

**TOPIC: -**

**FOOD CHAINS AND FOOD WEBS.**

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**PAPER NAME: - ENVIRONMENTAL GEOGRAPHY**

**SUBJECT: - GEOGRAPHY**

**SEMESTER: - M.A. –IV**

**PAPER CODE: - (GEOG. 403)**

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## **FOOD CHAINS AND FOOD WEBS**

### **INTRODUCTION: -**

Every ecosystem works in a systematic manner under natural conditions. It receives energy from the sun and passes it to various biotic components. All ecosystems have a feeding hierarchy which starts with the energy source i.e. the sun and then followed by producers, consumers and decomposers. These components are dependent on one another. One of the important features is presence of grazing or detritus food chains and food webs. In grazing food chains and food webs, green plants (i.e. producers) synthesize food from non-living nutrients with the help of the sunlight in the process of photosynthesis. Animals (i.e. consumers) consume plants and other animals to get the nutrients and energy. When plants and animals die and decay or when animals excrete waste, bacteria and fungi (i.e. decomposers) feed on the dead or waste materials and release the nutrients back into water and/or soil for reuse by the producers, but the energy is used or lost at every step of the food chain or food web. In a detritus food chain or food web, the energy comes from dead organic matter (i.e. detritus) instead of green producers. Therefore, the flow of energy and nutrients take place through food chains and food webs which become the lifeline of ecosystems.

### **FOOD CHAINS: -**

The transfer of food energy through a sequence of eating and being eaten by the organisms in an ecosystem is termed as the food chain. For example, in a grassland ecosystem, grass fixes the light energy from the sun into chemical energy via synthesis of food and eaten up by a grasshopper, which in turn is eaten by a frog and the frog itself is eaten up by a snake. So, grass is food for grasshopper, grasshopper is food for frog and the frog is food for snake. Thus, grass, grasshopper, frog and snake make a food chain, through which energy contained in food is transferred from one organism to another. In a pond ecosystem, the big fishes eat the small fishes which eat the zooplanktons which in turn consume phytoplanktons. The later fixes the light energy from the sun into chemical energy. All the organisms, whether live or dead, are potential food for other organisms. So, essentially there is no waste in an ecosystem.

Some examples of food chain are as follows:

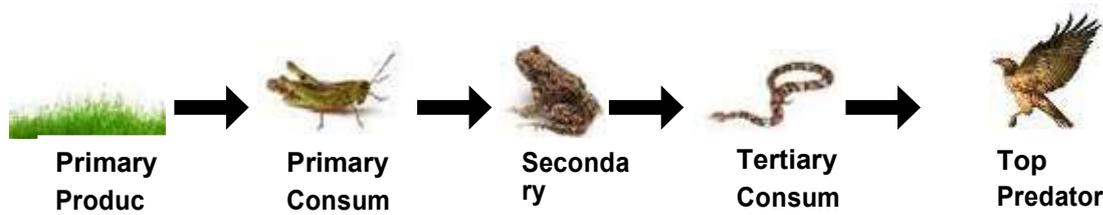
Grass → Grasshopper → Frog → Snake → Eagle (Grassland Ecosystem) (1)

Tree → Fruit eating Birds → Eagle (Forest Ecosystem) (2)

Plant → Deer → Lion (Forest Ecosystem) (3)

Phytoplankton → Zooplankton → Small fish → Big fish → Human beings  
(Pond Ecosystem) (4)

Therefore, there is a definite sequence of producers and consumers in an ecosystem and their interactions alongwith population size are expressed together as trophic structure. The position of organisms along a food chain is referred to as trophic level and the amount of living matter at each trophic level at a given time is known as standing crop or standing biomass. All the green plants (primary producers) belong to first trophic level, plant eaters or herbivores (primary consumers) belong to second trophic level, carnivores or secondary consumers to the third trophic level, and other carnivores or tertiary consumers to fourth trophic level and so on. The top carnivores in the food chain are known as the top predator (Fig 5.1).



**Fig. 5.1: A Food Chain in Grassland Ecosystem**

Trophic levels provide the framework for studying energy flow and efficiencies as well as for the cascading trophic interactions. They are based on the functions of species, not on the taxonomic positions. However, a species can occupy more than one trophic level. As in the above given examples of food chain (1), an eagle acts as a top predator and occupy fifth trophic level, whereas in food chain (2), eagle tends to be at secondary consumer level, occupying third trophic level. Further, the feeding habits of a juvenile animal and consequently its trophic level can change as it grows up (Table 5.1). Energy transfer efficiency limits food chain lengths: Energy is transferred between trophic levels in the form of food energy when one organism eats another in the ecosystem. There is approximately 80-90% loss of energy at each transfer. When energy enters a trophic level, some of it is stored as biomass, as part of organism's body. This is the energy available to the next trophic level since only energy stored as biomass can get eaten. As a rule of thumb, only about 10% of the energy stored as biomass in one trophic level per unit time ends up stored as biomass in the next trophic level per the same unit time. This is 10% rule of energy transfer in the ecosystem. This pattern of fractional transfer limits the length of food chains; after a certain number of trophic levels - generally three to six, there is too little energy flow to support a population at a higher level. Therefore, the shorter the food chain - or nearer the organism to the producer trophic level – greater will be the energy available at that population.

**Table 5.1: Trophic levels**

Trophic level	Type of organism	Energy Source	Example
1 <sup>st</sup>	Primary Producer	Sun	Trees, plants, algae, phytoplanktons
2 <sup>nd</sup>	Primary consumer	Primary Producer	Herbivores (Grasshopper, deer, giraffe, zooplanktons)
3 <sup>rd</sup>	Secondary consumer	Primary consumer	Carnivores (Frogs, lizards, crabs, wolf, small fish)
4 <sup>th</sup>	Tertiary Consumer	Secondary consumer	Top Carnivores (Eagle, tiger, lion, sea otters, big fishes)

**TYPES OF FOOD CHAINS: -**

Food chains are of two basic types:

**GRAZING FOOD CHAIN: -**

The grazing food chain is the major food chain dominantly occurring in ecosystems. As obvious from the name, it starts from the green plants, the major source of energy for this chain is taken from the sun as plants carry out the process of photosynthesis in presence of sunlight. The green plants are the primary producer and eaten up by herbivores, which in turn are eaten up by carnivores. This food chain doesn't consist of microbes or other decomposers; it is carried out by the macroscopic organisms. Examples are:

Plant → Deer → Tiger (Forest Ecosystem)

Grass → Insect → Sparrow → Snake → Hawk (Grassland Ecosystem)

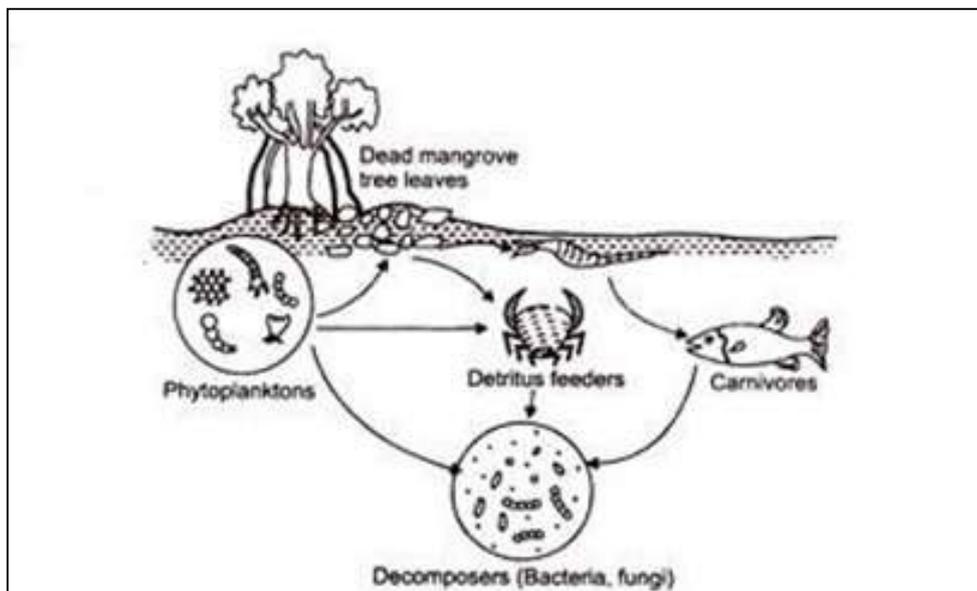
**DETRITUS FOOD CHAIN: -**

The detritus food chain starts from the dead organic matter such as dead bodies of animals or fallen leaves, which are eaten by microorganisms and then followed by detritus feeding organisms (detritivores) and their predators. This food chain has the remains of detritus as the major source of

energy, and this process gets completed by the subsoil organisms, which can either be macroscopic or microscopic. Thus, these food chains are less dependent on direct solar energy.

Unlike the grazing food chain, detritus food chain produces a large amount of energy to the atmosphere. This type of food chain ensures maximum utilization and minimum wastage of the available material. It is useful in fixation of inorganic nutrients and utilizing up to the maximum. For example, the food chain operating in the decomposing accumulated litter in a temperate forest ecosystem is a detritus food chain (Fig. 5.2).

Leaf Litter → Bacteria → Protozoa → Small fish → Big fish



**Fig. 5.2: Detritus Food Chain**

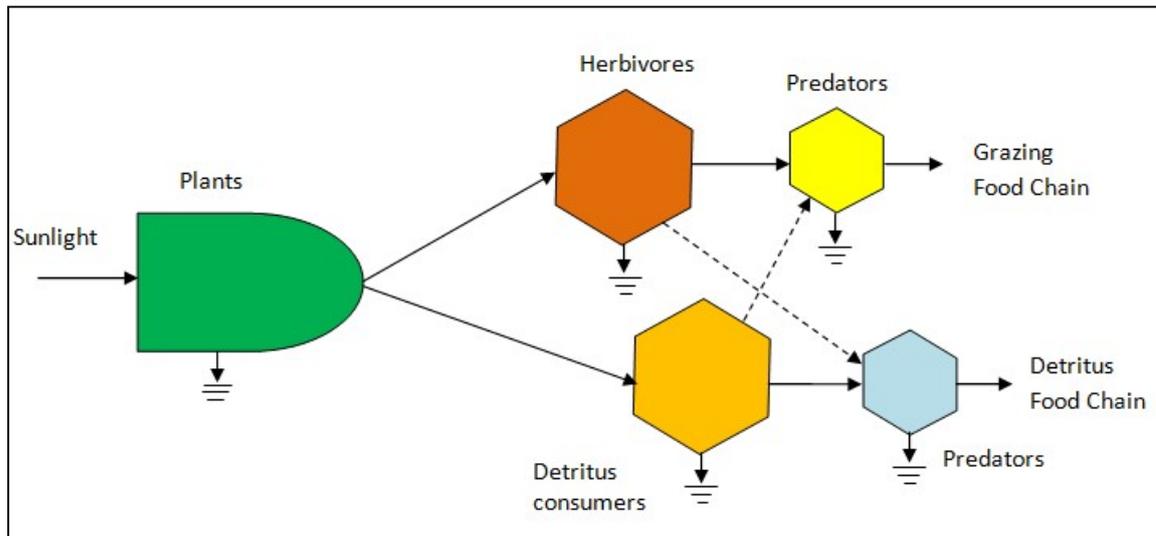
In an example of detritus food chain given by Odum and Heald (1972, 1975) in Southern Florida, leaves of red mangrove (*Rhizophora mangle*) fall into brackish waters at an annual rate of 9 metric tons per hectare. Of the total annual net primary production, only 5% of the leaf material is removed by grazing insects before leaf abscission and rest in the form of fallen leaves is widely dispersed over large areas of bay and estuaries. This dead organic matter is ingested upon a group of small detritus

feeders, often called meiofauna, comprising small crabs, shrimp, nematodes, polychaete worms, small bivalves and snails, and insect larvae. Leaf fragments acted upon by the detritus feeders and colonized by algae are eaten and re-eaten by small detritus consumers, which in turn provide the main food for carnivores' game fish, birds, etc.

**Table 5.2: Difference between Grazing and Detritus Food Chain**

S. No.	Feature	Grazing Food Chain	Detritus Food Chain
1	Definition	Starts from green plants.	Starts from the detritus.
2	Energy Source	The energy is taken from the sunlight as green plants prepare food in the process of photosynthesis.	The main source of energy is the remains of detritus.
3	Organisms	Macroscopic organisms are involved.	Subsoil organisms either macro or microscopic are involved.
4	Amount of energy	Produces less amount of energy to atmosphere.	Produces a large amount of energy to atmosphere.

The major differences between grazing and detritus food chain are given in Table 5.2. The grazing and detritus food chains are shown as separate flows in a Y-Shaped or two channel energy flow model (Fig.5.3). One arm represents the grazing food chain and the other arm represents detritus food chain. The Y-shaped energy flow model further indicates that the two food chains are in fact, under natural conditions, not completely isolated from one another. For example, dead bodies of small animals that were once part of grazing food chain become incorporated in the detritus food chain as do the faeces of grazing food animals. The importance of two food chains may differ in different ecosystems, in some cases, grazing is more important and in others, detritus is more important.



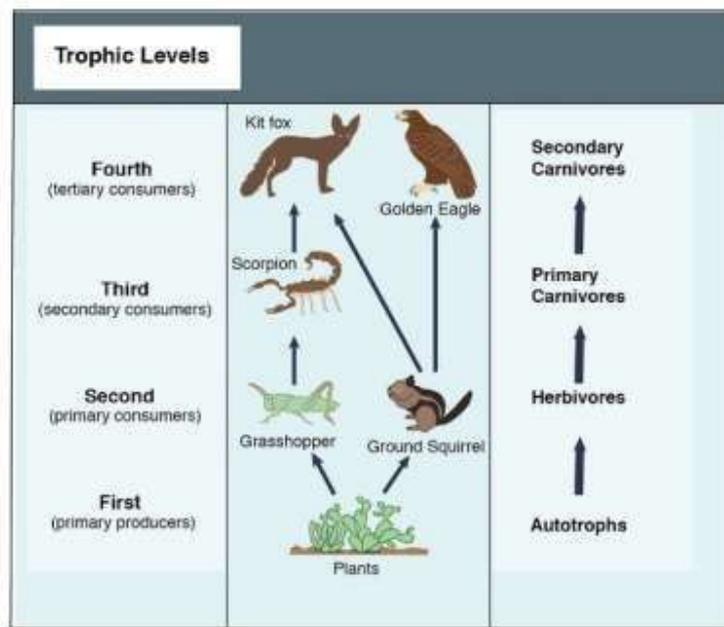
**Fig. 5.3: The Y-shaped energy flow model showing linkage between the grazing and detritus food chain.**

In shallow waters and heavily grazed grassland, 50% or more of the net production may pass down the grazing pathway. But aquatic systems like deep oceans, marshes or forests operate as detritus systems, for, over 90% of primary production is not consumed by heterotrophs until plant parts die and reach water, sediments and soils. This delayed consumption increases the structural complexity and biodiversity as well as the storage and buffering capacities of ecosystems. There would be no forests if all the trees seedlings were grazed down as soon as they appeared.

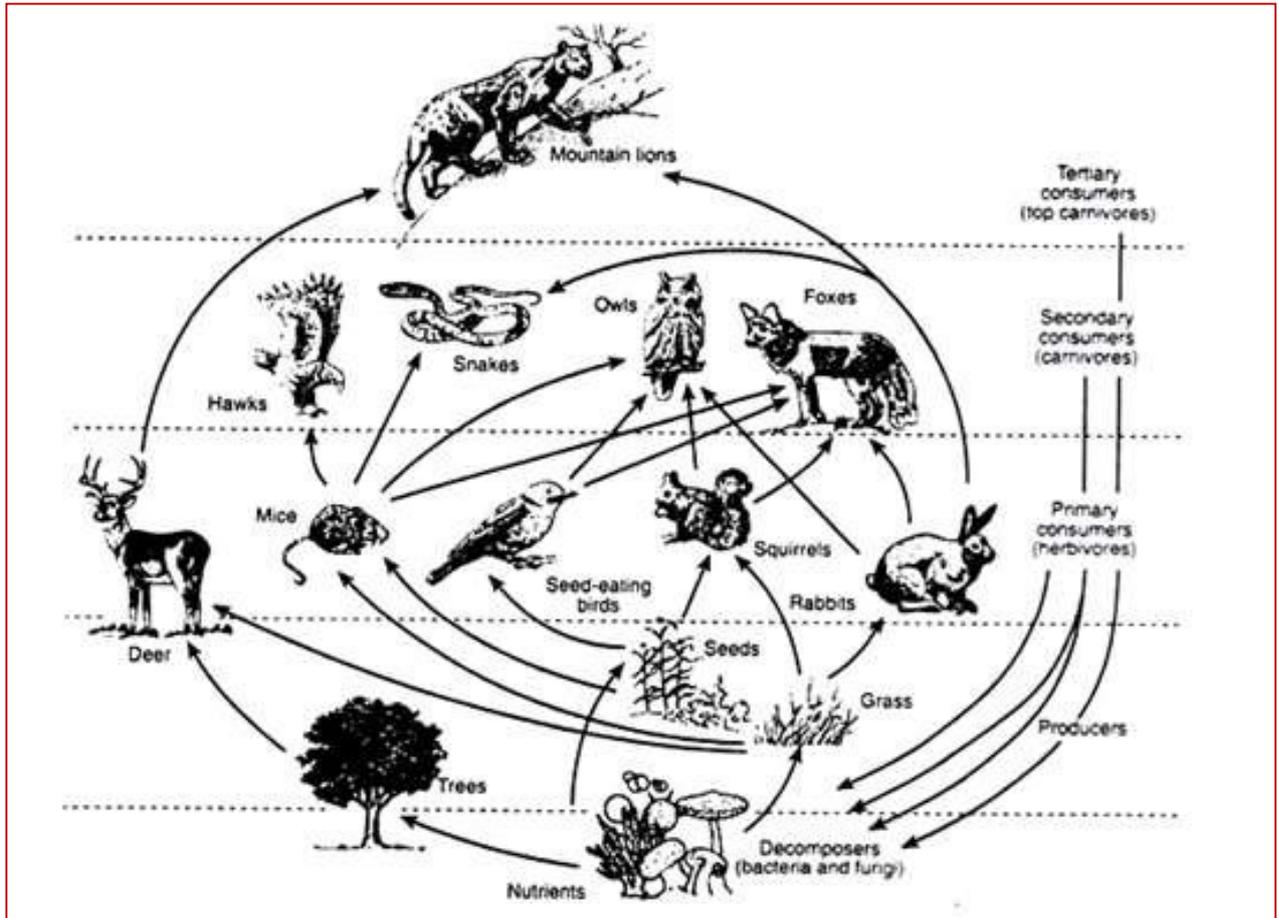
#### **FOOD WEBS: -**

In nature, the food chains never exist as isolated linear sequence; rather they are interconnected to form a network called food web. Therefore, a food web can be defined as a network of food chains interconnected to each other so that a number of options of eating and being eaten are available at each trophic level. It was Charles Elton who presented the notion of food web what he referred to as food cycle (Krebs 2009). In 1927, he recognized that the length of these food chains was mostly limited to 4 or 5 links and the food chains were not isolated, but hooked together into food webs. Food web is the real depiction and illustration of the feeding relationships amongst species in a community.

It offers an important tool for investigating the ecological interactions that define energy flows and predator-prey relationship (Cain et al. 2008). Fig. 5.4 shows a simplified food web in a desert ecosystem. In this food web, grasshoppers feed on plants; scorpions feed on grasshoppers; kit foxes prey on scorpions. In addition, the predators of a scorpion in a desert ecosystem might be a golden eagle, an owl, a roadrunner, or a fox. The analysis of food web is important to understand ecosystem dynamics. Fig. 5.5 represents a food web in terrestrial ecosystem.



**Fig. 5.4: A simple six-member food web for representative desert grassland.**



**Fig. 5.5: Food Web of a Terrestrial Ecosystem.**

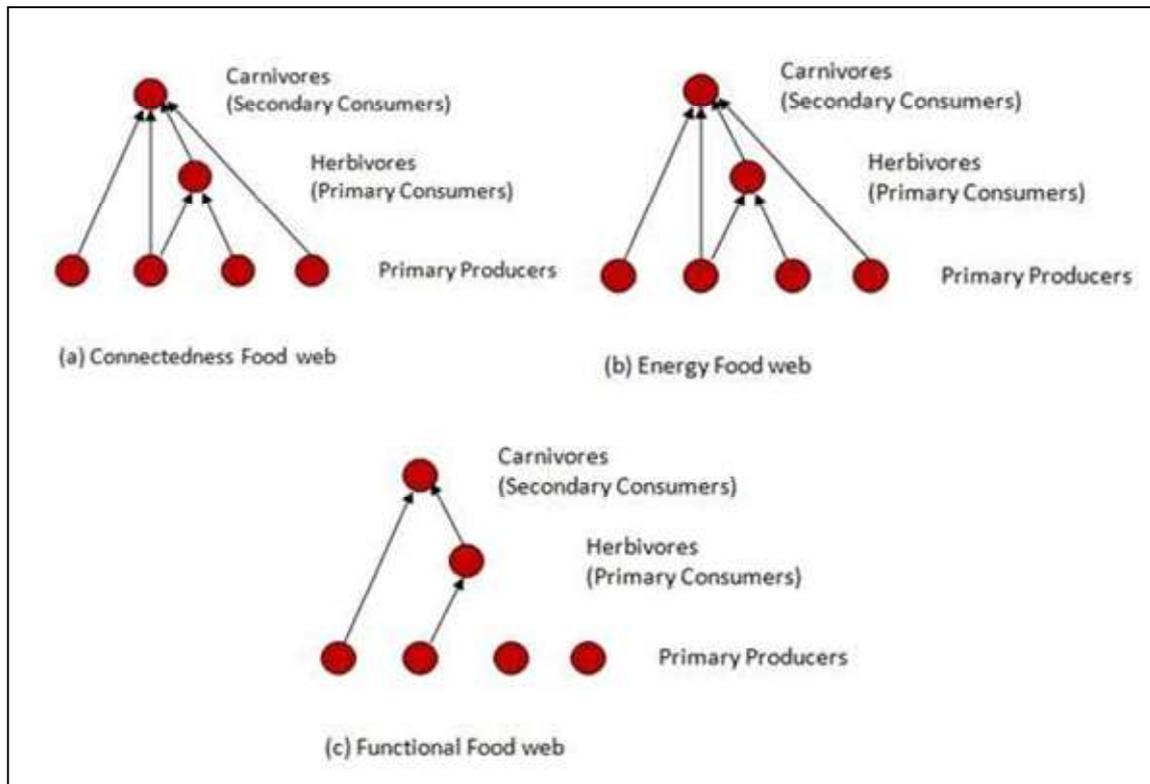
The complexity of food webs depends upon the diversity of organisms in the ecosystem. It would depend on two factors: a) *Length of food chain:* Diversity in the organisms based upon their food habits would determine the length of food chain. More diverse the organisms in food habits, longer would be food chain. b) *Alternatives at different trophic levels in the food chain:* More the alternatives, more would be the interlocking pattern. In deep oceans, sea etc. the food webs are very complex due to the presence of wide variety of organisms.

**TYPES OF FOOD WEBS: -**

Food webs illustrate the links or connections among species in an ecosystem, but these connections may differ in their importance in terms of energy flow and dynamics of species populations. Some trophic relationships are more important than others in dictating how energy flows through ecosystems. Some connections are more influential on species population change.

Based on how the species influence one another in a community, American zoologist, Robert Paine (1980) proposed three types of food webs (Fig. 5.6):

- 1. Connectedness webs:** These food webs depict feeding linkage among species in a food web. These are also called as topological food webs. These depict only the presence or absence of a trophic interaction. They, however, do not show the strength of the interaction, nor any change in trophic relationships. For the above reasons, topological food webs are sometimes referred to as static food web.
- 2. Energy flow webs:** These quantify energy flow from one species to another. The connections between populations are quantified on the basis of flux of energy between a resource and its consumer. In these food webs, the thickness of an arrow reflects the strength of the relationship.
- 3. Functional webs (or interaction food webs):** These food webs represent the importance of each species in maintaining the integrity of a community and reflect influence on the growth rate of other species populations.



**Fig. 5.6: Types of Food Web**

**CHARACTERISTICS OF FOOD WEBS: -**

**Reward Feedback**

Food webs involve much more than ‘who eats whom’- an effect known as *reward feedback*. When a downstream organism in an energy flow has a positive effect on its upstream food supply, say for example, a consumer (such as herbivore or parasite) does something that sustains the survival of its food resource (plant or host) is known as reward feedback. In a study, McNaughton (1976) has shown that if vast herds of antelope’s graze upon the East African Plains, it increases the net production of grass, inferring that annual vegetative growth is greater with the grazers than without them. In a similar study by Collins et al (1998), similar effect of bison grazing on North American grasslands has been found in a 10-years study in Kansas. The net primary production was increased by moderate grazing, as well as there was an increase in biodiversity. It was also hypothesized that the saliva of

grasshoppers and grazing animals contains growth hormones that stimulate root growth and the ability of plants to regenerate new leaves, providing a mechanism for this positive feedback effect (Dyer et al 1993, 1995). So food webs exhibit partnerships and relationships between producers and consumers and between different levels of consumers.

**FOOD WEBS DESCRIBE DIRECT AND INDIRECT SPECIES INTERACTIONS IN A COMMUNITY: -**

All species in the food webs are related to each other at different trophic levels. Different organisms may occupy same trophic level. All species in the food webs can be distinguished into basal species (autotrophs, such as plants), intermediate species (herbivores and intermediate level carnivores, such as grasshopper and scorpion) or top predators (high level carnivores such as fox) (Fig. 5.4). Therefore, grouping all of them into different functional groups or trophic levels helps us simplify and understand the relationships among these species.

**FOOD WEBS CAN ALSO BE USED TO ILLUSTRATE INDIRECT INTERACTIONS AMONG SPECIES: -**

Generally, two types of effects occur when the interactions between two species are influenced by a third species. If we manipulate one species in a food web, it may change the population of species that neither eat nor are eaten by the manipulated species. These effects include trophic cascades, where predators enhance producer growth by feeding on consumer species, and keystone predation, where predators consume dominant competitors, thus allowing inferior competitors to persist.

**Trophic Cascades:** In a prey-predator relationship, predators can impact both prey abundance and behaviour (e.g., prey get scared when predators are around and hide or move away). When the impact of a predator on its prey's ecology trickles down one more feeding level and affect the density and/or behaviour of the prey's prey, the impact is known as a feeding or trophic cascade (Fig. 5.7). In this condition, by controlling densities and/or behaviour of their prey, predators indirectly benefit and increase the abundance of their prey's prey.

Trophic cascades by definition must occur across a minimum of three feeding levels, although evidence of 4- and 5-level trophic cascades have been shown in nature, but are far less common. In figure 5.7, the bird/caterpillar/plant relationship is an example of a trophic cascade. The plant is

positively affected by the decrease in herbivory caused by a predator reducing herbivore numbers.

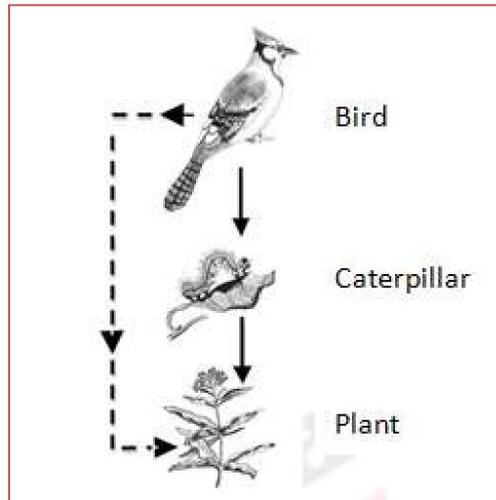


Fig. 5.7: An example of Trophic cascade, in which the predator (bird) has a positive effect on the basal species (plant) via reduction in the abundance of the herbivore (caterpillar).

During the 1980s and 1990s, a series of experiments demonstrated trophic cascades by adding or removing top carnivores, such as bass and yellow perch to or from freshwater lakes. Those experiments showed that trophic cascade controlled biomass and production of phytoplanktons, recycling rates of nutrients, the ratio of nitrogen to phosphorus available to phytoplanktons, activity of bacteria, etc.

**Keystone Predation:** Robert Paine, in an experiment study conducted in the rocky intertidal zone has demonstrated that predation can influence the competition among species in a food web (Cain et al. 2008; Smith and Smith 2009). In the experiment, a variety of mussels, barnacles, limpets and chitons inhabited the rocky intertidal zone. All these invertebrate herbivores are preyed upon by the predator *Pisaster* starfish. When starfish was removed from the food web, the number of prey species was found to be reduced significantly in that area with due course of time. It was inferred that in the absence of the predator starfish, the mussel and barnacle species, being superior competitors, excluded

some other species and reduced overall diversity in the community. Predation by starfish reduced the abundance of mussel and hence supported other species to persist. This type of indirect interaction is called keystone predation.

**There are two approaches by which food webs can be used to study the control of community structure - bottom-up or top-down approach.**

In **bottom - up approach**, the structure of food webs depicts that productivity and abundance of populations at any given trophic level are controlled by the productivity and abundance of populations in the trophic level below them (Smith and Smith, 2009). For example, plant population densities control the herbivores populations which in turn control the carnivore populations.

In **top - down approach**, as occurs in trophic cascade interactions, describes the indirect effects of predators. Here the population density of a consumer controls the population of its resource. In a trophic cascade, predators induce effects that cascade down the food chain and affect biomass of organisms at least two links away.

**SIGNIFICANCE OF FOOD CHAINS AND FOOD WEBS: -**

1. The food chains and food webs help understand the feeding relationships and the interactions between organisms in any ecosystem.
2. Nutrient cycling and energy flow in an ecosystem takes place through food chains and food webs.
3. Food chains keep a check on the population size of different organisms. For example, in a food chain in grassland, if deer population increases, there will be more food for the carnivores, their population will increase, which in turn will reduce the deer population. If there are less deer, some of the carnivores will starve and die, letting the deer population to grow.
4. Food webs are very important in maintaining the stability of an ecosystem in nature. In a linear food chain, if one species become extinct or one species suffers then the species in the subsequent trophic levels are also affected. In a food web, on the other hand, there are a

number of options available at each trophic level. So if one species is affected, it does not affect other trophic levels so seriously.

5. Each species of any ecosystem is kept under a natural check so that the system remains balanced. For instance, if the primary consumers (herbivores) had not been in nature, the producers would have been perished due to overcrowding and competition. Similarly, the survival of primary consumers is linked with the secondary consumers (carnivores) and so on.
6. The study of food chain helps us to understand the problems of biomagnifications. Sometimes certain toxic substances, instead of dispersing, get concentrated at each level in the food chain and are referred to as biological magnification or bioaccumulation.

### **BIOMAGNIFICATION: -**

Biological magnification refers to the process whereby certain substances such as pesticides or heavy metals become concentrated in successive trophic levels in a food chain. Usually, these substances find their way into lakes, rivers and the ocean, and then move up in the food chain in progressively greater concentrations as they are incorporated into the diet of aquatic organisms such as zooplanktons, which in turn are eaten often by fish, which then may be eaten by bigger fish, large birds, animals, or humans. The substances become increasingly concentrated in tissues or internal organs as they move up the chain.

There are two more related terms - bioaccumulation and bioconcentration which are sometimes used interchangeably with biomagnification, but the processes are entirely distinct from each other. Bioaccumulation occurs within a trophic level and is the increase in the concentration of a substance in certain tissues of organisms' bodies due to absorption from food and the environment. While, bioconcentration is defined as occurring when uptake from the surrounding environment is greater than excretion. Thus, bioconcentration and bioaccumulation occur within an organism, and biomagnification occurs across trophic levels in a food chain.

The fat soluble substances cannot be diluted or broken down and accumulate in fatty tissues of an organism. When eaten by another organism, fats are absorbed in the gut, carrying the substance,

which then accumulates in the fats of the predator. Since at each level of the food chain there is a lot of energy loss, a predator must consume many preys, including all of their fat soluble substances. An example of such a build-up can be illustrated in the case of DDT (dichlorodiphenyltrichloroethane), an insecticide used for the control of mosquitoes etc. DDT is soluble in fat but not in water. This toxic insecticide gets washed away in various water bodies and gets absorbed on detritus. Consequently, when DDT is in the food eaten by the herbivore, it tends to be stored in the fat of the organism, rather than excreted or metabolised or denatured. The organism present at the top trophic level is worse affected by high concentration of DDT.

Another example is of mercury which is present in small amounts in seawater; it is absorbed by phytoplanktons as methyl mercury. The later is efficiently absorbed, but only very slowly excreted by organisms and considered as the most harmful variation of mercury. Mercury gets accumulated in the fat tissues of successive trophic levels, i.e., zooplanktons, nektons, then fishes, etc. Anything which eats these fishes also consumes the higher level of mercury the fish have accumulated. This process explains why predatory fishes or birds have higher concentrations of mercury in their tissue than could be accounted for by direct exposure alone.

**SUMMARY: -**

7. The transfer of food energy through a sequence of eating and being eaten by the organisms in an ecosystem is termed as the food chain.
8. The position of organisms along a food chain is referred to as trophic level.
9. Energy transfer efficiency limits food chain lengths. The shorter the food chain - or nearer the organism to the producer trophic level – greater will be the energy available at that population.
10. Grazing food chain starts from the green plants, the major source of energy for this chain is taken from the sun as the plants carry out the process of photosynthesis in the presence of sunlight.
11. The detritus food chain starts from the dead organic matter such as dead bodies of animals or fallen leaves, which are eaten by microorganisms and then followed by detritus feeding organisms (detritivores) and their predators.

12. A food web can be defined as a network of food chains interconnected to each other so that a number of options of eating and being eaten are available at each trophic level.
13. Based on how the species influence one another in a community, food webs are of three types - Connectedness webs, Energy flow webs and Functional webs.
14. Food webs have been found to involve much more than 'who eats whom' - an effect known as Reward feedback. It has been seen that when a downstream organism in an energy flow has a positive effect on its upstream food supply, in the sense that a consumer (such as herbivore or parasite) does something that sustains the survival of its food resource.
9. Food webs can also be used to illustrate indirect interactions among species. When the impact of a predator on its prey's ecology trickles down one more feeding level to affect the density and/or behaviour of the prey's prey, ecologists term this interaction a feeding, or trophic cascade.
10. There are two approaches by which food webs can be used to study the control of community structure - bottom-up or top-down approach.
11. Biological magnification refers to the process whereby certain substances such as pesticides or heavy metals become concentrated in successive trophic levels in a food chain.