of any organism under ideal conditions under ideal conditions under ideal conditions . Any population shows a theoretical maximum natality whish represents the maximum production of new individuals and is constant for a given population. The realized or ecological natality or natality refers to population increase under the specific ambient environmental conditions. This varies with the size and composition of the population and the abiotic environmental conditions. It is generally expressed as a rate determined by dividing the number of new individuals produced by time or the addition of new individuals per unit of time per unit of population $\Delta N/\Delta t$, the absolute natality rate or as the number of new individuals per unit of time per unit of population $\Delta N / N\Delta t$, the specific mortality rate. Natality rate may be zero or positive but is never negative Natality can be expressed in many ways as follows.

ΔNn = production of new individuals in the population

$\Delta Nn / \Delta t = B$ or natality rate

$\Delta Nn / N\Delta t$ = b or natality rate per unit of population

N may represent the total population or only the adults (Reproductive part) in the population. The specific mortality rate, b, can be defined as the age-specific mortality rate for different age groups in the population. Natality rate may be zero or positive but is never negative. Maximum natality id the theoretical upper limit which the population or the reproductive portion of the population would be capable of producing under ideal conditions. Estimation of this rate is important as it provides basis for the comparison with the realised natality and is useful in setting up equations to determine or predict the rate of increase in a population

4.1.5.2 Mortality

Mortality refers to the death of individuals in the population. Mortality rate is also referred to as the death rate. It expresses the number of individuals dying in a population in a given period of time. Ecological or realized mortality— the loss of individuals under a given environmental condition as the mortality varies with population and environmental conditions. The theoretical minimum mortality a constant for a population, which represents the loss of individuals under ideal or nonlimiting conditions. The individuals die because of old age. The survival rate of population is of interest and is expressed as a fraction M, the survival rate is 1-M

Generally specific mortality. is expressed as a percentage of the initial population dying with in a given time. It is often more meaningful to express mortality in terms of the reciprocal survival rate. Mortality varies with age of the individuals in the population.

4.1.6 Survivorship curves

For a population the cohort life table data are often represented as survivorship curve. This graph shows the number of individuals that survive through each phase of life per thousand of population. This sort of survivorship curve is seen in figure.

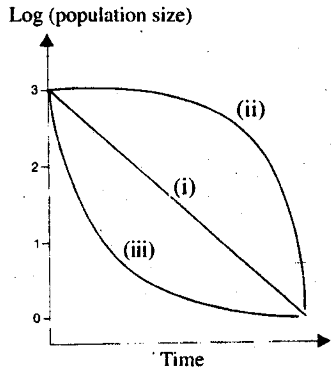

Fig. 4.2 The three general shapes of Survivor ship curves on a semi - plot to illustrate different patterns of population grouth (i) shows a steady mortality rate throughout life (ii) shows good surviral of young with high death rates in old age (iii) shows high mortality in the young with very little in adults

Another way of presenting survivorship curves is to use a log scale for the number of individuals these values are presented(y-axis) against time(x-axis). This type of semi- log plot in presented in fig. For any population where the proportion of individuals dying during each unit of time (per month or per year) is a constant, when the plot forms a straight line. This plot is quite useful in indicating the population dynamics of the organism. A straight line as in (i) shows that the mortality is constant whatever the age of organisms. A curve as in (ii) shows that the highest mortality rate occurs in older individuals and in curve as in (iii) the mortality rates are very high in young individuals and relatively low in older ones. Whenever there is a steep fall in the curve it indicates an increase in mortality, which indicates some environmental or developmental affect on the population. A survivorship curve can help to pin point critical periods in the life of the organisms.

4.1.7 Biotic potential and environmental resistance

The maximum possible rate of increase for a population of a species occurs under ideal conditions, in which the natality or birth rate is the highest possible for the species (potential natality) and death rate is the lowest (potential mortality). The values of maximum birth rate and lowest death rate are fixed by the life process inherent with in the organisms the maximum rate population rate increase, referred to as biotic potential, is an innate characteristic of each species and also differs widely from species to species

Under natural conditions the full biotic potential of an natural population is not released ordinarily since the conditions are rarely completely favorable. A moderate increase in the density may have an ameliorating affect, but the effects of over populations-scarcity of food supply, breeding sides, accumulation of metabolites-will appear. The combined affect of these factors tending to limit the population growth is called environmental resistance. The capacity to increase in size resides with in a species, but the degree to which it is realized is determined by the environment.

4.1.8 POPULATION GROWTH FORM

Populations exhibit characteristic patterns of increase, which are termed Population growth forms. Two basic patterns of population growth are commonly encountered. –the S-shaped or sigmoid growth form and the J-shaped growth form. In the S- sigmoid form the population increases slowly at first called the positive acceleration phase and then more rapidly-approaching a logarithmic phase. It soon slows down gradually as the environmental resistance increases percentage wise,-negative acceleration phase till a more or less equilibrium level is reached and maintained. This form may be represented by the simple logistic model

$$dN/dt = rN(K-N)/K$$

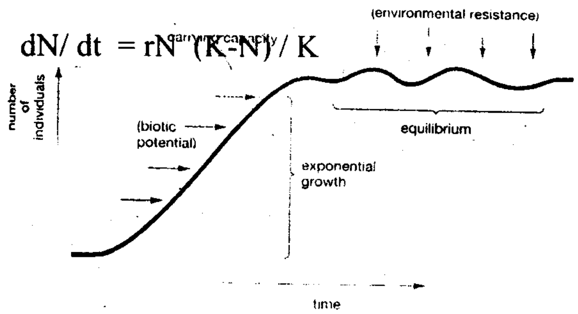

Fig. 4.3 The Population grows exponentially at first, then fluctuates around the carrying capacity. The growth is driven by biotic potential but levels off owing to environmental resistance.

Where K represents the upper asymptote of the sigmoid curve and is called the carrying capacity. In the J-shaped form density of the population increases rapidly in exponential fashion and stops abruptly as the environmental resistance becomes effective suddenly. This form is represented by the exponential equation

$$dN / dt = rN$$

In this form of growth of the population there may be no equilibrium level but the limit represents the upper limit imposed y the environment. The two growth forms are represented shown in figure

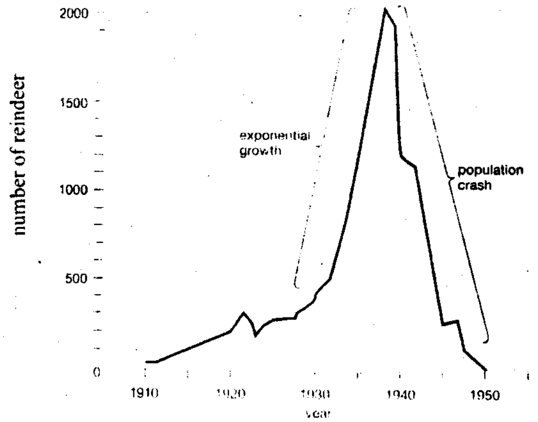

Fig. 4.4 Population growth showing J - shaped growth curve

Populations possess certain genetic characteristics related to their ecology namely adaptive ness, reproductive fitness and persistence. Populations show certain biological attributes, which it shares with its competent organisms and also show certain group attributes unique to them. The characteristics shared with the other members are its life history in that it grows, differentiates and maintains itself as soes the organism. The population has a definite organisation and structure.

A population is said to be stable when the number of individuals in the population neither increase nor decrease. The population is said to be in equilibrium. If the births and immigration of individuals are equal to the losses due to death and emigration then symbols representing increases and loses can be expressed by the following equation.

$$B + I = D + E$$

If the gains are greater than losses, the population size tends to increase and

$$B + I > D + E$$

if the losses are greater than the gains in number the population size will decrease

$$B + I < D + E$$

4.1.9 Age Structure in Populations:

One of the important ways of studying the populations is to determine the age structure of the population at a given point of time. Age distribution is an important population characteristic, which influences both natality and mortality. The ratio of various age groups in a population determines the current reproductive status of the population. A rapidly increasing population will contain large number of younger age groups while a stationary populations an even distribution of different age classes in the population and a declining population shows large number of older individuals. A population may undergo changes in age structure without changing in size of the population. Studies show that many populations establish a 'normal' or stable age structure characteristic of it and unusual natality or mortality rates result in temporary changes from it, which later returns to its characteristic age distribution over a time period. For a population Bodenheimer (1939) identifies three ecological age groups, the pre reproductive, reproductive and post reproductive. The relative distribution of these ages in proportion to the life span of the organisms varies greatly in different organisms. The stable age distribution of a population is an important attribute and it helps in analysis of the actual or realized age distributions The whole theory of populations is that it is a real biological unit with definite biological constants and defined limits to the variations that may affect them.

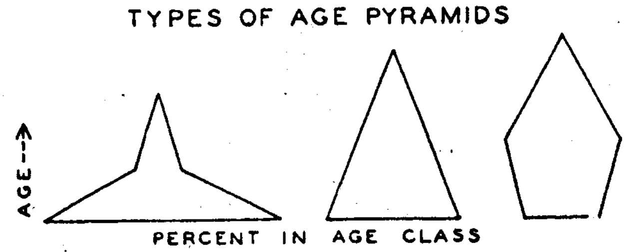

Fig. 4.5 Three types of age pyramids representing a large, moderate, and small percentage of young individuals in population

The data on the age distribution of a population is represented in the form of a polygon, commonly referred to as age pyramid, the number of individuals or the percentage in the different age classes being represented by the relative widths of successive horizontal bars. Among fish populations a phenomenon known as dominant year class has been noticed which have high potential natality rate. This represents a large year class due to an unusual survival of eggs and larval fish during a particular year of spawning.

4.1.10 The Study of Populations:

The Basic Equation:

The changes in the size of the population could be studied through different methods. This involves the collection of data on the numbers and ages of organisms. This study of population dynamics is referred to as demography.

The basic aim of demographic study is to quantify the changes in a population by estimating the number of births, deaths immigrants and emigrants. The changes in the population size over a given time period can be estimated by the addition of number of births and the immigration of individuals and subtracting the number of deaths and emigrated individuals to give the population size at time t+1 (Nt+1).

This is represented by the equation

$$Nt+1 = Nt + B + I - D - E$$

For estimating this the ages of the individuals in the populations and the total number of individuals (size) is to be determined.

In case of organisms, which are stationary and remain at a place like plants and sedentary animals, it is easier to estimate the number of individuals in a population. If the organisms are mobile like fish, insects, or mammals, it becomes difficult to determine the number. One of the commonly used methods to estimate the population of such organisms is called the Mark-Recapture method. In this method individuals are captured from the population, they are marked by use of tag or an identification mark and are released back into the population. These tagged/marked individuals mix with the other members of the population and move about. After sometime when a sample from the population is collected it contains both the unmarked and marked individuals. Using the equation can use these data to calculate the proportion of individuals in the whole population, which are originally marked, and the population size. by working with equation

$$R / C = M / N$$

$$N = CM / R$$

This method of estimating the population size 'N' calculated by using the method is called the 'Lincoln Index ' Estimation of the population by this method is carried out under certain assumptions regarding the marked and released individuals

1. The marked individuals, after release into the population, mix freely with the other members and have the same probability of the capture as any unmarked individuals.
2. the marked individuals in the population during the experiment do not loose the identification marks
3. the marked individuals do not undergo selective mortality being identified by the predator within the habitat or the tagging or marking method lower the survival chances if the markings / tags wear off or lost
4. Addition of new individuals to the population by migration or nearly born individuals will also affect the population estimation.

As long as these conditions are fulfilled the mark and recapture method for the estimation of the population size provides a method. Problems in estimation of the size will arise if both and the number of marked individuals decrease and the number of new additions through immigration into the population increase. This results in overestimation of the population size.

Another information needed to describe the population is the age of the individuals in the population. In some organisms the age of the individual could be determined with accuracy as they possess some character leaves a regular pattern in their structure representing fixed interval of time such as a year. The formation of growth rings in an year in temperate trees is a good example. In animals structures used to indicate the age include the growth rings on the scales of fish, bones and shells of mollusks and otoliths in mammals. In majority of organisms determination of age of the organisms employing this me principle and not be made.

4.1.11 Factors affecting the growth of population : Density independent and density dependant factors

Populations tend to be regulated by physical components of the environment such as weather, water currents, and chemical limiting factors, pollution and so on in low diversity ecosystems . In the high density ecosystems populations tend to be biologically controlled. In all ecosystems there is a strong tendency for all populations to evolve through natural selection process through self-regulation of the population numbers.

Any factor, whether limiting or favorable to a population is

1. Density -independent, if the effect is independent of the size of the population. Density-independent factors limit the population size regardless of the population density (number of individuals per given area)
2. Density- dependent if the effect on the population is a function of density. Climatic factors often act in a density-independent manner, where biotic factors such as Competition, parasitism and pathogens often act in density –dependent manner

4.1.11.1 Density-independent factors:

Weather is the most important natural density-independent factor. Many insects and annual plant populations are limited in size by the number of individuals that can be produced before the first hard freeze in winter. Such populations typically do not reach their carrying capacity, because the density-independent factors intervene first. Weather is responsible for the sudden increase and collapse of the population cycles. Severe storms sudden drops in temperature and other sudden changes in the physical factors generally provide the examples for density-independent action. Frank (1965) found that in the snail, *Acmaea* that lives in the intertidal zone following severe winter frosts, when portions of the rock surface crumble away removing the snails regardless of the numbers present. Space is also a factor that regulates the population size. The number of adult barnacles that can inhabit a rock is determined by the number of barnacle bases for which area of the rock affords room. The english sparrow, a practically domesticated word will breed regularly in large avarivs but not in small cages. Natural ecosystem in the temperate zone or the best noon from the ecological stand point and or intermediate in terms of important of physical and biotic regulators.

The density – independent aspects of the environments attend to bring about variations, some times severe, in population density and to cause shifting of upper asymptoeic are carrying capacity levels, while the density dependent natality and mortality tend maintained a population in a state of equilibrium.

Anthropogenic activities can also limit the growth of natural populations in ways that are independent of population density. Pesticides and pollutants released in to the environment can cause sudden decline in natural populations

4.1.11.2 Density dependent factors:

Populations possess certain genetic characteristics related to their ecology namely adaptivity, reproductive fitness and persistence. Populations show certain biological attributes, which it shares with its competent organisms and also show certain group attributes unique to them. The characteristics shared with the other members are its life history in that it grows differentiates and maintains itself as does the organism. The population has a definite organisation and structure.

Biotic factors such as competition, predation, parasites and pathogens often act in a density dependent manner. They are considered as one of the chief factors preventing over population and responsible for the achievement of a steady state. The density dependent natality and mortality tend to maintain population in a study state or to hasten the return to such level. Interspecific interactions are less likely to show linear density-dependance. Varley's (1947) studies on knapweed gall fly showed that the action major parasitic insect *Eurytoma curta* is density dependent, since it killed a much greater percentage of host population, when host population is high. Natality and mortality rates also vary with the density of the population. In the laboratory cultures of cladecera(water fleas) and in the wild populations of the great Tits (birds). It was observed that the production of eggs and young, per female decreased with increased density.

Predation

Predation is a feeding strategy, which results in controlling the prey population and acts in a density - dependant manner. Many predators will eat a variety of prey depending on what is most abundent in the environment and is the easiest to find. Some species exhibit species specific diet regimes. Coyotes might eat more mice when the mouse population is high but switch to eating more squirrels as the mouse population declines, incidentally the mouse population recovers.

Predators can also exert density dependent effects by increasing in number, as their prey population grows. Predators that feed heavily on lemmings, such as arctic fox and snowy owl, regulate the number of offspring they produce according to the abundance of lemmings. Snowy owl might produce up to 13 chicks, when lemmings are scarce but not reproduce at all in years when lemmings are abundant.

In some cases an increase in predators might cause a crash of the prey populations and a decline in predator population follows. This pattern results in out of phase population cycles of both prey and predator. Predators maintain the population well below the carrying capacity

Parasitism:

Parasitism is a type of association between individuals of different species, in which a smaller sized organism obtains nourshment from a large organism. Parasites live on or in their larger prey or host in certain instances the host animals die due to heavy infestation. Parasitism is also density dependent. Most parasites have limited mobility and spread more readily at high population densities. Parasitism is also density dependent factor that affects populations growth.

Competition:

The resources that determine the carrying capacity of the system are often limited , relative to the demand for them. Competition among the individuals which attempt to utilize the limiting resources limits population size in a density dependent manner. There are two major forms of competition among organisms a)interspecific(among the members of the different species) and b)intraspecific(among the individuals of same species). Since the needs of the members of the same species for water, nutrients, food, shelter, breeding sites, light and other resources are almost identical. Intraspecific competition is more intense than interspecific competition.

Organisms have evolved several ways to deal with intraspecific competition. Studies conducted by the Hudson Bay company between 1845 and 1935 showed that Lynx (predator) and show shoe hare (prey) show out-of-phase population cycle of predator and prey in nature. Laboratory studies on Braconid wasps(predator) and the Bean Weevil (prey) populations showed regular cycles, with the predator population rising and falling, slightly later than that of the prey populations. Many animals have evolved "context competition " which help to regulate the population size and reduce competition. Context competition consists of social or chemical interactions used to limit access to important resources. Territorial species such as wolves, many fish, song birds- defend an area that contains important resources, only the best adapted individuals are able to defend adequate territories.

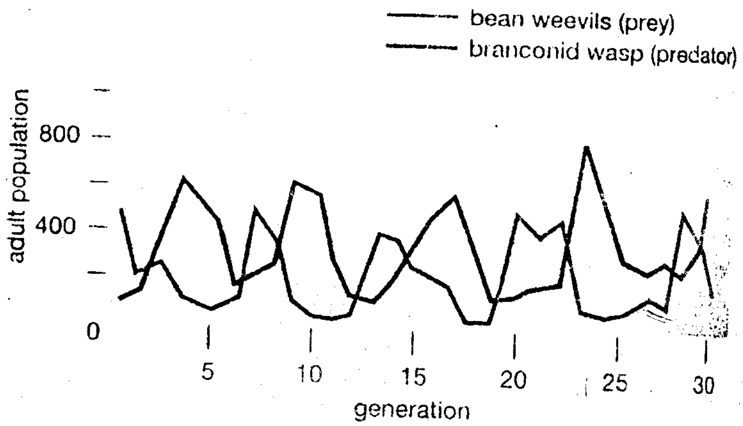

Fig. 4.6 Out-of-phase fluctuations in predatory - prey pupulations of the bean vevil and its braconid wasp predator

As population densities increase and competition becomes more intense, some animals react by migrating to colonize new areas. Mass movement of Lemmings and migrating swarms of locusts are examples of this type of movement.

4.1.12 Evolutionary strategies: r and K strategies

Living organisms show different types of strategies to maintain the population size. In contain species these is relatively low mortality of younger age groups, while the older age groups show higher mortality. In some other species, the young individuals have a higher mortality rate than the older individuals. Mac Arthur and Wilson (1967) classified these evolutionary strategies. They applied the terms r-selected and k-selected to populations for those which exhibit different strategies. The initials r and k are taken from the logistic equation describing the actual growth of a population.

$$R = dN/dt = rn (1-n/k)$$

Where r = the maximum rate of increase of the population

K= the number of organisms able to live in the population, when it is in equilibrium, that is the carrying capacity of the population.

N= the number of organisms in the population at time t.

An r-selected population is one in which the maximum rate of increase R is important, An r-selected population can take advantage of a favorable situation by having the ability to increase the population size rapidly. Many offspring under normal circumstances die before they reach maturity.

Similarly a k-selected populations with a steady carrying capacity (k). have less ability to take advantage of particular opportunities to expand. They are in general more stable and less likely to suffer high mortality rates of immature individuals. Usually k-selected organisms have few well cared for young individuals.

In ecological systems, it is probable that populations are constantly undergoing r- or k- selection. Some of the populations enter new conditions suitable to a more r - oriented strategy; then a new balance will be set up.

4.1.13 Population energy flow

In a Population, energy flow (the rate of assimilation) provides the most important factor evaluating the observed fluctuations in density and in determining the role of a population within the community. The energy defined as the ability to do work is of paramount importance in the ecosystem studies. Variety of manifestations of life, are all accompanied by energy charges, even though no energy is created or destroyed. The energy that enters the earth's surface as light is balanced by the energy that leaves the earth's surface as invisible heat radiation. Energy is transferred from one form to the other during changes such as growth, reproduction and synthesis of complex relationships of matter. All ecological systems show energy transfers, which accompany these changes. In ecological studies the chief concern is about the manner in which light is related to ecosystems and the manner in which energy transformed within the system. The radiation that is associated with and leaves the sun and passes in to the space. Some of this radiation falls on the earth passes through the biosphere. When light is absorbed, light energy is transformed in to another form of energy called the heat energy, this energy in the ecosystem transforms in to other types such as kinetic and potential energy, During photo synthesis green plants synthesise carbohydrates which contains potential energy, that changes to other types as these are utilised as food by other organisms. It is possible to calculate the transformation of energy from one form to the other since the quantity of light energy absorbed and the conversion factor can be estimated to determine the amount of heat energy. In the ecosystem the ratio of the total community respiration to the total community biomass (R/B) can be considered as the thermodynamic order function. This is also called the " Schrodinger ratio" and represents the ecological turnovers. In the ecosystem, Turnover is defined as the ratio of throughput to content. It can be conveniently expressed as a rate fraction or as "turnover time' which is the reciprocal of the ratio fraction. The productive energy flow is considered as the throughput and the standing crop expressed as biomass (g dry Wt/m2) as the content. This can be better understood by the following example. It we assume that a pond and shadow show a gross photosynthetic ratio of 5 grams per m2 per day, then the turnover rate for the pond would be 5/5 or 1 and the turnover the would be 1 day. While in a shadow the turnover rate would be 5/500 or 0.61 and the turnover time would be 100 days. Thus in the pond, the tiny plants replace themselves in a day when the pond metabolism is at its peak, while land plants are much longer lived and the 'turnover' much more slow. The larger the biomass, the greater would be the maintenance cost .

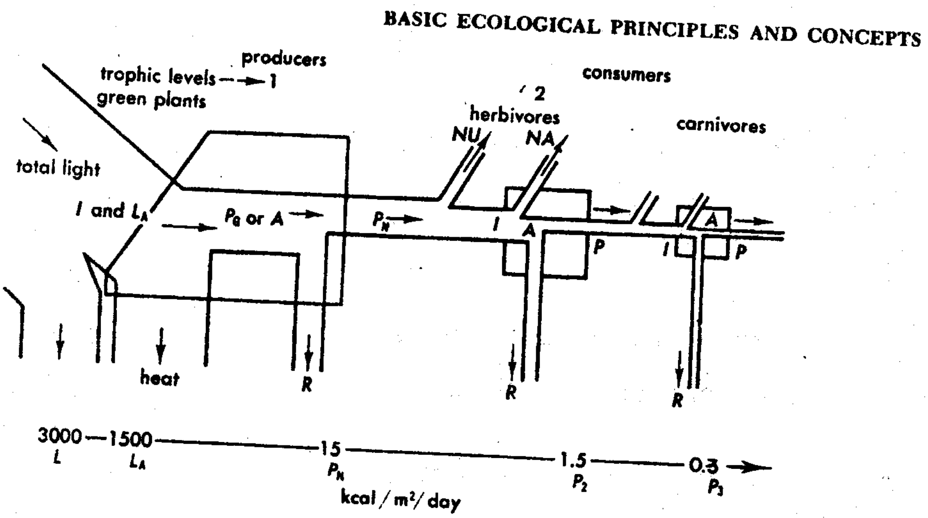

Fig. 4.7 A simplified energy flow diagram showing three trophic levels in a food chain : I Total energy input P_G- gross primary production A- total assimilation P_N - Net primary production, P - secoundary (consumer) production

The primary productivity of an ecosystem or a community or any part of it, is defined as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of produce organisms, in the form of organic substances which can be used as food . The transfer of food energy from the source in plants through a series of organisms, which eat, or being eaten is referred to as the food chain. At each transfer 80 to90 percent of the potential energy is lost as heat. The shorter the food chain the greater the available energy. Food chains are of two basic types the grazing food chain, which starts from a green plant base, goes to grazing herbivores- organisms eating living plant material and on to carnivores i.e. the animal eats and the detritus food chain which goes from dead organic matter in to microorganisms and then to detritus feeding organisms (detritivores) and their predators. Food chains are interconnected with one another. The interlocking pattern is referred as the food web. The organisms whose food is obtained from plants (producers) by the same number of steps are said belong to the same trophic level. The green plants occupy the first trophic level, plant-eaters the second trophic level (the primary consumer level) carnivores which eat the herbivores, the third trophic level(the secondary consumer level) and secondary carnivores the fourth trophic level(the tertiary consumer level). The trophic classification refers to the function only; a given species population may occupy one or more than one trophic level according to the source of energy actually assimilated.

The energy flow through a trophic level equals the total assimilation(A) at the level, which equals production (P) of biomass plus respiration R The principle of food chains can be represented in the form of flowcharts.

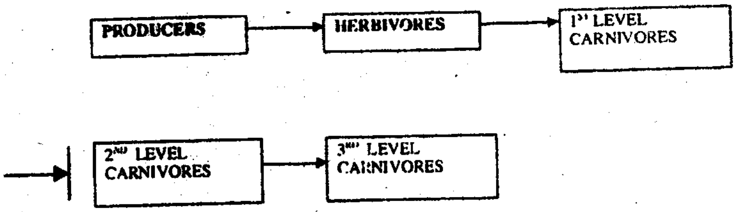

Fig. 4.8 A generalized food chain showing passage of food energy from producers to 3rd level carnivares.

4.1.14 SUMMARY

* The growth and development of a population is the result of to opposing forces, the capacity for reproduction or is also called bioticpotential and the capacity for the death/mortality or environmental resistance.

* Growth curves of populations demonstrate an S - (sigmoidal) shape or a J shape, the former type being predominant, both can be mathametically described in form of a logistic equation.

* The rapid phase of growth in both S - and J - shaped population curves in a logarithmic phase; the equilibrium phasc of a S - shaped curve reflectes the carrying capacity of the environment, a variable that results in oscillations and fluctuations of varying degrees.

* Under optimal conditions, biotic potential of a populations is its inntrinsic rate of natural increase :

* Surivorship curves constructed from the propbabilities of death rates and life expectancies are of three major forms - convex, concave and straight line.

* Age structure of a population is generally stable being variable within certain limits, in most populations.

* The population growth is affected by both abiotic and biotic factors of the ecosystem. These factors effect the population grwoth in a density independent and density dependent manner.

*In autotrophic ecosystems the energy accumulated through net primary production is used to support higher trophic levels, moves unidirectionally through those levels and decreases in amount at each level. in detritus based ecosystems energy also moves unidirectionally, with losses at each trophic level. The detritus chain is of greater importance in energy flow in may ecosystems than is that of the producer / consumer chain. In general, the transfer of energy from one trophic level to the next is in the order of 10 percent. Generally food chains show 3 to 5 trophic links with 15 to 20 species; with in food webs the number of links involved ranges from 20-30.

4.1.15 KEY TERMINOLOGY

Assimilation efficiency: Percentage of energy ingested that is actually absorbed across the wall of the gut

Autecology: Study of the ecological relationships of an individual organism.

Biome : A major regional community extending over a large area

Community: Collection of organisms of different species which occur together in some common environment or habitat in which they are integrated in someway with one another.

Ecology: A scientific study of the interactions that determine the occurrence, distribution, abundance and characteristics of the organisms.

Ecosystem : Community of organisms and its physical, chemical and its biological environment.

Growth Efficiency: Percentage of energy assimilated that is devoted realised has growth rather than used in respiration.

Habitat A place where an organism lives naturally

Niche: It is the functional role of the organism in the habitat. It is defind spatially, functionally and behaviorally and is inclusive of all the environmental factors of the species.

Population: group of organisms of the same species living together with is a common area at the same time:

Synecology : Study of the ecological relationships of organisms in a community

Trophic level: It is the position at which an organisms feeds in a community.

4.1.16 SELF ASSESSMENT TEST

1.Explain the term population. Write an account of the factors that influence the population growth

2. Explain the population growth form

3.What is energy flow in the ecosystem. Explain the energy flow in an aquatic ecosystem.

4.Short Answer question

a. Sigmoid growth
b. J shaped growth curve
c. Predation as a population controlling factor
d. k- oriented strategics
e. Biotic potential
f. Food web

4.1.17 Additional Reading

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LESSON 5.1

WILD LIFE MANAGEMENT

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5.1.1 Introduction

The expression wild life is a broad term covering any or all non cultivated and non-domesticated life forms. Earlier, only wild animals moving freely in Nature were considered to represent wild life (Brokow, 1978) but presently the word wild life encompases fish, amphibians eptiles and birds which live freely in Nature. It is being used largely in recent times to game and fur-bearing vertebrate animals and the plants which directly interact with the game species. It is realised that the preservation of out door recreation in general depends more on the preservation of the totality of the wild life ecosystem.

Wild life conservation and management is an area under applied ecology which is receiving greater attention in recent years, in view of the benefits to the society. It also provides opportunities for employment and training for wild life Conservation and Managementtechniques in developed countries.

Harvesting of wild plants and exploitation of wild animals influences the composition, structure and functions of these populations. Ecological diversity in the community and density may be affected due to selective harvesting of induviduals of a sex, age, size or of other phenotypes. Deer hemp, an often-targeted animal as a large dominant male, is an example of selective harvesting, affecting the population.

Earlier, Wild Life management was chiefly based on the ecology of the individual species of interest. Management approaches now, often recognize differences in the individual populations that are harvested (Coughley, 1994). Conservation and Management requires a precise ecological information about the Wild Life populations. Environmental variations cause changes in the size of the population and also promotes the coexistence of genotypes or species in the communities. Recent studies have identified certain ecological conditions that relate environmental variations to the long-term population dynamics, of the Wild animals in nature.

In addition to the environmental changes, harvested populations can increase or decrease in abundance, in relation to other species in the community. As such there is need to develop multi-species models in wildlife management, which include the species harvested and its resource base. They should consider all-important associations related to sustainable harvesting of the species of intent. They also should consider the weather conditions, which may affect the resource base of the target species. Risk factor assessment for estimation in the context of changing environmental conditions should also be made (Lande *et al.* 1994). In cases, where the population estimates are uncertain, the optional long-term strategy is to harvest the stock at less than maximum sustainable yield (MSY).

5.1.2 Wild Life values

In Nature Wild life has certain values, some of which are negative that affect other animals in the community while others are positive values, which enhance its importance. When Coyote, Jackal, Wolf, Hyaena begins to hover around the flocks or herds of a sheepherder or a cowboy the value of that particular kind of wild life seems totally negative to the human involved, but when a school of fish entangles itself in the nets spread out by a fishing boat, its value is positive. A mocking bird in the back garden, a giraffe moving across the plains, a dolphin playing in the surf can have values to the observer that cannot fit any body's economic yard stick

Commercial value

The commercial value of wild is life best seen in the worlds marine fisheries yielding about 110 million tons of food a good percentage of worlds animal protein and at a affordable price to many. Its cash value is in billions of dollars. It creates livelihood opportunities to those who process, prepare, transport and sell fish products. It is a value provided entirely by the wild stocks.

Other than fish, the commercial value of many forms of marine life such as aquatic mammals, sea turtles, Shell fish, large variety of invertebrates all have a cash value attached to them. They have provided oppurtunities for biologists, managers conservationists who seek to preserve these wild species. Freshwater fish another aquatic life have a direct commercial value in many countries globally. The commercial value of the wild animal life on land is well recognised. They are the principal base. Wild animal life makes a considerable contribution to the monetary value of wild foods. Fur of animals, Ivory of elephants, horns of rhinoceros, glands of musk deer, Antlers of deer, command high prices in the market.

Wild life has its negative economic values that often become much too clear to the farmers or rearers. Elephants in African gardens, deer in the almond orchards, wild predators in the pasture lands can cause serious economic loss.

Balancing losses and gains controlling negative effects while enhancing positive values are a part of the the Wild Life Management.

Game Value

Among European people Wild life has game value, a recreational value to those who hunt or fish for sport. The principal local industry in many parts of these countries is tourism, which fetch millions of dollars.

Aesthetic Value

Wild life enjoys value for its beauty and appeal to human spirit. Bird watching is one such activity. Ornithological Societies all over the world are a major force for wild life conservation.

Ethical value

To some the main reason for protecting the nature is that we have an obligation to do so and no right destroy wild species.

Scientific Value

The pursuit of science has led many people to a knowledge and understanding of many of the earth's species and how they interact to keep the planet habitable. Sea Urchins have helped an understanding of the human embryology, rhesus monkeys have contributed to wards an understanding of human blood groups, the antlers of deer have provided a means for measuring the degree of radioactive contamination of Natural environments.

Ecological value

Wild life shows definitive ecological values. The interactions between populations of the species and among other species in the community establishes needs an ecological approach. Management of wild life has a basis in the ecological role they play in the ecosystem.

Wild life conservation is an important activity. Wild life is a natural resource which is vulnerable and useful to humanity and its economic value is measured partially. Wild life constitute a renewable resource, which renews itself through reproduction.

5.1.3 Causes of Depletion

Wild life populations show changes in their distributional range and also in their numbers, over a period of time in nature. In certain regions they decline in numbers under different conditions of the environment which they encounter. The important causes for the depletion in numbers are as follows

1) Destruction of the tropical rain forests and tropical humid forests in general, in which most species of land animals are now live. This is a world wide threat that could seriously endanger many land species.

2) The growing spread of desert into the drier lands of the world and into regions that were not so dry. This is bringing the elimination of a broad category of animal and plant species.

3) The wide spread use of chemicals substances for the control of animals and plants considered to be pests. Accidental or deliberate release of numerous chemical substances, organic and inorganic compounds, radioactive substances and gases in to the biosphere. These substances may have adverse environmental effects globally including destruction of the ozone screen of the atmosphere, that now protects the life on earth from severe ultraviolet radiation and climatic changes that are mostly unfavorable to the existing forms of life.

5.1.4 IUCN classification of rare animals

Species conservation should begin when a species is known to be declining in numbers but is not threatened with extinction. The World Conservation Union, formerly known as the International Union for Conservation of Nature and Natural Resources (IUCN), keeps record and publishes detailed list of species at risk of becoming extinct. They recognize four categories:

1) Rare species that have small population, usually within restricted geographical limits or localized habitats or widely scattered individuals, that are at risk of becoming extinct.

2) Vulnerable species are those which are rare or under threat or actually decreasing in number or species which have been seriously depleted in the past and have not yet recovered.

3) Endangered species have very low population sizes and are in considerable danger of becoming extinct.

4) Extinct species are believed no longer to exist, and cannot be found in areas they ones inhabited nor in other likely habitats.

The IUCN and the conservation organizations produce Red Data Books on species at risk. in number of groups, including vascular plants, swallow tail butterflies, cetaceans, African primates and New world birds (Colston *et. al.*). The Red Data Book for some of the groups, lists all known species in these four categories. Nature reserves are created as refuges for threatened species or as a means of preserving one or more ecosystems. Nature reserves are intended to preserve the biodiversity of an area, though they may also be used for recreation and tourism.

Threatened species

Threatened species are those that are rare, often genetically impoverished, of low fecundity and with extremely variable population density or otherwise prone to extinction in human – dominated landscape (WCMW, 1992). As the number of threatened species increases worldwide, the identification and monitoring of these species is critical for conservation.

The IUCN Red list represent species that are recognized globally as threatened species with extinction. The threatened species category used in red list provides the most widely used system for describing the threatened status of a species. The current categories have been in place now for nearly 30 years and highlight the species under higher extinction risk. These categories are being used to set priorities for conservation. These categories have undergone a review of the categories delimitation, during the past six years (Mac and Stuart, 1994).

The new IUCN Red list categories (IUCN, 1994) require specific approach for assigning the threatened status of the species. Under the threatened status there are three categories.

1. Critically endangered 2. Endangered 3. Vulnerable

For listing under these categories, there is a range of quantitate cryteria. meeting any one of these cryteria qualifies a tax on for listing at the level of threat. the defferent cryteria mentioned are drived from a wide review aimed at detecting risk factors across the broad range of organisms.

1. Critically endangered (CR) : A taxon is said to be Critically Endangered when is facing an extremely high risk of extinction in the wild in the immediate future, according to the following criteria:

a. population reduction with in the 80 percent over the last 10 years or three generations which-ever is the longer.
b. extent of occurrence estimated to be less than 100km^2 or area of occupancy estimate to be less than 10 km^2
c. population enstimated to number less than 250 mature individuals or continuing decline of at least 25 percent within three years.
d. population estimated to number less than 50 mature individuals
e. quantitative analysis showing the probability of extinction in the wild is at least 50% with in 10 years or three generations which ever is longer.

2. Endangered (EN). A taxon is said to be endangered when it is facing very high risk of extinction in the wild in near future as defined by the following criteria :

a. If there is an estimated or observed reduction of atleast 50 percent in the populations size over the last 10 years or three generations which ever is longer
b. Extent of oocurrence estimated to be less than 5000 km^2 of area of occupancy estimated less than 500 km^2, severely fragmented or continuing decline and extreme fluctuations
c. Population estimated number less than 2500 mature individuals and either an estimated con-tinuing decline of atleast 20 numbers with in 5 years or 2 generations
d. Population estimated to number less than 250 mature individuals
e. Quanitative analysis showing the probability of extinction in the wild is at least 20 percent within 20 years or 5 generations whichever is the longer.

3. Vulnerable (VN) : A taxon is said to be vulnerable when it is not critically endangered or endan-gered facing a high risk of extinction in the wild in the mid-term future as defined by the following criteria.

a. population reduction observed, estimated or suspected is at least 20 percent over the last 10 years or three generations
b. extent of occurrence estimated to be less than 20,000 km^2 or the area of occupancy less than 200 km^2
c. population is estimated to number less than 10,000 mature individuals
d. population very small or restricted to form either of the following, population estimated to number less than 1000 mature individuals or population is characterized by an acute restric-tion in its area of occupancy.
e. quantitative analysis shows the probability of extinction in the wild is at least 10 percent in 100 years

These categories are defined on the quantitative criteria that can be applied to a taxonomic unit at or below the level of species (IUCN 1994). Meeting one of the criteria stated above qualifies a taxon after listing at that level of threat. These categories provide an assessment of the likelihood of extinction under current circumstances. Extinction is seen as a probabilistic or a chance process and this in higher risk categories implies higher expectation of extinction.

5.1.5 Exotics and their impact

These are newly appearing species in the natural or human - influenced ecosystems. They may be almost any type of organism which becomes, a new pathogen, a vector, a weed or an invasive animal. Monitoring the spread in respect of these invasive species is a critical component of biodiversity conservation.

Potentially all ecosystems can suffer the ravages of exotic invasives. Introduction of species into alien habitats are of three major categories:

1) Accidental introduction 2) Species imported for limited purposes which often escape in to Nature 3) Deliberate introduction

As stated by Levin 1989, many introductions relate to the human interest, in providing species that are especially helpful to people. This is an essential part of human welfare in virtually all parts of the world.

Despite some protective effects on biodiversity at the local level, overwhelming evidence indicates negative effects on species and genetic diversity at both local level and global level. Globally almost 20 per cent of the vertebrates thought to be in danger of extinction are threatened in some way by invasive species. As a result of introduction of Nile perch, *Lates niloticus* into lake Victoria at least 200 of the 3000 endangered species are probably lost (Lowe-McConnell, 1993).

Invasives have been found in almost all parts of the world. Invasive species are known to have wide-ranging effects on eco-systems, affecting both the ecosystem structure and function. They eliminate native species directly through animal predation or the browsing effects of herbivores as has happened, for example in fish (Balin *et al.* 1985), mollusks (Wells, 1995), many bird species (Beechie *et al.*, 1988).

Invasive species may also act in concert, to threaten native species in a variety of direct and indirect ways. For example, in Australia European settlement also brought with them rabbit (*Oryctolagus cuniculatus*) and fox (*Vulpes vulpes*). Rabbits soon reached very high numbers and led to further habitat destruction. Foxes increased in number and had a considerable impact on prey populations – native mammals, reptiles, frogs, scorpions and large insect species. Certain species have been shown to have range of indirect effects, which have an impact on several species and sometimes whole ecosystems. The probable extinction of snail ***Bulimulus darwini*** on the Galapagos islands, as a result of the destruction of this habitat through the effects of introduction of goats (Coppis, 1995) is another example. Another serious effect at the ecosystem structure level is the genetic effect on the species. Through hybridization, serious loss in genetic diversity with local species have been recorded in ducks, wild cats, donkeys, fish, birds, grasses (Hammer ***et al.***).

The consequences of invasion on ecosystem functions are generally less studied than on its structure. Invasion of exatics can alter the conditions of life for all organisms; alter soil erosion rates, biogeo-chemical cycles, hydrological cycles, nutrient cycles and their regimes (MacDonald *et al.*, 1989).

5.1.6 International commerce in wild life species (wild life trade)

The export volume of wildlife products is large. Estimates show (Edwards 1995), the international trade in wild species rivals that of the forest and fisheries resources globally.

The trade of wild fauna and flora is restricted under the Convention on International trade in Endangered Species of Wild flora and fauna (CITES) to which 122 countries in the world are parties. About 675 Species considered to be endangered are prohibited from trade globally are listed in Appendix-I of the CITES convention. Appendix-II of the convention includes 3,700 species of animals and 21,000 species of plants which are allowed in International trade under specific guidelines and subject to monitoring and reporting in an effort to minimize the impact of legal trade on species survival. Trade in the species listed in this Appendix-II is regulated through issue of export permits, when the harvest of the species has not been detrimental to the survival in the wild. Most of the reported exports come from a handful of countries in Asia (Indonesia, Philippines, Thailand), and Africa (Cameroon, Tanzania and Mali) (WRI, 1992).

Historically, the principal markets for the wild flora and fauna were in USA and European countries. The majority of the trade is now directed at several Asian countries (Japan, Singapore, Hong Kong, China, Taiwan), while the US and a few European countries (Germany, Belgium, France, Austria, Italy and UK) import most of the rest.

As commerce in wild species has become more regulated and controlled, captive management or cultivation of species has begun to replace supplies, traditionally harvested from the wild. Butterfly ranching in Papua, New Guinea is a successful example, where ranching has produced economic benefits and protected the Wild resource.

5.1.7 Conservation of the wild life

In situ conservation of the wild life indicates the development of a comprehensive system of protected areas. There are different categories of protected areas, which are managed, with the objective of conferring benefits to the society. These include:

a) National parks
b) Sanctuaries
c) Biosphere reserves

These areas vary in sizes of protected areas, purpose of design of management strategies. The national parks are created, oriented towards the conservation of particular species of wild animals like Tiger, Lion, Rhino etc., they range in size from 0.04 sq. km. to 3162 sq. km. As these are created through a legislation the boundaries of the national park are specified. Except in the buffer zone no biotic interference is permitted. In National Parks grazing is prohibited. Tourism is permissible. Sanctuaries are also created based on protection of a particular species e.g. great Indian Bustard. The area varies ranges from 0.61 to 7818 sq. km. and usually between 100 to 500 km^2 in area. Boundaries are not well demarcated and very limited biotic interference is permited. Biosphere reserves are ecosystem oriented and aims at conservation of all species present in the ecosystem. They extent in size over 5670 sq. km. The boundaries of the biosphere reserves are earmarked through legislation.

Except in buffer zone there is no biotic interference. Tourism is not permitted with the objective of conservation of wildlife. The biosphere reserves are formed under the Biosphere Reserve Network program launched by UNESCO in 1971 under its Man and Biosphere program. There are four major objectives:

1) Conservation 2) Research 3) Education 4) Local involvement

Man and Biosphere committee in India has identified in 1979 a network of 13 representative ecosystems to be protected as Biosphere reserves. Table 1 presents the list of Biosphere reserves in India along with the states in which they are located.

Table 1. Biosphere reserves in India

S.No.	Biosphere reserve	State/Union Teritory
1	Namdapha	Arunachal Pradesh
2.	Uttarakhand (Valley of flowers)	Uttar Pradesh
3.	Gulf of Mannar	Tamilnadu
4.	Sundarbans	West Bengal
5.	Thar Desert	Rajasthan
6.	Manas	Assam
7.	Little Rann of Kutch	Gujarat
8.	North Islands of Andamans	Andaman and Nicobar
9.	Nanda Devi	Uttar Pradesh
10.	Kaziranga	Assam
11.	Kanha	Madhya Pradesh
12.	Nokrek (Tura Range)	Meghalaya
13.	Nilgiris	Karnataka, Kerala, Tamilnadu

Biosphere reserves include natural, disturbed, modified and degraded ecosystems. For management purposes biosphere areas are divided into:

a) Core zone-natural and minimally disturbed ecosystems
b) Manipulation zone – Areas demarcated for forestry, tourism and agriculture
c) Restoration one – degraded areas selected for restoration to natural conditions

These areas are created with different purposes like protection of a habitat and protection of a particular species. In India, i. national parks, ii. sanctuaries iii. biosphere reserves iv. Nature reserves v. Natural monuments vi. cultural landscapes for *in situ* conservation of Biological Diversity, are created with the aim of protection and conservation of declining wildlife population.

For conservation of the declining populations of following wildlife animals special projects were initiated by the Government of India.

1) Project tiger
2) Gir Lion project
3) Crocodile breeding project
4) Rhino conservation
5) Snow-leopard project
6) Project elephant

As biodiversity conservation is a pragmatic science with the management component, it is important to note those species that highlight conservation efforts. There are two general categories:

a) Umbrella and flagship species b) Threatened species

a) Umbrella species are those whose occupying area (plants) or home range (animals) are large enough that, if they are provided with a sufficiently large area for their protection, will bring other species under protection. Many of the world's nature or game reserves created principally for large mammals or birds and have also become reserves for other species with small ranges particularly Invertebrates (Owen-Smith, 1983). Some habitat types may also acts as umbrella and these can be wider than those provided by large vertebrates. Flagship species are popular charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action. These include Pandas, Rhinos, large primates, Butterflies. Flagship species may serve as both indicator and or umbrella species and also provide a highly credible reminder of the progress of a particular conservation and management plan.

b) Theatened species : Threatened species are those wild organisms that are rare, often genetically impoverished, with exptremely variable population densities and are prone to extenction in human-dominated land scapes. These species need conservation mesures. Habitat destruction due to increased anthropogenic activities, environmental degradation, overxploitation of the natural resources are the chief reasons for these species to be categorised under threatened species.

5.1.8 National wildlife action plan

With the increase of depletion in the number wild life species and the continuous hreat to them, as early as 1887 an act, The Wild birds and Game Protection Act 1887, for the preservation of wild birds and game animals was proposed by the then government. Later, another act for protecting wild fauna, the Wild Birds and Animals Protection Act 1912 was passed. In certain regions of the country, special protection acts were made, such as wild Elephants Preservation Act 1879, Bengal Rhinoceros Preservation Act 1932 for protecting the vanishing species. The Wild Bird and Animal Protection Act 1912 was extended to the whole of India to include various animals and birds **e.g.** bustards, ducks, floricans, jungle fowls, partridges, pea fowls, Pheasant, pigeons, quails sand grouse, painted snipes, spur fowls, wood cocks, herons, egerts, rollers, king fishers, antelopes, asses, bison's, buffaloes, deers, gazelles, goats, hares, oxen, rhinoceros, and sheep when in their wild state. This Act empowered the state governments to declare the whole year or any part of the year as a closed period. Penalties were prescribed for killing, capturing, selling such scheduled animals or buying and selling of their flesh, fur, feather or droppings during the closed periods. The state governments accordingly issued licenses for capture or hunting. Some areas were declared as sanctuaries where shooting was prohibited in order to prevent the extinction of rare species.

The Government of India made another Act "Wild Birds and Animals Protection Act 1935, with improvements over the already existing earlier Act. It enabled the State Governments to declare a particular area as a sanctuary where killing of birds and animals living in that area was prohibited More birds and animals were added to the Appendix of 1912 Act.

The Indian Forest Act 1927 applicable to a majority of the states of the country, contained provisions for protecting wild life in reserved and protected forests. The Act also regulated the activities that cause disturbance to the habitat. Realizing the need for protecting the forests and the habitats of the wild life, the following directive principle in Article 48 of the Indian Constitution was included. It states, "The states shall endeavor to protect and improve the environment and to safe guard the forests and wild life of the country. In the 42nd Constitutional Amendment, Article 51A was included which makes a fundamental duty of the citizen of the country. It shall be the duty of every citizen of India, to protect and improve the natural environment including foresters, lakes, rivers and wild life and to have compassion for the living creatures. sThe forests and protection of wild birds and animals were transferred from the state list (List II of the constitution) to the concurrent list (List III of the Constitution), there by empowering the Government of India to legislate on these subjects and issue directives.

Indian Board for wildlife has been constituted in 1952, to promote conservation and propagate wildlife. Government of India constituted an expert committee in 1969 to examine the existing national parks and wildlife sanctuaries in the country and suggest suitable measures for development. It was suggested that a four percent of the total land area be reserved for wild life and national parks needs special legislation. The national parks created are to be preserved as a national heritage.

In 1970, when the report was submitted there are seven national parks and 130 sanctuaries over an area of 18,500 sq. km. representing 2.3 per cent of the forest area and only 0.535 per cent of the total land area. The committee recommended an area of 4 percent of the total land area. Today India has 80 national parks and 441 sanctuaries covering area of 1.48 lakh sq. km. Representing 23.2 per cent of the forest area and 4.533 per cent of the total land area.

Wild life (Protection) Act, 1972 was passed and enacted by the Parliament with the concurrence of 11 States and deals with all aspects relating to the protection of wild life hunting, formation of sanctuaries, National parks and closed areas. Regulation of trade in wild life and its products. According to this act the state governments were empowered to declare an area as a sanctuary or a national park. According to the sections 18 & 34 of the Act, the State Government may set up a sanctuary by notification an area if such an area is of adequate ecological, faunal, floral geomorphological, natural or zoological significance for the purpose of protecting, propagating and developing wild life and its environment. This Act has been amended in the later years, and recently in 1991 which included prohibiting trade or commerce in trophies, animal articles derived from scheduled animals. The Prime Minister headeds the Indian Board of Wildlife (IBPL) and a National Wildlife Action Plan has been formulated and is currently in operation.

Under section 35 of the wildlife (Protection) Act, 1972, the State Government by notification may declare an area as national parks by specifying its area corresponding its ecological, floral, geomorphological or zoological association or importance.

5.1.9 National parks in India

Wild life globally is being exploited on a large-scale during the first part of this century. The decline in the number of species that became extinct because of overexploitation of the resources and the habitat destruction of the wild life, created an awareness and realization regarding the necessity for the conservation of these natural resources not only for aesthetic and cultural value but for conserving soil and water for human survival. Settings up of national parks are a means to achieve these objectives globally. United Kingdom, France, Africa and United States of America have realized the importance of Nature Conservation and the developed national parks for the conservation of the wild life.

The concept of creating a National park in India is of recent origin. The first national park in the country - Hailey (now called as Corbett) national park was set up in 1936 in Uttar Pradesh. The principle and objective underlying the formation of the wildlife sanctuary and the national park are almost same, i.e. conservation and protection of the wildlife. The national park is constituted by a specific statute, while the wildlife sanctuary can be set up by the competent authority.

In the national parks and sanctuaries hunting of animals is prohibited. No damage to the habitat can with in this area. In the sanctuaries, the Chief wild life warden can regulate, control or prohibit the grazing or movement of cattle. In national parks no grazing is permitted and no cattle can be permitted to enter.

For durable protection to national park its surrounding should be specified as special area for eco-development (SEAD) where conservation-oriented development programs should be implemented, with the participation of local people.

In 1936, the first national park was set up in the foothills of Himalayas in Uttaranchal state called the Hailey National Park. It is now named after the wild life lover as Corbett National Park. In 1970, there were only five national parks in India. Now there are 80 national parks in the country spread over 34,829 sq. km. The statewise list is provided in Table 1.

Statewise List of National Parks in India

S.No.	Name of State	Name of the National Park	District	Area (Sq.km.)
1	Andhra Pradesh	Sri Venkateswara	Chittoor, Cuddapah	352.62
2	Arunachal Pradesh	Namdapha Mouling	Tirap. Siang	1985.23 483.00
3	Assam	Kaziranga Manas	Jorhat Kamrup-Golapara	430.00 500.00
4	Bihar	Betla Valmiki	Palamau West Champaran	231.67 335.65
5	Goa	Bhagwan Mahabir	Goa	107.00
6	Gujarat	Gir National park Velavadar Vansda Marine	Junagarh Bhavnagar Balsad Jamnagar	258.71 34.08 24.00 162.89
7	Haryana	Sultanpur	Gurgaon	1.47
8	Himachal Pradesh	Great Himalayan Pin Valley	Kullu Lahul-Spiti	765.00 675.00
9	Jammu & Kashmir	Dachigam Kishtwar Hemis High Altitude City Forest	Srinagar Kishtwar Leh Srinagar	141.00 310.00 3550.00 9.07
10	Karnataka	Bandipur Bannerghatta Nagarhole Kundremukh Anshi	Mysore Bangalore Mysore-Koorg South Kanada & Chikmangloor Uttar Kana	874.20 104.27 643.39 600.32 250.00
11	Kerala	Eravikulam Silent Valley Periyar	Idukki Palghat Idukki	97.00 89.52 350.00
12	Madhya Pradesh	Kanha Bandhavgarh Madhav Indravati Panna Satpura Sanjay Van Vihar	Mandla-Balaghat Shahdol Shivpuri Bastar Panna-Chatarpur Hoshangabad Sidhi-Sarguja Bhopal	940.00 105.40 337.00 1258.00 543.00 524.37 1938.00 4.45

		Fossil Kanger Valley Pench	Mandla Bastar Seoni	0.27 200.00 293.00
13	Mizoram	Murlen Blue Mountain	Aizawl Chhimtui-Pui	200.00 50.00
14	Manipur	Keibul Lamjao Sirohi	Imphal-Bishnupur East District	40.00 41.80
15	Meghalaya	Balphakram Nokrek	West Garo Hills West Garo Hills	339.22 47.48
16	Maharashtra	Todoba Panch Nawegaon Sanjay Gandhi Gugmal	Chandrapur Nagpur Bhandara Bombay-Thane Amaravati	116.55 257.26 133.88 86.96 361.80
17	Nagaland	Itangki	Kohima	202.02
18	Orissa	North Simlipal Bhittar Kanika	Mayurbhanj Cuttak	845.70 367.00
19	Rajasthan	Ranthambore Sariska Keoleo Ghana Desert	Sawai Madhopur Alwar Bharatpur Jaisalmer	392.00 273.80 28.73 3162.00
20	Sikkim	Khanchendzonga	North Sikkim	850.00
21	Tamilnadu	Guindy Marine Indira Gandhi Mudumalai Mukhurji	Chennai Gulf of Manner Coimbatore Nilgiris Nilgiris	2.82 6.23 117.11 103.24 78.46
22	Uttaranchal	Valley of Flowers Nanda Devi Corbett Rajaji Govind Pashu Vihar Gangotri	Chamoli Chamoli Garhwal-Nainital Dehradun-Hardwar Uttarkashi Uttarkashi	87.50 630.33 520.82 820.03 472.08 23.90
23	Uttar Pradesh	Dudhwa	Lakhimpur	488.29
24	West Bengal	Sundarbans Neora Valley Singhalila Buxa Gurumara	24-Pargannas Darjeeling Darjeeling Jalpaiguri Jalpaiguri	1330.10 88.00 78.00 117.10 79.45
25	Andaman & Nicobar Islands	Saddle Peak North Button Middle Button South Button Mount Harriet Marine	Andaman Andaman Andaman Andaman Andaman Andaman	32.54 0.44 0.64 0.03 0.46 281.50

5.1.10 Inventorying and monitoring for conservation

A number of existing international agreements are concerned with inventorying and monitoring eco-systems and species for their safe use and conservation.

1. The Ramsar conservation

The Ramsar Conservation (1971) is an international treaty that provides a framework for co-ordinated designation and conservation of the internationally important habitats. As of 1994, 81 state were contracting parties to the conservation and 654 Ramsar wetlands had been designated covering an area of over 43 million hectares (David, 1994). The conservation has generally been very successful.

2. CITES

The Conservation of an International Trade in Endangered Species of wild fauna and flora (CITES) (1973) provides an International legal frame work that aims to control, reduce or eliminate the International trade in threatened species, whose numbers and conditions suggest that further removal of individuals would be detrimental to species survival (Farve, 1989). It includes a list of species which might be effectively be regulated and for which trade must be effectively monitored. 113 countries of the world are now parties to the convention (WCMC 1992). CITES monitors the trends in trade, and routes of trade over the short and long term.

3. Species Survival Commission (SSC)

Established in 1949, IUCN's Species Survival Commission (SSC), which now has approximately 3500 numbers in 135 countries (WCMC, 1992) has been very successful. Its aim is to promote action to arrest the loss of the Worlds Biological Diversity and to restore threatened species to safety and provided an excellent forum through which amatures and professionals can make a direct contribution. The SSC is divides into 95 specialist groups which cover different taxonomic groups, geographical areas and subject areas. The taxon based specialized groups are responsible reviewing the status and requirements of their taxon and then producing action plans for their long-term conservation.

4. World Conservation Monitoring Center

The World Conservation Monitory Center (WCMC) was founded in 1998, jointly by the World Conservation Union (IUCN), the United Nations Environment Program (UNEP) and the World Wide Fund for Nature (WWF), having been previously IUCN conservation and sustainable development information on Global Conservation issues. WCMC's global database includes information on National Parks and Protected Areas, threatened plant and animal species and habitats of conservation concern.

5. Red data books and Red list

The IUCN's Red data books, produced by the SSC in collaboration with CMC provide information on the current status and conservation requirements of globally threatened species. The Red Data books give an assessment of its distribution, population status, habitat and ecology and potential conservation measures. The Red list for threatened animals is published by WCMC in collaboration with the IUCN-SSC on a two-year cycle.

6. The International species inventory system

These systems have been designed for monitoring the genetic resources of vertebrates in captivity and to facilitate the co-operation among different institutions in management plans for species. Standard books present an international register, listing all the captive individuals of a taxon, to help prevent inbreeding programs. Since 1984, the standard book system has been supplemented by the International Species Inventory System (ISIS), a global network designed to help the zoological collection and to enable zoos to meet the increasing conservation responsibilities.

5.1.11 Self Assesment Questions

1. Difine wild life? Explain the values of wild life.
2. Explain the wild life protection measures taken in India.
3. What is mant by conservation? Explain the international actions to monitor conservation activities.
4. Write an essay on National Parks in India.
5. Write short notes on
   a. Tiger project
   b. WWF
   c. Wild life protection Legislations in India
   d. Bioreserves

5.1.12 Reference Books

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Prof. S.V. Sharma M.Sc., Ph.D.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2011.

Paper IV — ANIMAL ECOLOGY AND WILD LIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

Each question carries equal marks.

1. (a) Describe the life supporting properties of water.

Or

(b) Describe the classification of ecosystems with examples.

2. (a) Give brief notes on food chains and food webs.

Or

(b) Describe the Shelford's Law of Tolerance.

3. (a) Write an essay on interspesific competition and coexistence.

Or

(b) Describe the concept of habitat, ecological niche and guild.

4. (a) Describe the properties of the population group.

Or

(b) Describe the r-and K-selection.

5. (a) Write an essay on IUCN classification on rare animals and write the causes of depletion.

Or

(b) Write an essay on National Wild life Action Plan.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, DECEMBER 2010.

Paper IV — ANIMAL ECOLOGY AND WILDLIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

All questions carry equal marks.

1. (a) Write an essay on nature and scope of ecology.

Or

(b) Write short notes on :

(i) Availability of light in natural waters

(ii) Ecosystem.

2. (a) What is productivity? Explain.

Or

(b) Write short notes on :

(i) Nitrogen cycle

(ii) Food chain.

3. (a) Write an essay on concepts of habitat.

Or

(b) Write short notes on :

(i) Mutualism

(ii) Ecological niche.

4. (a) Give a detailed account on population dynamics.

Or

(b) Write short notes on :

(i) Population growth form

(ii) Optimization.

5. (a) Explain the IUCZ classification of rare animals.

Or

(b) Write short notes on :

(i) National parks

(ii) World wildlife fund.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, JUNE 2010.

Paper IV — ANIMAL ECOLOGY AND WILD LIFE

Time : Three hours Maximum : 100 marks

Answer ALL questions

Each question carries 20 marks.

1. (a) Write an essay on concept of ecosystem with detailed classification.

Or

(b) Short notes on :

(i) Scope of Ecology.

(ii) Life Supporting properties of water.

2. (a) Write an essay on fundamental concepts of energy.

Or

(b) Write short on :

(i) Phosphorus and sulfur cycles

(ii) Concept of limiting factors.

3. (a) Write an essay on various types of Biotic interactions.

Or

(b) Write short on :

(i) Ecological niche and guild.

(ii) Concept of habitat.

4. (a) Write an essay on Population dynamics

Or

(b) Write short on :

(i) r – and k – selection.

(ii) Population growth form.

5. (a) Explain the characteristics and objectives of Biosphere reserves.

Or

(b) write short notes on :

(i) Wild life trade.

(ii) National parks and Sanctuaries.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2009.

Paper IV – ANIMAL ECOLOGY AND WILDLIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

Each question carries 20 marks.

1. (a) Write an essay on nature and scope of ecology and its relation to other sciences with suitable examples.

Or

(b) Short notes on:

(i) Feed-back loop

(ii) Thermal stratification.

2. (a) Write an essay on bio-geo chemical cycles.

Or

(b) Write short on:

(i) Ecological pyramids

(ii) Liebig's law of minimum.

3. (a) Explain various types of biotic interactions.

Or

(b) Write short on :

(i) Concept of habitat

(ii) Commenslism and co-operation.

4. (a) Explain the properties of population growth. Add note on population dynamics.

Or

(b) Write short on:

(i) Energy partitioning

(ii) Density dependent population control.

5. (a) Give an account of National parks and Sanctuaries.

Or

(b) Write short notes on:

(i) Management strategies.

(ii) Biosphere reserve.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, DECEMBER 2009.

Paper IV – ANIMAL ECOLOGY AND WILDLIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

1. (a) Give a detailed account on the factors affecting light availability in natural waters

Or

(b) Write short notes on

(i) Ecosystem

(ii) Thermal Stratification.

2. (a) What is energy? Explain the fundamental concepts of energy.

Or

(b) Write short notes on

(i) Food webs

(ii) Ecological pyramids.

3. (a) Write an essay on Interspecific competition.

Or

(b) Write short notes on

(i) Predation

(ii) Cooperation.

4. (a) Describe Density-independent action in population control.

Or

(b) Write short notes on

(i) r - and k- selection

(ii) population group.

5. (a) Give an account on Rare and Threatened species.

Or

(b) Write short notes on

(i) Values of wildlife

(ii) National sanctuaries.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, DECEMBER 2008.

Paper IV — ANIMAL ECOLOGY AND WILDLIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

1. (a) Give an account on Life supporting properties of water.

Or

(b) Write short notes on :

(i) Feed-back loop.

(ii) Concept of Ecosystem.

2. (a) Explain the fundamental concepts related to energy.

Or

(b) Write short notes on :

(i) Liebig's law of the minimum.

(ii) Carbon cycle.

3. (a) Describe the predation and herbivory in animals.

Or

(b) Write short notes on :

(i) Positive interactions.

(ii) Mutualism.

4. (a) Give an account on Density - Independent and density-dependent action in population control.

Or

(b) Write short notes on :

(i) Population dynamics.

(ii) Energy partitioning.

5. (a) Describe the positive and negative values of wildlife.

Or

(b) Write short notes on :

(i) Biosphere reserves.

(ii) National Wildlife Action Plan.

M.Sc. (PREVIOUS), ZOOLOGY, EXAMINATION, MAY 2008.

Paper IV — ANIMAL ECOLOGY AND WILDLIFE

Time : Three hours **Maximum : 100 marks**

Answer ALL questions.

1. (a) Describe the classification of ecosystems with suitable examples.

Or

(b) Write short notes on :

(i) Nature and scope of Ecology.

(ii) Factors affecting light availability.

2. (a) Explain Biogeochemical cycles and describe nitrogen cycle.

Or

(b) Write short notes on :

(i) Concept of productivity.

(ii) Shelford's law of Tolerance.

3. (a) Write the properties of a population group.

Or

(b) Write short notes on :

(i) r- and k-selection

(ii) Population growth form.

4. (a) Describe the parasitism and allelopathy.

Or

(b) Write short notes on :

(i) Biotic interactions.

(ii) Ecological niche and guild.

5. (a) Describe the different National Parks and Sanctuaries in India.

Or

(b) Write short notes on :

(i) World Wildlife Fund.

(ii) Rare and Threatened species.

(కత్తిరించి పంపవలెను)

అధ్యాపకుల, విద్యార్థుల సలహాలు, సూచనలు :

అధ్యాపకులు, విద్యార్థులు ఈ స్టడీ మెటీరియల్‌కు సంబంధించిన సలహాలు, సూచనలు, ముద్రణ దోషాలు తెలియపరచినచో, పునర్ముద్రణలో తగు చర్యలు తీసుకొనగలము. తెలియపరచవలసిన చిరునామా : డిప్యూటీ డైరెక్టర్, దూరవిద్యా కేంద్రం, ఆచార్య నాగార్జున విశ్వవిద్యాలయం, నాగార్జున నగర్ – 522 510.

Course	Year	Paper No. & Title
M.Sc.	Ist Year	Paper - IV : Animal Ecology and Wildlife

(కత్తిరించి పంపవలెను)