The Structure & Dynamics of Ecosystem

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Now a days we hear about ecological imblances. The plants, animals and human beings of a particular area depend on one another for their existence. These along with environmental conditions constitute, what is called, ecosystem. They have interrelationship with one another and there are time dependent changes.

An ecosystem may be defined as the dynamic system of nature present in a given area. Such a system includes all the living organisms, plants as well as animals, alongwith their environmental conditions. All the living and non-living parts of the ecosystem are intricately interrelated according to some basic pattern of relationships and show time-dependent changes according to well defined rules. The study of various components and their interrelationship is termed as the structure of ecosystem and the study of time-dependent changes in the components with the rules governing such changes is termed as the dynamics of the ecosystem.

Components of Ecosystem

Basically all the living and non-living organisms and parts of the ecosystem may be grouped into an *abiotic* and a *biotic* component of ecosystem.

The abiotic component constitutes the physical environment of living organisms and includes all the matter and energy in the ecosystem. The matter includes all the inorganic elements and compounds used as micro-and macronutrients, *e g.*, sodium, potassium, calcium, carbonates, phosphates, etc, and all the organic compounds which are the product of organismic activity or death and decay. The energy available to an ecosystem is mainly the solar radiation. All the physical factors and gradients, *e.g.*, moisture, temperature, wind, currents etc., are also included in the abiotic component. Thus, it is the non-living setting in which living organisms interact in an energy dependent manner.

The biotic component of the ecosystem includes all the plants and animals which may basically be catagorised into *producers* and *consumers*. The producers are all the organisms that can take up matter from the abiotic component, absorb solar radiation and convert the radiant energy into chemical energy which is then stored as bond energy in the complex organic molecules manufactured in photosynthesis. All the green, autotrophic plants and animals (*e.g.*, mastigophores) are the producer part of the ecosystem, producing organic food required for the activities of living organisms. Consumers are all those plants and animals which can not photosynthesize food for themselves and depend upon producers for it. These consumers are further subdivided into different types according to the level at which they get their food. The consumer animals using plant or animal producers directly as food are called *herbivores* or *primary consumers*. Those animals or plants (*e.g.*, insectivorous plants) which use herbivores as food are *primary carnivores* or *secondary consumers*. Animals using primary carnivores as food are *secondary carnivores* or *tertiary consumers*. The carnivores for which no further predator exists are called *top carnivores* or *top consumers*. All these herbivores and carnivores together are grouped into *macroconsumers* in the ecosystem and the *ecto*-and *endo*-parasites, both on producers and macroconsumers, are grouped into *microconsumers*. Lastly, all the saprophytes and bacteria which obtain their food from decaying and decomposing organic matter are termed as *decomposers* in the ecosystem. In addition to these basic catagories, the herbivores in the ecosystem are identified as *grazing herbivores* which feed upon living producers by grazing on them and *detritus herbivores*, which feed upon dead producers (*e.g.*, snails, earthworms and millipedes). These two types of herbivores start two separate predatory chains in the ecosystem.

Thus the biotic component is catagorised into several groups according to the manner in which organisms are obtaining their food in the ecosystem

Interrelationships Between Components of Ecosystem

The relationship of abiotic and biotic components is obvious as all the matter and energy required for living organisms is derived from abiotic component In the biotic component the basic relationship among organisms is that of food. This has lead to the concept of treating each category of biotic component as a perticular level at which food is obtained, in the ecosystem, in a particular way, *i.e.*, as a trophic level in ecosystem. Detailed study of such trophic relationships in the ecosystem is done by unraveling food chains and food webs while general study of numerical, biomass and energy relationships among trophic levels is done by constructing ecological pyramids.

Food chains and food webs

In an ecosystem every population is feeding on some other population and the linear sequence of populations showing their prey-predator relationships is called a **food chain.** *For example, Cynodengrass, Rabbit, Lion* is a very simple food chain. Such food chains may be longer than this but generally do not go beyond 4 or 5 steps. Each chain in the real ecosystem is found to be highly branched because a population feeds upon many other populations instead of only one and in turn is eaten by, not only one but many other populations. Such branched food chains are interlinked resulting in very complex networks of trophic relations amongst populations of the ecosystem, which are called **food webs** of the ecosystem.

Though it is very essential to ennumerate complete food web of an ecosystem for the study of its detailed structure, diagrammatic representation of even a small portion of the complete food web grows so complicated that it becomes very difficult to identify individual food links and yet retain in mind the system as a whole. Therefore, disregarding individual links has benefit of simplicity and basic features of ecosystem structure are better represented by various types of pyramids.

Ecological pyramids

These are diagrams of some basic relation among trophic levels in which the magnitude of the relation is represented by a horizontal bar for each trophic level. Such horizontal bars are piled on top of each other starting from producers at the base and top carnivores at the top. The relations generally studied in this way are those of numbers, biomass and energy utilisation.

If total number of organisms in producer level is represented by a horizontal bar at the base and similar bars are placed over it representing herbivore, primary carnivore and top carnivore levels respectively. the resulting diagram is termed as *pyramid of numbers.* (*c.f.* **Fig.—1**). This enables us to state the numerical relationship between trophic levels, *e.g.*, the number of producer organisms supporting a particular number of herbivores and so on. The difficulty with this approach is that such pyramids in forest or parasitic ecosystems show greater number of consumers being supported by lesser number of producers which seems implausible. In fact comparisons between ecosystems cannot be made without some consideration of the size of organisms in two systems. It is ridiculous to assume one diatom equal to one tree on the basis of number only.

For comparable data of two ecosystems, total biomass of organisms in a trophic level present at a time (*standing crop*) is better than numbers. From data of standing crops of trophic levels, *pyramids of biomass* or standing crop can be constructed (*c.f.* **Fig.—1**). But

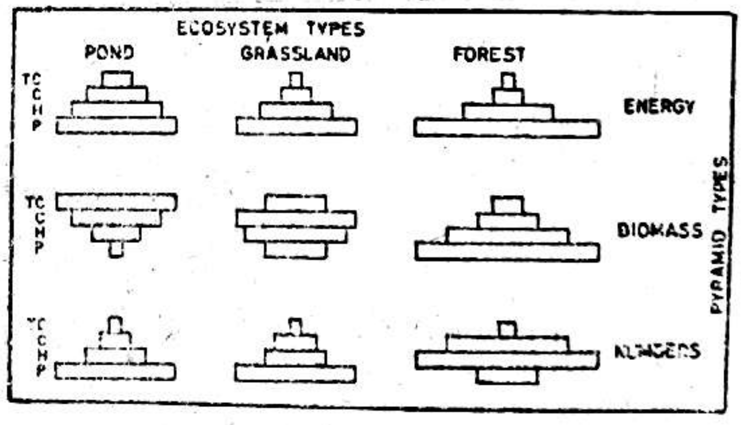


Fig.—1.

Different types of ecological pyramids in different types of ecosystems.

(TC=*Top Carnivores;* C=*Carnivores;* H=*Herbivores* ; P=*Producers*).

even these pyramids for aquatic or grassland ecosystems are found to be inverted in dicating lesser biomass supporting greater biomass in its next higher trophic level which again seems illogical. Actually, standing crop is a measure of total material present at an instant and it does not take into account the fact that different producers produce material at different rates. Larger trees produce material at a very slow rate while algal plankton produces it at a very high rate. The total amount of material produced by both in a longer span of time, say an year, may be comparable but that is also not certain. Thus rate of biomass production (productivity), rather than standing crop, is a more basic feature of ecosystems.

The objections in use of the pyramids of numbers or biomass can be overcome by constructing *pyramid of energy* (*c.f.* **Fig —1**). Such a pyramid shows the amount of energy passed on by a trophic level to its next higher level in the form of food. The amount of material used as food from a trophic level can be converted into equivalant calories of energy for construction such pyramids. Pyramid of energy is always erect for any type of ecosystem as it is thermodynamically impossible that a level can pass on more energy to its next higher level than the amount of energy it received from its preceding lower level.

Thus the concept of using energy units provides a uniform concept in which the differences due to numbers, size and rate of product tion are all taken into account in a trophic level This also permits comparison of the productivity in different ecosytems, howsoever varied their composition may be.

Dynamics of Ecosystem

In the ecosystem the energy and matter in a trophic level are always in a state of flux thereby making ecosystem a dynamic unit. The study of time-dependent changes in the amount of energy and matter in different trophic levels of an ecosystem. *i.e.*, dynamics of the ecosystem started with the classical paper of **Lindemand** (*1942*). Two major types of changes are recognised in the ecosystem, one due to flow of energy and other due to flow of matter between trophic levels.

Energy flow in ecosystem

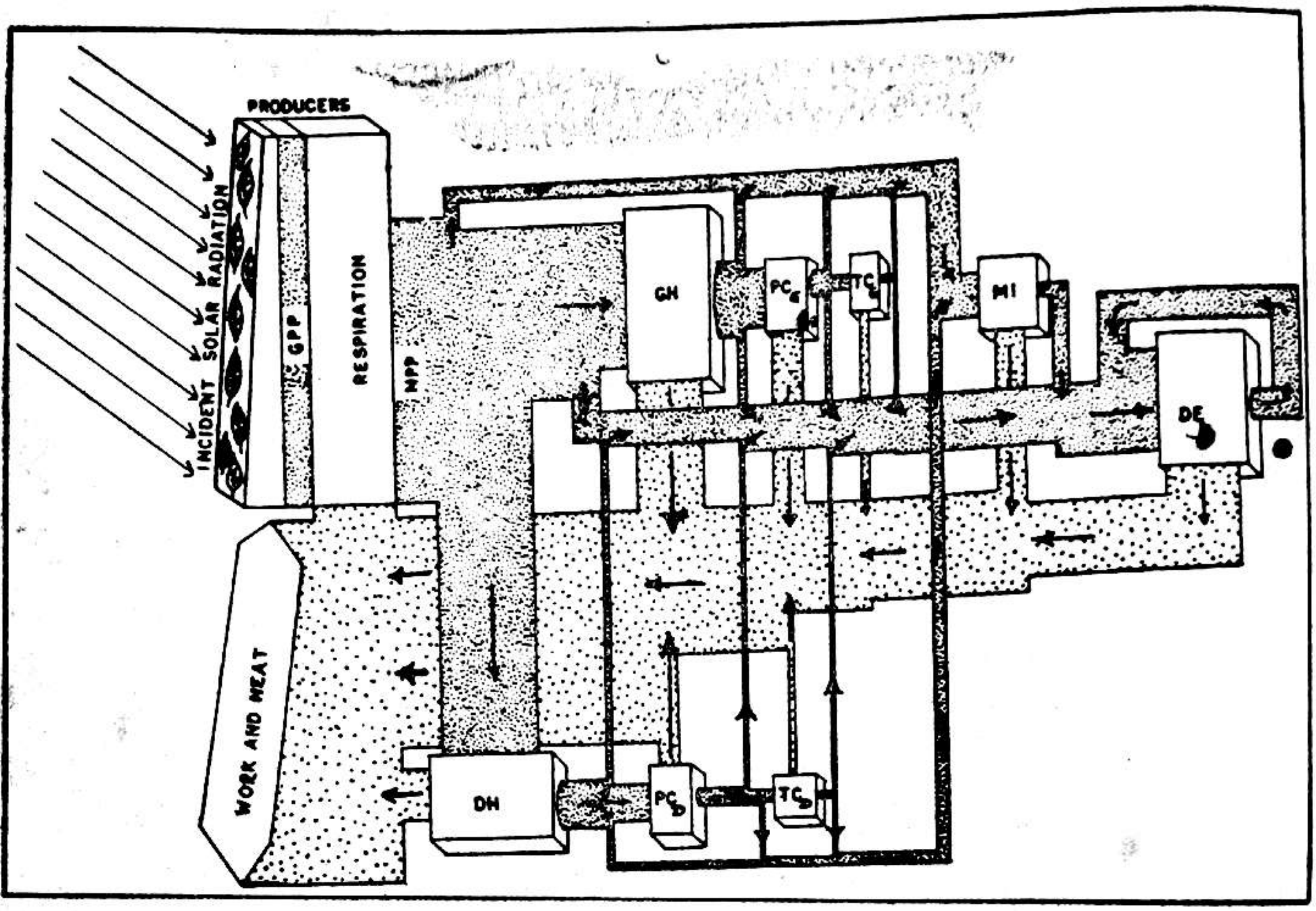
All the energy used in the ecosystem basically comes from solar radiation. Radiant energy of sun coming into an ecosystem is incorporated in its biotic component at the level of producers which convert it into chemical energy and store it in the organic food made by photosynthesis. At each trophic level a portion of this trapped energy is used in the activities of that level which can be measured by respiration of that level and remaining unused energy is passed on to its next higher trophic level. Concepts used in the study of this energy flow are as follows.

Incident solar radiation

Though the sun gives off a huge amount of energy, a large portion of it is reflected by

SYSTEMATIC REPRESENTATION OF THE FATE OF ENERGY IN ECOSYSTEM

Gross primary production.	=	**Total work done by organisms in all the trophic levels.**	+	**Total heat produced in all trophic levels.**	+	**Total increase in biomass in all the trophic levels.**
(*GPP*)	=	**(*W*)**	+	**(*H*)**	+	**(*S*)**
Total energy entering a trophic level.	=	**The net production of that level.**	+	**Total work done in that level.**	+	**Total heat produced in that level.**
(*E*)n	=	**(*NP*)n**	+	**(*W*)n**	+	**(*H*)n**
Net production of a trophic level.	=	**Total energy entering the trophic levels next to it.**	+	**Total increase of biomass in that trophic level.**		
(*NP*)n	=	**(*E*)n+1**	+	**(*S*)n**		



Fig—2.

Schematic representation of energy flow in a hypothetical autotrophic ecosystem at equilibrium.

(GPP=*Gross Primary Production;* NPP=*Net Primary Production;* GH=*Grazing Herbivores;* PC_g= *Primary Carnivores in grazing chain;* TC_g=*Top Carnivores in grazing chain;* DH=*Detritus Herbivores;* PC_d=*Primary Carnivores in detritus chain;* TC_d= *Top Carnivores in detritus chain;* MI=*Microconsumers;* DE=*Decomposers*).

and the density estimates of populations, the total amount of energy used in work and heat production in the trophic level can be calculated as through respiration food is burnt to liberate energy for activities of living organisms and heat is produced in the process. Now the amount of energy leaving the trophic level as net production of that level can be accurately calculated simply by subtracting the amount of energy dissipation from the amount of energy entering in the trophic level.

Ecological Effeciency

The ratio of net production to energy intake in a trophic level represented as percentage is termed as the ecological effeciency of that trophic level, *i.e.,*

$$\text{Ecological effeciency of a trophic level} = \frac{\text{net production of that level}}{\text{total energy intake of level}} \times 100$$

Some laboratory studies point out that the ecological effeciency is a constant 10% in all the trophic levels in every type of ecosystem but field data shows great variability in the ecological effeciencies of trophic levels in an ecosystem and also in different ecosystems.

Material flow in Ecosystem (Biogeochemical Cycles)

In addition to energy, living organisms also require various substances for various activities in their life. All the matter required in the biotic component is obtained from the atmosphere and soil constituting the abiotic component of the ecosystem. Most of the matter enters in a trophic level alongwith energy. At the producer level various inorganic and organic substances enter into the ecosystem's biotic component. During photosynthesis when energy is trapped a huge amount of matter is also trapped in making the organic food. This trapped matter can only be released again when the complex organic molecules are broken down to liberate energy for work otherwise the matter alongwith energy is passed on from one trophic level to other. At each trophic level some energy is released for the activities of that level through respiration and then the molecules of organic food are broken down into their constituent parts and these are again returned into the abiotic component of the ecosystem. The flow of matter in the ecosystem has a cyclic path, the matter enters the biotic component at the producer level obtained from abiotic component and from these passes between trophic levels. Acting as a carrier of energy, it is returned to the abiotic component whenever energy is dissipated as work and heat. Total amount of matter present in a trophic level at an instant is called *standing state* of that trophic level for that substance. Pathways of different substances in the ecosystem are quite different and difficult to unravel, therefore, paths of very few of the more important substances, *e.g.*, CO_2, H_2O, NO_3^-, PO_4^{-3}, S, O_2 etc. have been worked out to some extent. These pathways involve both biotic as well as physio chemical and geological parts of the ecosystem also, therefore, are called biogeochemical cycles. Most important difference between flows of energy and matter in the ecosystem is that while energy is constantly being used up, the matter is only recycled; the total amount of any substance in the ecosystem always remains constant. Interestingly, decomposers play a very important role in maintaining the proper balance between abiotic and biotic components as far as cycling of matter is concerned. Decomposers are the last organisms which ultimately breakdown decayed and decomposed organic matter into its constituent inorganic parts. Therefore, by increasing or decreasing their activity they can regulate the balance of nutrient substances in the environment.

Production *Vs.* Consumption in the Ecosystem

In an ecosystem total energy available for use is gross primary production and total energy actually utilized is total respiration in the trophic levels. If the ratio of production/consumption in the ecosystem is one or more than one, the system is called *autotrophic ecosystem* and if it is less than one it is *heterotrophic ecosystem*. The ecosystem with equal production and consumption is considered to be a mature one in which everything is at equilibrium steady state. The system having more production than consumption is either an immature growing one showing increase in its size, or is an exporter one sending its excess production to some other ecosystem. If the system produces less than its total consumption, it has to import food from some surplus system. Aquatic ecosystem at the bank of river is such a system and depends on incoming biomass from some upstream ecosystem on land from which falling leaves etc., form export to the defecit system.

Thus the ecosystem is a finely tuned engine of nature in which all the living and non-living parts are intricately related to each other as well as to their environmental conditions. Any disturbance in any of its parts, effects whole of the system and may have far reaching effects. This realisation, in recent times, has brought increasing concern about rational exploitation of natural resources without causing permanent damage to the ecosystem and this can only be possible with a thorough knowledge and understanding of the structure and dynamics of natural ecosystems.

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