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Ecosystem function– Energy flow through ecosystem

By

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The ultimate source of energy for all ecological systems is the sun. The energy that enters the earth's atmosphere as heat and light is balanced by the energy that is absorbed by the biosphere, plus the amount that leaves the earth's surface as invisible heat radiation (first law of thermodynamics which refer to the energy can neither be created nor destroyed but only transformed from one form to another).

When solar energy strikes the earth, it tends to be degraded into heat energy. Only a very small part (about 10 per cent) of this energy gets absorbed by the green plants, and is subsequently transformed into food energy. The food energy then flows through a series of organisms in ecosystems. All organisms, dead or alive, are potential sources of food for other organisms. Food chains and energy flow are the functional properties of ecosystems which make them dynamic. The biotic and a biotic components of an ecosystem are linked through them.

Food Chain

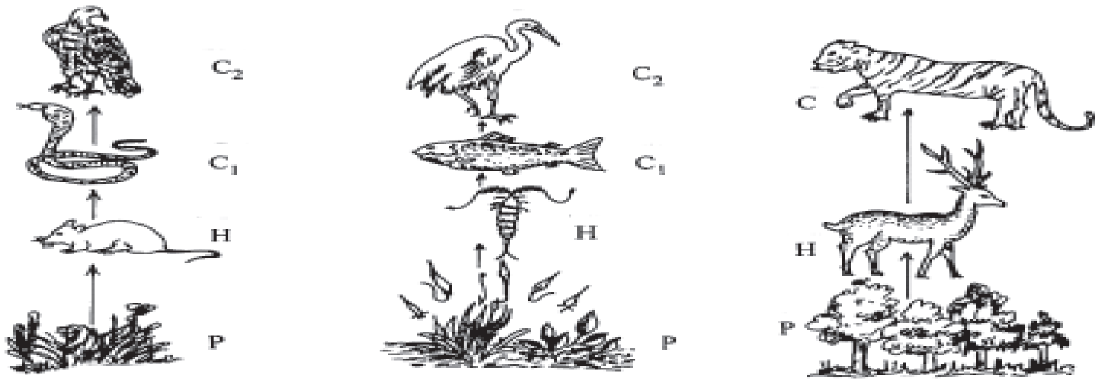
Transfer of food energy from green plants (producers) through a series of organisms with repeated eating and being eaten is called **a food chain**. e.g.

Grasses → Grasshopper → Frog → Snake → Eagle

Each step in the food chain is called **trophic** .

In the above example grasses are 1st, and eagle represents the 5th trophic level.

Some more example of food chain are given in fig**ure** 11.



P = Producer, H = Herbivore, C = Carnivore, C1 = First level carnivore, C2 = Top Carnivore

Figure 11 shows some examples of food chain

During this process of transfer of energy some energy is lost into the system as heat energy and is not available to the next trophic level. Therefore, the number of steps are limited in a chain to 4 or 5.

Following trophic levels can be identified in a food chain.

(1) **Autotrophs:** They are the producers of food for all other organisms of the ecosystem. They are largely green plants and convert inorganic material in the presence of solar energy by the process of photosynthesis into the chemical energy (food). **The total rate at which the radiant energy is stored by the process of photosynthesis in the green plants** is called **Gross Primary Production** (GPP). This is also known as total photosynthesis or total assimilation. From the gross primary productivity a part is utilized by the plants for its own metabolism. **The remaining amount is stored by the plant as Net Primary Production** (NPP) which is available to consumers.

(2) **Herbivores:** The animals which eat the plants directly are called primary consumers

or herbivores e.g. insects, birds, rodents and ruminants.

(3) **Carnivores:** They are secondary consumers if they feed on herbivores and tertiary consumers if they use carnivores as their food. e.g. frog, dog, cat and tiger.

(4) **Omnivores:** Animals that eat both plant and animals e.g. pig, bear and man

(5) **Decomposers:** They take care of the dead remains of organisms at each trophic level and help in recycling of the nutrients e.g. bacteria and fungi.

There are two types of food chains:

(i) **Grazing food chains:** which starts from the green plants that make food for herbivores and herbivores in turn for the carnivores.

(ii) **Detritus food chains:** start from the dead organic matter to the detrivore organisms which in turn make food for protozoan to carnivores etc.

In an ecosystem the two chains are interconnected and make y-shaped food chain. These two types of food chains are:-

(i) Producers → Herbivores → Carnivores

(ii) Producers → Detritus Feeders → Carnivores

The significance of studying food chains

1- It helps in understanding the feeding relations and interactions among different organisms of an ecosystem.

2- It explain the flow of energy and circulation of materials in ecosystems.

3- It help in understanding the concept of biomagnification in ecosystems.

Food web

Trophic levels in an ecosystem are not linear rather they are interconnected and make a food web. Thus food web is a network interconnected food chains existing in an ecosystem. One animal may be a member of several different food chains. Food webs are more realistic models of energy flow through an ecosystem .

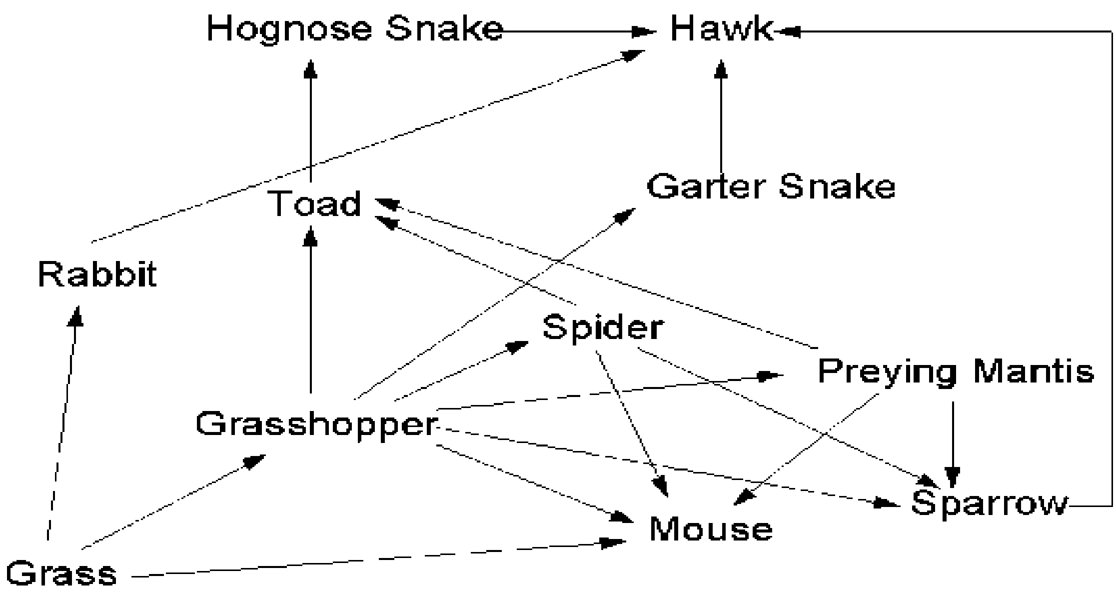


Figure 12: Simple food web

The flow of energy in an ecosystem is always linear or one way. The quantity of energy flowing through the successive trophic levels decreases as shown by the reduced sizes of boxes in figure 13. At every step in a food chain or web the energy received by the organism is used to sustain itself and the left over is passed on to the next trophic level.

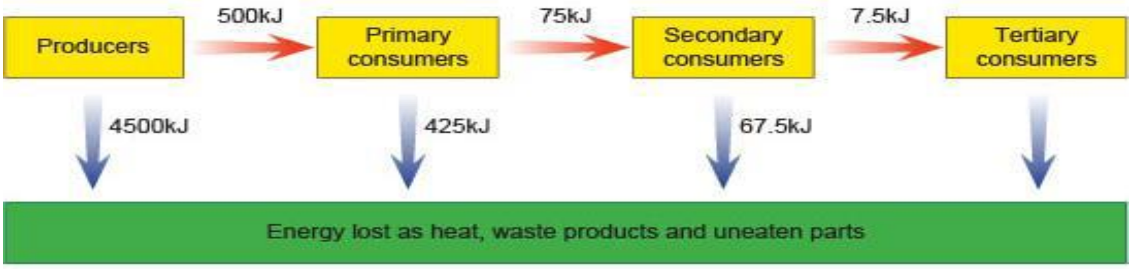


Figure 13: Model of energy flow through an ecosystem

Ecological pyramids

Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types: The producers make the base of the pyramid and the subsequent tiers of the pyramid represent herbivore, carnivore and top carnivore levels.

(1) Pyramid of number: This represents the number of organisms at each trophic level.

For example in a grassland the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores.

In some instances the pyramid of number may be inverted, i.e herbivores are more than primary producers as you may observe that many caterpillars and insects feed on a single tree.

Therefore, there are two kinds of this pyramid.

A- The primary producers are small in size with high numbers.

B- The primary producers are large in size with few numbers.

(2) **Pyramid of biomass:** This represents the total standing crop biomass at each trophic level. **Standing crop biomass** is the amount of the living matter at any given time. It is expressed as gm/unit area or kilo cal/unit area. In most of the terrestrial ecosystems the pyramid of biomass

is upright. However, in case of aquatic ecosystems the pyramid of biomass may be inverted e.g. in a pond phytoplankton are the main producers, they have very short life cycles and a rapid turn over rate (i.e. they are rapidly replaced by new plants). Therefore, their total biomass at any given time is less than the biomass of herbivores supported by them.

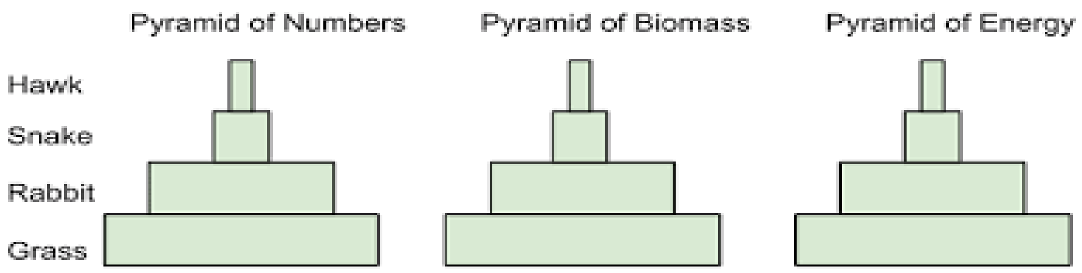


Figure14: Ecological pyramids

(3) **Pyramid of energy:** This pyramid represents the total amount of energy at each trophic level. Energy is expressed in terms of rate such as k cal/unit area /unit time or cal/unit area/unit time. eg. in a lake autotroph energy is 20810 kcal/m/year. **Energy pyramids are never inverted.**

It is clear from the trophic structure of an ecosystem that the amount of energy decreases at each subsequent trophic level. This is due to two reasons:

1- At each trophic a part of the available energy is lost in respiration or used up in metabolism.
2- A part of energy is lost at each transformation, i.e. when it moves from lower to higher trophic level as heat. The percentage of usable chemical energy transferred as biomass from one trophic level to the next is called **ecological efficiency.** It ranges from 2% to 40% (that is, a loss of 60–98%) depending on what types of species and ecosystems are involved, but 10% is typical.

Assuming 10% ecological efficiency (90% loss of usable energy) at each trophic transfer, if green plants in an area manage to capture 10,000 units of energy from the sun, then only about 1,000 units of chemical energy will be available to support herbivores, and only about 100 units will be available to support carnivores. The more trophic levels there are in a food chain or web, the greater is the cumulative loss of usable chemical energy as it flows through the trophic levels.

The **pyramid of energy flow** in Figure 15 illustrates this energy loss for a simple food chain, assuming a 90% energy loss with each transfer. The energy flow in ecosystem with one direction from solar energy to producers, consumers and at last to decomposers, in each step there is losing of this energy as heat.

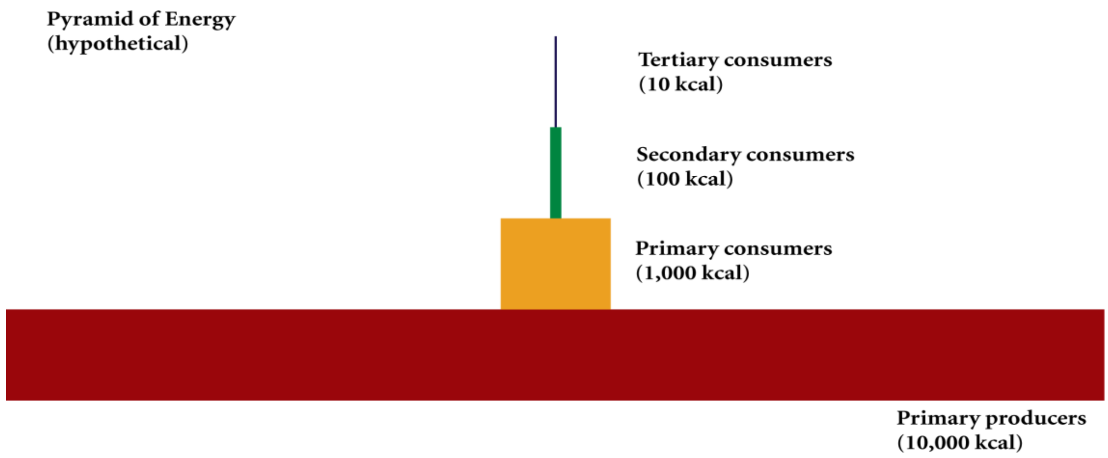


Figure 15: pyramid of energy

Productivity of ecosystem: Primary, Secondary and Net Productivity

Most solar energy occurs at wavelengths unsuitable for photosynthesis. Between 98 and 99 percent of solar energy reaching the Earth is reflected from leaves and other surfaces and absorbed by other molecules, which convert it to heat. Thus, only 1 to 2 percent is available to be captured by plants.

The productivity of an ecosystem refers to the rate of production, i.e., the amount of organic matter accumulated in any unit time.

Productivity is of the following types:

1. Primary productivity

It is defined as the rate of which radiant energy is stored by the producers, most of which are photosynthetic, and to a much lesser extent the chemosynthetic microorganisms. Organisms responsible for primary production include land plants, marine algae and some bacteria (including cyanobacteria).

Primary productivity is of following types:

(a) Gross primary productivity:

It refers to the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. Much of the energy assimilated by plants through photosynthesis is not stored as organic material but instead is used during cellular respiration. In this process organic compounds such as carbohydrates, proteins, and fats are broken down, or oxidized, to provide energy (in the form of adenosine triphosphate [ATP]) for the cell’s metabolic needs.

(b) Net primary productivity (NPP):

Also known as apparent photosynthesis or net assimilation, it refers to the rate of storage of organic matter in plant tissues in excess of the respiratory utilisation by plants during the measurement period. Therefore, NPP = GPP - respiration [by plants]

About 40 to 85 percent of gross primary productivity is not used during respiration and becomes net primary productivity. Both gross and net primary productivity are in units of mass per unit area per unit time such as grams per square meter per year (g/m2 /yr).

2. Secondary productivity:

It is the rate of energy storage at consumer's levels-herbivores, carnivores and decomposers. Consumers tend to utilize already produced food materials in their respiration and also converts the food matter to different tissues by an overall process.

Some ecologists such as Odum (1971) prefer to use the term assimilation rather than 'production' at this level-the consumer's level. It actually remains mobile (i.e., keeps on moving from one organism to another) and does not live-in situ like the primary productivity.

3. Net Productivity:

It refers to the rate of storage of organic matter not used by the heterotrophs or consumers, 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 over by the consumers.