INTRODUCTION TO FRESHWATER ECOLOGY

Key words: Ecosystem, Food web, Lakes, Rivers

Fig-1.1

INTRODUCTION

Freshwater ecology is a specialized sub category of the overall study of organisms and the environment. Unlike biology, ecology refers to the study of not just organisms but how they react, and are affected by the natural surrounding environment or ecosystem. By studying the plants and animals in a body of water as well as the components of the water itself, a scientist specializing in freshwater ecology can discover vital information about the health and needs of a freshwater system. Freshwater Ecology is a study of the interrelationships between freshwater organisms and their natural and cultural environments**.**

Classification of Habitats

In studies of the ecology of freshwater rivers, habitats are classified as **upland and lowland**. Upland habitats are cold, clear, rocky, fast flowing rivers in mountainous areas; lowland habitats are warm, slow flowing rivers found in relatively flat lowland areas, with water that is frequently coloured by sediment and organic matter.

Classifying rivers and streams as upland or lowland is important in freshwater ecology as the two types of river habitat are very different, and usually support very different populations of fish and invertebrate species.

Upland

In freshwater ecology, upland rivers and streams are the fast flowing rivers and streams that drain elevated or mountainous country, often onto broad alluvial plains (where they become lowland rivers). However, altitude is not the sole determinant of whether a river is upland or lowland. Arguably the most important determinants are that of stream power and course gradient. Rivers with a course that drops in altitude rapidly will have faster water flow and higher stream power or "force of water". This in turn produces the other characteristics of an upland river - an incised course, a river bed dominated by bedrock and coarse sediments, a riffle and pool structure and cooler water temperatures.

Fig-1.2 Upland lake
Courtesy: www.conchsoc.org/images/upland_lk.jpg

Rivers with a course that drops in altitude very slowly will have slower water flow and lower force. This in turn produces the other characteristics of a lowland river - a meandering course lacking rapids, a river bed dominated by fine sediments and higher water temperatures. Lowland rivers tend to carry more suspended sediment and organic matter as well, but some lowland rivers have periods of high water clarity in seasonal low flow periods.

The generally clear, cool, fast-flowing waters and bedrock and coarse sediment beds of upland rivers encourage fish species with limited temperature tolerances, high oxygen needs, strong swimming ability and specialized reproductive strategies to prevent eggs or larvae being swept away. These characteristics also encourage invertebrate species with limited temperature tolerances, high oxygen needs and ecologies revolving around coarse sediments and interstices or "gaps" between those coarse sediments.

Lowland

The generally more turbid, warm, slow-flowing waters and fine sediment beds of lowland rivers encourage fish species with broad temperature tolerances and greater tolerances to low oxygen levels, and life history and breeding strategies adapted to these and other traits of lowland rivers. These characteristics also encourage invertebrate species with broad temperature tolerances and greater tolerances to low oxygen levels and ecologies revolving around fine sediments or alternative habitats such as submerged woody debris ("snags") or submergent macrophytes ("water weed").

Fig-1.3 Lowland river
Courtesy: www.conchsoc.org/habitats/freshwater-habitats.php

There are four main constituents of the living environment that form the freshwater ecosystem, they are as follows.

- **Elements and Compounds** of the ecosystem that are absorbed by organisms that are required as a food source or for respiration. Many of these compounds are required by plants and passed along the food chain.

- **Plants** which are autotrophic by nature, meaning that they synthesize food by harnessing energy from inorganic compounds (plants do so by photosynthesis and the sun); this is done via photosynthesis. These plants (and some bacteria) are the primary producers, as they produce (and introduce) new energy into the ecosystem.

- **Consumers**, which are the organisms that feed on other organisms as a source of food. These may be primary consumers who feed from the plant material or secondary consumers who feed on the primary consumers.

- **Decomposers** attain their energy by breaking down dead organic material (detritus), and during this reaction, release critical elements and compounds which in turn are required by plants.

Biotic and Abiotic Factors – Freshwater Ecology

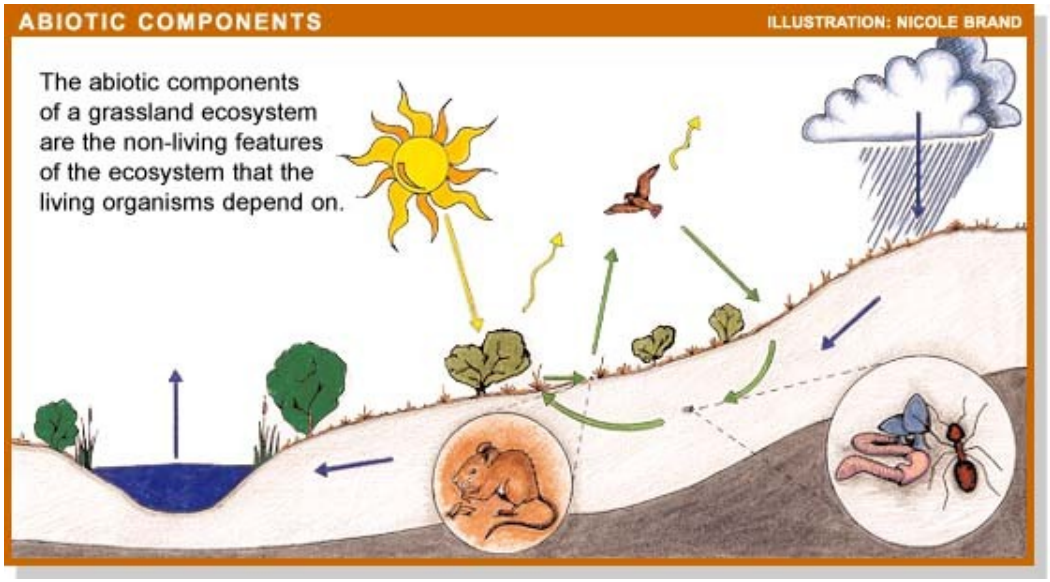


Fig- 1.4

Abiotic factors are essentially non-living components that affect the living organisms of the freshwater community.

When an ecosystem is barren and unoccupied, new organisms colonizing the environment rely on favorable environmental conditions in the area to allow them to successfully live and reproduce. These environmental factors are abiotic factors. When a variety of species are present in such an ecosystem, the consequent actions of these species can affect the lives of fellow species in the area; these factors are deemed biotic factors.

The light from the sun is a major constituent of a freshwater ecosystem, providing light for the primary producers, plants. There are many factors which can affect the intensity and length of time that the ecosystem is exposed to sunlight;

- **Aspect** - The angle of incidence at which light strikes the surface of the water. During the day when the sun is high in the sky, more light can be absorbed into the water due to the directness of the light. At sunset, light strikes the water surface more acutely, and less water is absorbed. The aspect of the sun during times of the day will vary depending on the time of the year.
- **Cloud Cover** - The cloud cover of an area will inevitably affect intensity and length of time that light strikes the water of a freshwater ecosystem. Species of plants rely on a critical period of time where they receive light for photosynthesis.
- **Season** - The 4 seasons in an ecosystem are very different, and this is because less light and heat is available from the sun in Winter and vice versa for Summer, therefore these varying conditions will affect which organisms are suited to them.

- **Location** - The extreme latitudes receive 6 months of sunlight and 6 months of darkness, while the equator receives roughly 12 hours of sunlight and darkness each day. This sort of variance greatly affects what type of organisms would occupy freshwater ecosystems due to these differences.
- **Altitude** - For every one thousand metres above sea level, average temperature drops by one degree Celsius. Altitude will also affect the aspect of which sunlight hits the freshwater ecosystem, therefore playing a part on which organisms will occupy it.

Many abiotic factors can play a part in determining the end product, which organisms live and succeed in the freshwater ecosystem. The sun provides light for *photosynthesis*, but also provides heat giving a suitable temperature for organisms to thrive in. The temperature of a freshwater environment can directly affect the environment as a whole and the organisms that occupy it.

Enzymes operate best at an optimum temperature, and any deviation from this temperature 'norm' will result in below optimum respiration in the organism. All aquatic life are ectotherms, meaning their body temperature varies directly with its environments.

Temperature affects the density of substances, and changes in the density of water means more or less resistance for animals who are travelling in the freshwater environment.

Abiotic Factors - Water Conditions

Evidently, the light and heat from the sun play an important role in providing suitable conditions. However, the water conditions also inevitably have an effect on life in the ecosystem. A still body of water will inevitably be disturbed by various factors, which will affect the distribution of organisms in the water. Wind is considered to be the prime factor responsible for disturbing water, though changes in temperature can create convection currents where temperature is evened out across the body of water via this movement.

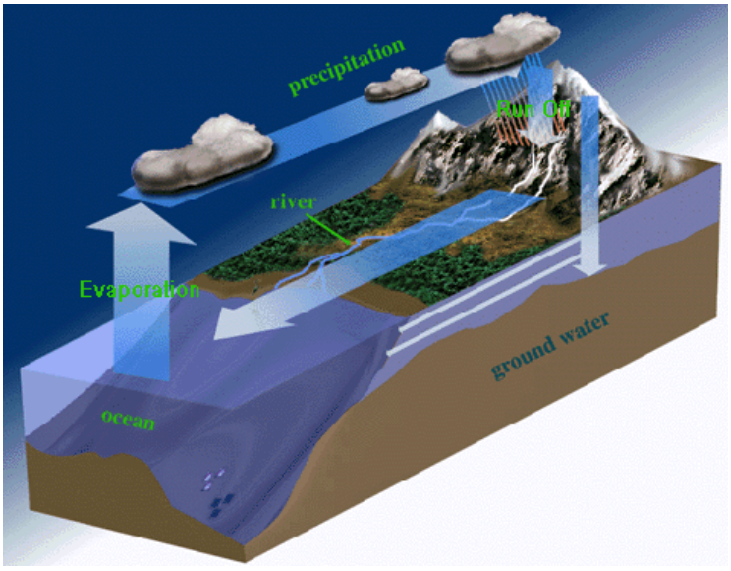


Fig-1.5

Naturally, a river will have water movement as water succumbs to gravity and moves downstream. These are relatively constant factors that affect water movement though, for example, human intervention can also cause water movement. The surface tension of the water will also affect the organisms that occupy the area, depending on the cohesion of water at the surface; it can affect the amount of oxygen that reaches organisms living below the water surface.

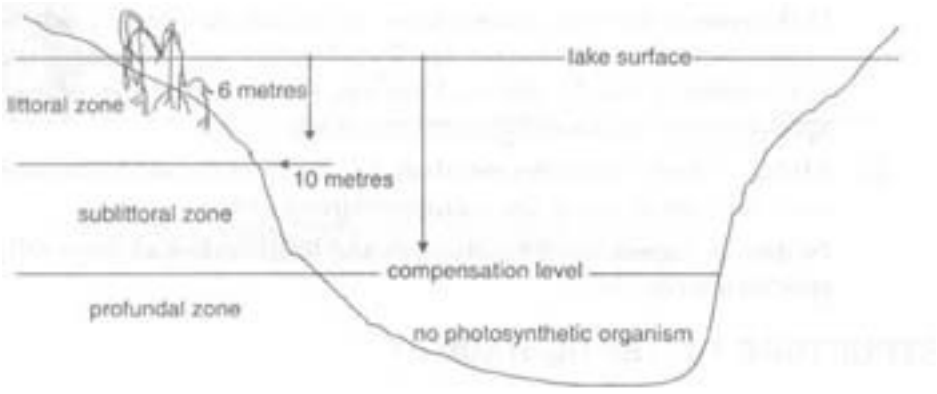
These factors all affect the way of life for organisms occupying such a freshwater ecosystem. On a more molecular level, the chemical compositions of the water, soil and surrounding air also play a part in determining the face of the ecosystem.

The *oxygen* concentration of the water and the surrounding air will have great bearing on which organisms can survive in a particular environment. Oxygen is required for aerobic respiration in animals, and the concentration of oxygen in an area is determined by many factors, including temperature and abundance of organisms for example.

Many chemical reactions and cellular processes rely on the availability of oxygen; therefore the concentration of oxygen in the ecosystem will inevitably alter the ecosystem itself. The same applies to carbon dioxide concentration. CO_2 is required for photosynthesis, and can also affect the pH of the water for example.

The study of ecology in freshwater is usually divided into 2 categories, lentic (still) and lotic (running) water. These two bodies of water also have a bearing on which organisms are likely to occupy the area.

Freshwater Communities & Lentic Waters



Different zones of a deep freshwater lake

Fig-1.6

Lentic (still water) communities can vary greatly in appearance; anything from a small temporary puddle to a large lake is capable of supporting life to some extent.

The creation of many of today's long standing freshwater lentic environments are a result of geological changes over a long period of time, notably glacial movement, erosion, volcanic activity, and to an extent, human intervention.

The consequence of these actions results in troughs in the landscape where water can accumulate and be sustained over time. The size and depth of a still body of water are major factors in determining the characteristics of that ecosystem, and will continually be altered by some of the causes mentioned above over a long period of time.

One of the important elements of a still water environment is the overall effect that temperature has on it. The heat from the sun takes longer to heat up a body of water as opposed to heating up dry land. This means that temperature changes in the water are more gradual, particularly so in more vast areas of water. When this freshwater ecosystem is habitable, many factors will come into play determining the overall make up of the environment which organisms will have to adapt to.

As with osmosis, temperature will even out across a particular substance over time, and this applies to a still body of water. Sunlight striking the water will heat up the surface, and over time will create a temperature difference between the surface and basin in the body of water. This temperature difference will vary depending on the overall surface area of the water and its depth.

Over time, two distinctly different layers of water become established, separated by a large temperature difference and providing unique ecological niches for organisms. This process is called **stratification**, where the difference in temperature between surface and water bed are so different they can easily be distinguished apart. The surface area is deemed the **epilimnion**, which is warmed water as a result of direct contact with sunlight. The lower layer is deemed the **hypolimnion,** found below the water surface, and due to increased depth, receives less heat from the sun and therefore results in the colder water underneath.

Some factors can affect the amount of light received by autotrophic organisms (organisms that perform photosynthesis) can affect their level of photosynthesis and respiration, hence affect their abundance and therefore and subsequent species that rely on them.

Organic material and sediment can enter the still water environment via dead organisms in the area, and water flowing into the area from hills and streams. Buoyant material will also block out light required by the primary producers of the ecosystem.

When water moves, the friction caused by the moving water against the water bed and its banks will result in disturbing loose sediment. Depending on the weight of this sediment, heavier particles will slowly sink back to the bottom of the body of water while lighter materials will remain suspended in the water. The lightest material will rise to the surface, resulting in less light available to organisms underneath the surface.

Naturally, the consequences of the above will result in less light for organisms that rely on photosynthesis as a means of food, and subsequently means that organisms that feed on these autotrophic organisms will soon find that their food source is less freely available.

Another major factor affecting still water communities is the oxygen concentration of the surrounding area. Oxygen concentration is primarily affected by three factors

- The surface area which the body of water is exposed to the open air environment
- The circulation of water, chiefly due to temperature differentiations in different areas of the water body (convection currents)
- Oxygen created as a result of respiration, consumption, and the oxygen consumed by animals and bacteria.

Temperature can also affect the concentration of oxygen available, which in turn, means that the depth of the water will therefore also have an effect. In turn, carbon dioxide levels, which are closely related to the oxygen levels available, will be required by organisms undergoing photosynthesis. The availability of these will affect the organisms in the ecosystem. Their relationships with temperature will also affect their availability. Evidently, some of these factors vary through different conditions, and changes in one of the factors usually results in changes with the others. This is also the case of pH, for example, as an increase in carbon dioxide results in a drop of pH.

Still Water Animals

Through millions of years of evolution, animals living in an aquatic environment have diversified to occupy the ecological niches available in the ecosystem. When studying the habitats of these particular organisms, three main areas of the freshwater environment can be distinctly classified.

- **The Profundal Region** - An area of still water that receives no sunlight therefore lacks autotrophic creatures. The animals in this zone rely on organic material as a means of food, which is sourced from the more energy rich areas above the profundal region.
- **The Pelagic Region** - The pelagic region can be found below the surface water, and is defined by the light that is available to it. The pelagic region does not include areas near the shore or sea bed.
- **The Benthic Region** - The benthic region incorporates all the freshwater environment in contact with land, barring the shallow shore areas. The benthic region is capable of hosting a large volume of organisms, as nutrient and mineral rich sediments are available as a food source while part of the benthic region can occupy the euphotic zone, the area of water where light is available. This will allow an ecological niche for autotrophic organisms which in turn can be a food source for herbivores.

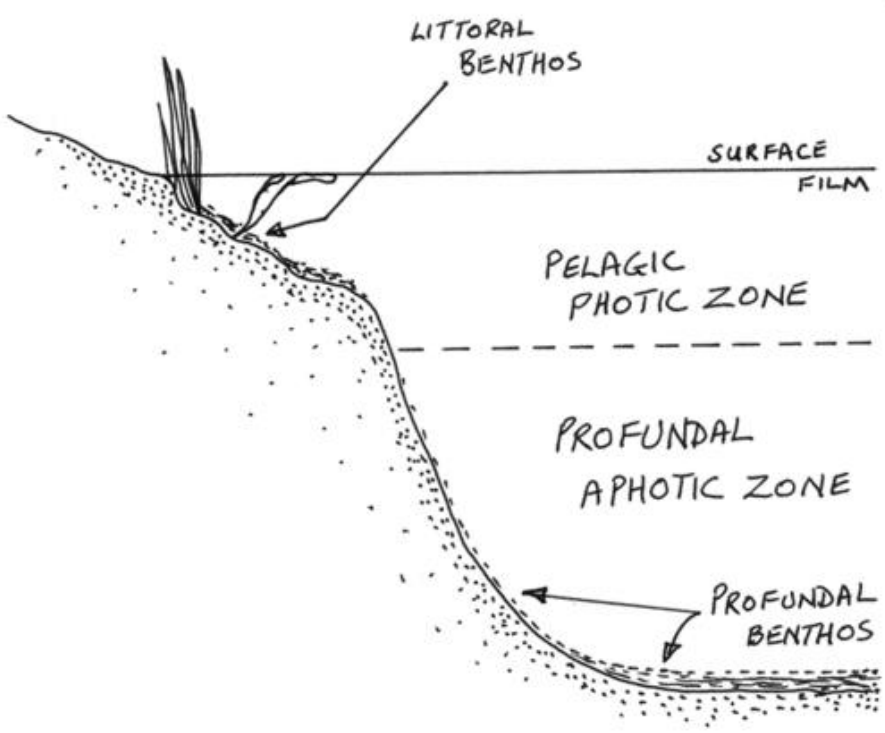


Fig-1.7

Another distinctive niche for the animal community is that above (**epineuston**) and below (**hyponeuston**) the water surface. Epineustic animals receive food from the surrounding hydrosere vegetation, where small animals fall into the water from vegetation and are preyed upon by these epineustic animals.

Below these surface dwelling animals are a collective of animals called the **nekton**, which live in the pelagic and profundal regions, though rise to the pelagic regions to feed upon these epineustic animals. Fish are included in this nekton community, which play a vital cog in these freshwater communities. Some of these fish are only temporary members of the community, as they move between fresh and salt water. *Anadromous* fish spawn in freshwater, but live much of their lives in salt water. *Catadromous* fish are the opposite of this, and spend much of their lives in the freshwater community. Each way, the fish present in the environment at any time form the link between the upper and lower layers of the freshwater community.

Freshwater Lentic Communities & Animals

Plants that live partially or completely submerged in water are deemed **hydrophytes**. A form of symbiosis occurs with these hydrophyte plants, which provide means for algae and other organisms to survive in the surrounding environment. This is because the hydrophytes provide the conditions for the likes of algae and bacteria to survive in the environment. In return, herbivore animals tend to feed on this rich blanket of algae as opposed to the plants themselves, therefore protecting them from being consumed.

Animals in this environment feed on these algae, and also upon the detritus matter, the organic material that is rich on the water bed. It is an area of abundant organic material because the plants that survive in this area provide a source of food, and also a source of shelter which can provide protection from predators or a location to hatch offspring in a closed protected area.

The ecological niche alongside the still water banks is occupied by plants called **hydroseres**, which are partially or totally submerged by water along the banks. Some of these hydroseres are rooted in the water, though some of their leaves penetrate the water surface, while others float on the surface, one side in contact with the water, the other side in contact with the open air environment. In essence, hydroseres possess evolutionary adaptations and dithering respiration rates from land plants that have allowed them to adapt in live in such an environment. Such evolutionary adaptation in plants has meant that their physical structure has changed to suit the environment, and therefore making freshwater plants distinctly unique in appearance.

An example of these adaptations is the lack of rigid structures in freshwater plants. This is due to the density of the water (much higher than that of an open air environment), which 'pushes' against the plant in its daily life. This allows such plants to be more flexible against oncoming water tides, and prevents damage to the plant.

As plants require a minimum concentration of gases in their diet such as carbon dioxide, they require a degree of buoyancy so that contact can be made with the open air environment. Adaptations may include;

- Air Spaces - Air spaces in the plant will decrease density and increase buoyancy.
- Broad Leaves - Broader leaves will spread their weight more evenly across the water surface allowing them to float.
- Waxy Cuticle - On the upper half to allow water to run off the surface to prevent the weight of the water dragging the leaves under the surface

In still water plants, the method of transpiration as a whole is altered in freshwater plants, due to the abundance of water in their external environment, or in the case of some, uptake of water from a wet environment, but loss of water via their leaves in the open air environment.

An example of transpiration problems for such plants is as follows;

- The plant lives in a marshy environment, where roots uptake water from soaked ground, allowing plenty of water to be up taken and transported up and across the plant.
- The difference in water concentration between the plants' leaves and the open air environment is so great that much of the water absorbed is lost to the external environment, meaning the plant loses water rapidly
- Such a problem is solved by evolutionary adaptations. These adaptations essentially address the issue of re-balancing the critical deviations between the water that is absorbed and lost in a plant.

Freshwater Plants & Nutrients

On top of the need for plants to maintain a suitable water concentration in plant cells, they also require various nutrients which are found in the nutrient rich soil and the surrounding waters. In addition to the carbon, hydrogen and oxygen required for photosynthesis, plants require a range of macro-elements, notably magnesium (Mg), nitrogen (N), phosphorous (P) and potassium (K). Some of these elements, notably the gases, are readily available in the atmosphere, while carbon dioxide is produced from decomposing organic matter. Other elements are readily available in the soil, with nutrients becoming available from decomposing matter adding to the fertility of the surrounding soil. Oxygen becomes available from the photosynthetic activities of plants, which provide the link between oxygen and carbon dioxide concentrations in the area.

Lotic Communities

Running water freshwater communities are also known as lotic communities (lotic meaning running water). Lotic communities are formed by water being introduced to the freshwater body from a variety of sources;

- **Rainfall** - A percentage of water in the running water community will be present as a result of rainfall directly entering it.
- **Ground Surface Water** - Deriving from previous rainfall, water will enter the running water community.
- **Underground Water** - Water absorbed into the soil can also enter.
- **Water Table** - Deep underground there is a 'water table' which can also provide water for the running water community.

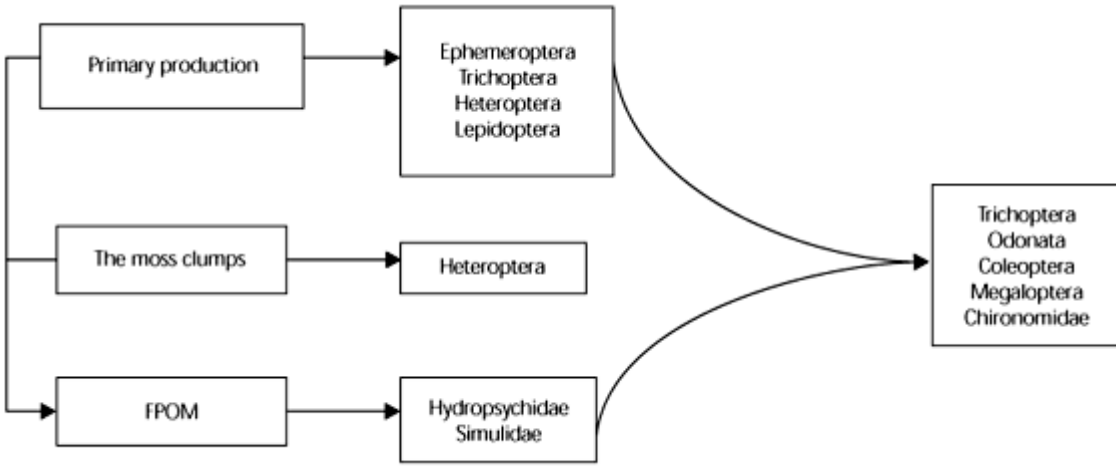


Fig -1.8

One of the main differences between lotic and lentic communities is the fact that the water is moving at a particular velocity in lotic communities. This can have great bearing on what organisms occupy the ecosystem and what particular ecological niche they can exist in. Running

water can bring many factors into play affecting the lives of the organisms in this particular environment:

- Movement of minerals and stones caused by the velocity and volume of the water means the water bed is constantly changing. The faster and higher volume of water present will result in a direct increase in amount and size of particles shifted downstream.
- Standing waves are used by salmon at the bottom of waterfalls to spurn them upstream. At the same time, they cause small air pockets caused by oxygen replacing the splashing water, which results in a small micro-habitat becoming available suited to particular organisms
- Erosion is caused by the running water breaking down the river bank and beds, causing the geography of the river to change over a long period of time. This means that hydroseres previously occupying the river bank may find themselves distanced from the running water for example, and over time this would mean the overall ecosystem would change over time.

The following is some of the physical and chemical factors that provide the framework of a running water community in which organisms in their favored ecological niches occupy.

- **Temperature** - The difference between running water and still water temperature is that running water communities' temperature varies more rapidly but over a smaller range. In summer, water from the source of the river is usually colder than the water found at the delta because it has not been exposed to the warm air heated by the sun. The reverse occurs in winter where water is warmer until exposed to the colder air.
- **Light** - On the whole, less light penetrates a running water body due to ripples in the water, debris blocking out sunlight to lower layers as well as overhanging shrubs that perhaps are taking advantage of a tributary water source. These are all examples of how the intensity of light reaching the lotic community can be affected, and in turn, directly affects the rate of photosynthesis done by plants in the community.
- **Chemical Composition** - Many factors can alter the chemical composition of the freshwater environment, including precipitation, the percolation of water via vegetation and sea spray to name a few. All in all, various elements and compounds are required by organisms in their daily activities and fluctuations or even an absence of such elements and compounds results in a direct effect on the lives of such organisms.
- **Organic Matter** - Organic matter previous external to the running water environment can also play a part in altering the ecosystem. This mostly occurs due to overhanging vegetation, although organic matter can be drawn into the ecosystem by the various sources mentioned on the previous page.

Lotic Communities & Algae

In general the diversity of plant species in a lotic community is small compared to that of a still water (lentic) community although small parts of the lotic community host similar conditions to that of a lentic community. Most plants have went through evolutionary adaptations to cope with the force and different conditions that running water brings. Such adaptations have allowed a

number of species to successfully take advantage of the lotic community as their ecological niche.

As these conditions are more harsh for a typical species of plant, more notably larger plants, smaller species have found the conditions of the lotic community more favorable. This is due to the fact that they are more flexible in regards to the physical conditions of the water. Algae can grow in all sorts of different places and surfaces, and therefore are a successful constituent of the running water ecosystem. Most of these algae have developed evolutionary adaptations over times that prevent the water current sweeping them away.

There are many species of algae, all of which are capable of growing and reproducing at a quick rate. This consequence results in competition for niches in the freshwater environment, and in light of this, colonies of algae can heavily occupy one area at one moment in time and weeks later they can be succeeded by another species that can succeed in the conditions more favorably.

Algae are also the primary producers of this community, meaning they harness new energy into the ecosystem from the sun which provides the primary consumers with a valuable food source. With this in hand, it is apparent why algae populations and where they can be found in the lotic community is variable on a short-term basis.

Lotic Communities & Animals

The running water environment offers numerous microhabitats that simulate favorable conditions for many types of animals to successfully succeed the freshwater lotic community. As with plants, animals in this ecosystem have also undergone ongoing evolutionary adaptations to better suit this running water environment.

Some of these animals are sessile, meaning they are immobile and fixed to the one place. These animals are usually small, and include the protozoans and some freshwater sponges. These animals either remain attached to the mass of a plant or the water bank surface or rock. They usually obtain their food via tentacles which branch out into the flowing water and form a catchment area that can trap microscopic organisms (such as plankton) that is floating downstream.

As much as these sessile animals have developed adaptations to prevent being washed downstream, they are not thought to be one of the important pillars of the freshwater community. Over time when biotic and abiotic factors affect the landscape of the ecosystem over time, the location of these animals may not be as favorable as it once was, and they are unable to correct this due to their immobile nature. With this in light some animals have developed adaptations that allow them to travel through the water without being inhibited in same spot.

Animals have developed some of the following adaptations over time that helps them cope with the conditions in hand:

- **Suckers** - These suckers attach themselves to a surface that leeches them into position and can also assist movement in any given direction.

- **Hooks / Claws** - These sharp objects can dig into any given object and allow the animal to cling to a position or claw their way around the surface.
- **Body flattening** - This adaptation can allow the animal in the water bear less of the brunt of the force of water moving downstream, therefore reducing it as an inhibitor of their movement. This also allows these animals to enter confined areas (such as under stones) that may present a useful environment for them to live in.
- **Streamlining** - Just like man-made transport, animals who have underwent streamlining adaptations on their external appearance means that less resistance is presented by the running water when the animal attempts to move.
- **Flight -** Some animals have adaptations allowing them to fly, removing themselves from the force of the current at ground level and enabling them to move upstream more easily if needs be.

Freshwater Communities & Plankton

Plankton are microscopic organisms that live suspended in the water environment, and form a very important part of the freshwater community. They move via convection or wind induced currents. In almost every habitat of a freshwater ecosystem, thousands of these organisms can be found, and due to their small size and simplicity, they are capable of occupying large expanses of water and multiplying at an exponential rate.

Plankton can be subdivided into two categories.

- **Phytoplankton** - Phytoplankton are microscopic plants which obtain their energy via photosynthesis. However, some species of bacteria are also capable of photosynthesis and also fall under this taxonomic category. They are important to the ecosystem because they are part of the primary producing community and assist in recycling elements such as carbon and sulphur which are required elsewhere in the community.
- **Zooplankton** - Zooplankton consist mainly of crustaceans and rotifers, and on the whole are relatively larger than their phytoplankton counterparts. They are relatively unspecialized as their environment does not resist the large populations that can exist in within their environment. Physiologically, there are many evolutionary adaptations that can be found that assist in the buoyancy of them, and prevent their deaths by allowing them to be suspended in the water away from harm.

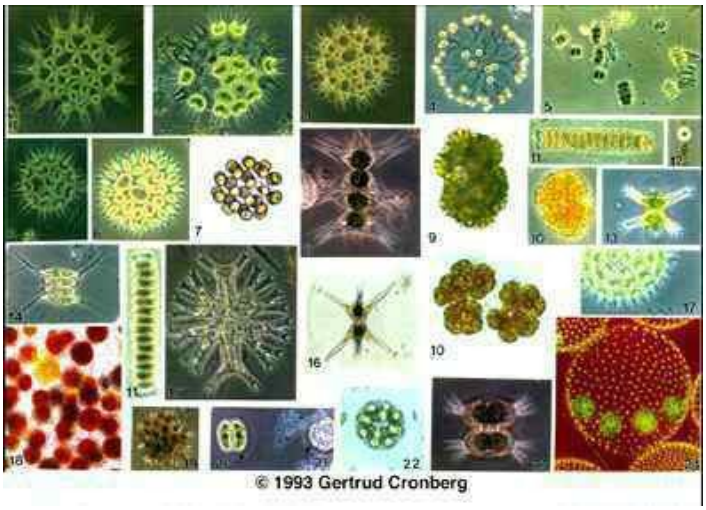


Fig – 1.9

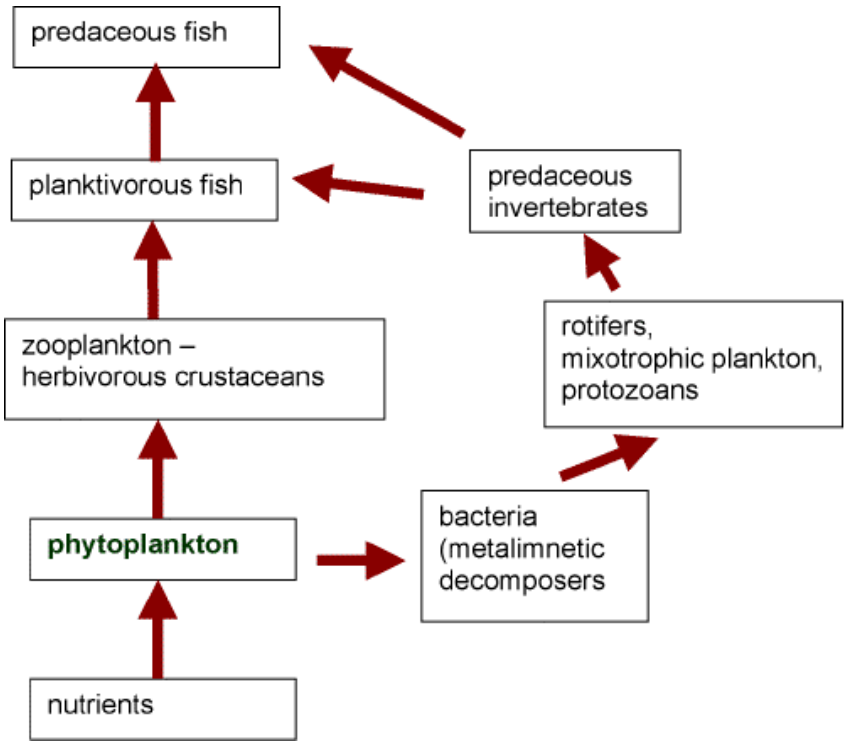


Fig- 1.10 Food webs in lakes
Courtesy:science.kennesaw.edu/.../LecBio/LecBio.html

Many factors can affect the distribution of plankton in an ecosystem, which has a detrimental effect on the rest of the ecosystem, because as mentioned, they form an essential part of the ecosystem. Phytoplanktons are more abundant in areas with a high intensity of light, as they can convert this light energy into chemical energy while higher temperatures increase growth and multiplication of the both phytoplankton and zooplankton. Elementary, the amount of available nutrients in the environment also plays a part in the distribution and density of phytoplankton.

Pollution in Freshwater Ecosystems

Fish mortality from water pollution

Fig -1.11

As with all ecosystems, the existence and operations of human society inevitably have an effect on the way of life in a freshwater community. Particularly in Western society, where a huge amount of resources are harnessed from the land to fund our lifestyle, there is a resulting effect on the ecosystems of our planet.

- Hot water is used in many industries to cool machinery. This water is removed via a discharge pipe into the river. This increase in temperature can affect the level of oxygen freely available to organisms, which, in turn affects respiration and essentially their way of life. Due to this temperature change, life in the ecosystem is affected.
- Removal of foliage next to a freshwater ecosystem allows more running water to enter its capacity. In light of this, periods of heavy rainfall can result in the water levels fluctuating wildly, which in turn can also affect the temperature of the water quite considerably not to mention all the new chemical agents that would enter the stream from this extra water.
- Recreational use of water bodies such as canoeing also has their effect. Litter from these people can sit on the surface of water and block out sunlight required by the primary producers for photosynthesis. If these primary producers way of life is affected in such a way that their population level decreases, there is a knock on effect to all those organisms who rely on these primary producers for survival.
- At a molecular level, chemicals discharged into the water, notably from industry or pesticides from farmland can affect the freshwater environment considerably. Higher concentrations of particular chemicals (perhaps toxic) mean a lower concentration of essential chemicals required by the organisms of the ecosystem. If this is the case, these organisms cannot perform respiration and function at an optimum level, thus reducing overall biomass in the ecosystem.