FRESHWATER BIOTIC COMPONENTS

Key words: Lentic, Lotic, Food chain, Monitoring

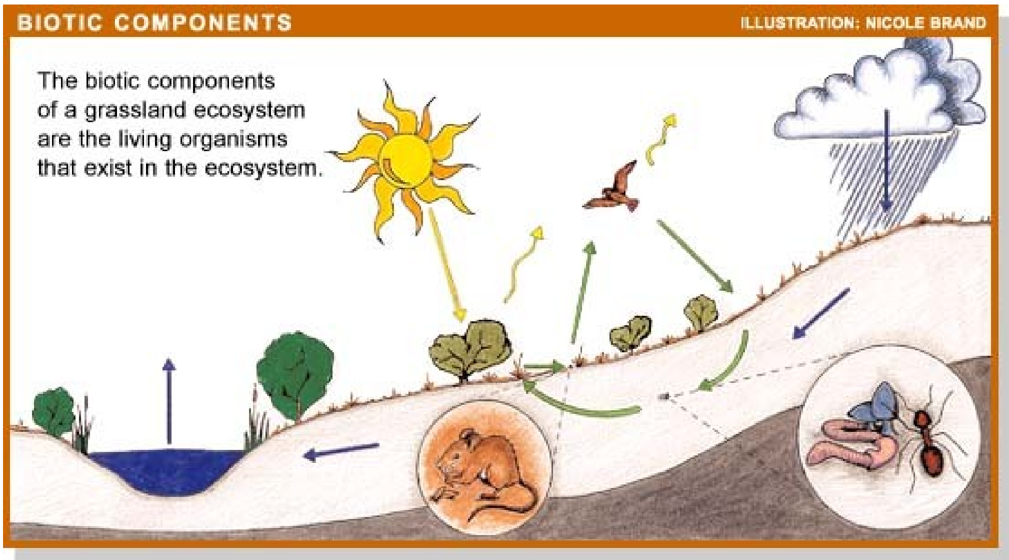

Fig – 20.1

INTRODUCTION

An ecosystem consists of the biological community that occurs in some locale, and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems - a pond, a forest, an estuary, grassland. The boundaries are not fixed in any objective way, although sometimes they seem obvious, as with the shoreline of a small pond. Usually the boundaries of an ecosystem are chosen for practical reasons having to do with the goals of the particular study. The study of ecosystems mainly consists of the study of certain processes that link the living, or biotic, components to the non-living, or abiotic, components. Energy transformations and biogeochemical cycling are the main processes that comprise the field of ecosystem ecology. As we learned earlier, ecology generally is defined as the interactions of organisms with one another and with the environment in which they occur. We can study ecology at the level of the individual, the population, the community, and the ecosystem.

Studies of individuals are concerned mostly about physiology, reproduction, development or behavior, and studies of populations usually focus on the habitat and resource needs of individual species, their group behaviors, population growth, and what limits their abundance or causes extinction. Studies of communities examine how populations of many species interact with one another, such as predators and their prey, or competitors that share common needs or resources.

Aquatic ecosystem:

Aquatic ecosystem is the most diverse ecosystem in the world. The first life originated in the water and first organisms were also aquatic where water was the principal external as well as internal medium for organisms. Thus water is the most vital factor for the existence of all living organisms. Water covers about 71% of the earth of which more than 95% exists in gigantic oceans. A very less amount of water is contained in the rivers (0.00015%) and lakes (0.01%), which comprise the most valuable fresh water resources. Global aquatic ecosystems fall under two broad classes defined by salinity – freshwater ecosystem and the saltwater ecosystem. Freshwater ecosystems are inland waters that have low concentrations of salts (< 500 mg/L). The salt-water ecosystem has high concentration of salt content (averaging about 3.5%).

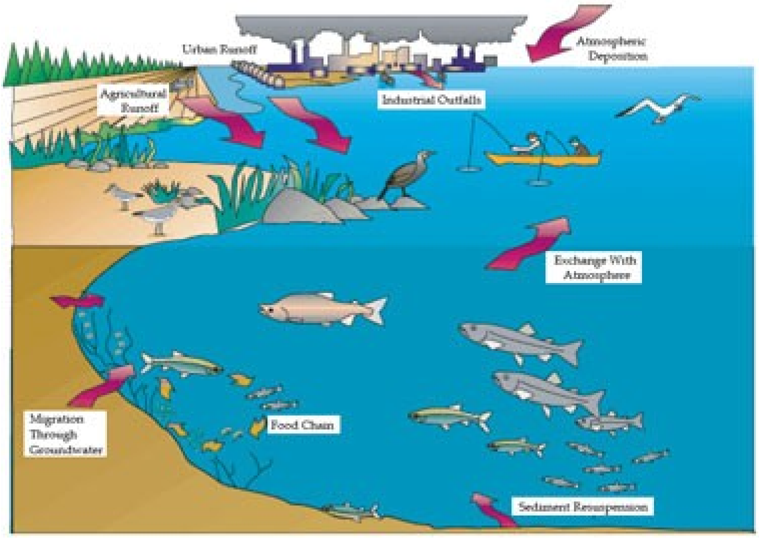

Fig – 20.2

An aquatic ecosystem (habitats and organisms) includes rivers and streams, ponds and lakes, oceans and bays, and swamps and marshes, and their associated animals. These species have evolved and adapted to watery habitats over millions of years. Aquatic habitats provide the food, water, shelter, and space essential for the survival of aquatic animals and plants. Aquatic biodiversity is the rich and harbors variety of plants and animals-from primary producers algae to tertiary consumers large fishes, intermittently occupied by zooplankton, small fishes, aquatic insects and amphibians. Many of these animals and plants species live in water; some like fish spend all their lives underwater, whereas others, like toads and frogs, may use surface waters only during the breeding season or as juveniles.

Freshwater Ecosystem:

Freshwater ecosystems cover 0.8% of the Earth's surface and contain 0.009% of its total water. They generate nearly 3% of its net primary production. Freshwater ecosystes contain 41% of the world's known fish species.

The study of freshwater habitats is known as limnology. Freshwater habitats can be further divided into two groups as lentic and lotic ecosystems based on the difference in the water residence time and the flow velocity. The water residence time in a lentic ecosystem on an average is 10 years and that of lotic ecosystem is 2 weeks. In lotic ecosystem, the average flow velocity ranges from 0.1 to 1 m/s whereas lentic ecosystems are characterized by an average flow velocity of 0.001 to 0.01 m/s (Wetzel, 2001; UNEP, 1996). The lentic habitats further differentiate from lotic habitats by having a thermal stratification with is created in a lake due to differences in densities. Water reaches a maximum density at 4^0C, a warm, lighter water floats on top of the heavier cooler water thus creating thermally stratified zones which corresponds to epilimnion, the warm layer, the hypolimnion, the colder layer separated by a barrier called thermocline. The lotic ecosystem is characterized by stream orders depending on the origin and flow and various types of stream pattern namely Dendritic, Radial, Rectangular, Centripetal, Pinnate, Trellis, Parallel, Distributory and Annular, which determines the flooding and soil erosion hazards of the region. However, the basic unity among these ecosystems is that any alteration in the catchment area of these ecosystems will affect the water quality of both lotic and lentic ecosystem. The catchment area is all land and water area, which contributes runoff to a common point, which may be a lake or a stream. The term catchment is equivalent to drainage basin and watershed (Davie, 2002; Tideman, 2000).

The term lotic (from lavo, meaning ‘to wash') represents running water, where the entire body of water moves in a definite direction. It includes spring, stream, or river viewed as an ecological unit of the biotic community and the physiochemical environment. Lotic ecosystems are characterized by the interaction between flowing water with a longitudinal gradation in temperature, organic and inorganic materials, energy, and the organisms within a stream corridor. These interactions occur over space and time.

Biological characteristics:

Lentic ecosystem:

Fig – 20.3

The biological characteristics of still water bodies may be broadly classified into – pelagic and benthic systems. Benthic system is subdivided into littoral and profundal types. The species composition of communities of all those types is greatly influenced by the nutrient status of the water concerned. The pelagic habitat is that of the open water away from the influence of shore or bottom substrate, while benthic habitat is associated with the substrate of the lake. The littoral habitat is extending from the shoreline out to the deeper water. The plankton community, phytoplankton and zooplankton, occupy the regions of high light intensities namely on the surface layer of pelagic zone and the littoral zone. Some of the zooplankton members also inhabit the benthic zone feeding on detritus and sinking phytoplankton. Fishes occupy the littoral, pelagic and occasionally profundal zones, when the dissolved oxygen content in the lake is high. Macroinvertebrates are confined to the benthic zone.

Lotic ecosystem:

In the lotic habitats, the water moves continually in one direction. The current is more pronounced at the surface than in the bottom substrate. Hence, the bottom substrate conditions are similar to lentic habitats. Often the plankton community is at the mercy of currents. In riffles and pools, the plankton exhibit the characteristics similar to lentic ecosystem. The fishes are highly adopted to resist water currents. Since the dissolved oxygen levels are high throughout the water column due to water turbulence, the fishes are distributed from surface to bottom substrate and often among the rocks (Moss, 1998).

Abiotic and Biotic components:

Abiotic factors are non-living chemical and physical properties in the environment. This would include the amount of sunlight, depth of water, substrate, temperature. Chemical properties would include the pH, salinity(dissolved minerals), polution, turbidity, etc.

The Biotic factors would be all the living and previously living components, including single cell organisms and decomposing plant and animal material. This would include the food chain/web of the biome, who eats who, prey-preditor relationship.

Food web:

As in the terrestrial ecosystem, the main source of energy in aquatic ecosystem is the solar energy. The transfer of solar energy from one community to another takes a specific path. The solar energy is trapped by the phytoplankton, the producers which inturn are consumed by the zooplankton, which are primary consumers and secondary consumers are the macro-invertebrates and planktivorous fish, which are consumed by large fishes. At each step of energy transfer, a proportion of energy is lost as heat. Thus the transfer of food energy from the source (phytoplankton) through a series of organisms that consume and are consumed is called as food chain. Food chains are of two basic types, the grazing food chain, which starts from the phytoplankton to the herbivores and carnivores and the detritus food chain that goes from non-living organic matter into microorganisms and then to detritus feeding organisms and their predators. These food chains are interconnected and often this interlinking pattern is called the food web (Figure 1).

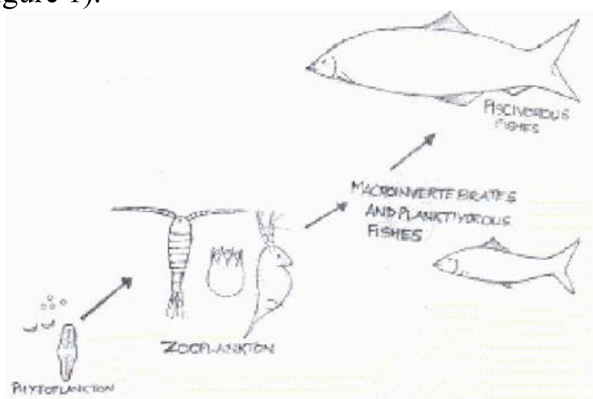

Fig – 20.4 - Plankton in Aquatic Food Chain

The term “Plankton” refers to those minute aquatic forms which are non motile or in sufficiently motile to overcome the transport by currents and living suspended in the open or pelagic water. The planktonic plants are called phytoplankton and planktonic animals are called zooplankton (APHA, 1985). Phytoplankton are the base of aquatic food webs and energy production is linked to phytoplankton primary production. Excessive nutrient and organic inputs from human activities in lakes and their watersheds lead to eutrophication, characterized by increases in phytoplankton biomass, nuisance algal blooms, loss of water clarity from increased primary production and loss of oxygen in bottom waters. The freshwater phytoplankton of the Indian region belongs to the following classes:

Cyanophyceae: Cyanophyceae comprises of prokaryotic organisms popularly known as blue-green algae. They are like gram-negative bacteria and due to the nature of the cell wall, cell structure and capacity to fix atmospheric nitrogen these are considered as bacteria and named cyanobacteria. However, they possess the oxygen evolving photosynthetic system, chlorophyll a accessory pigments and thallus organizations resembling other algae. They occur abundantly in freshwater habitats along with other groups of algae. Cyanophyceae members are broadly classified into coccoid and filamentous forms. The coccoid forms range from single individual cell to aggregates of unicells into groups or in regular or irregular colonies and pseudoparenchymatous conditions. The filament forms range from simple uniseriate filaments to heterotrichous filaments, which may be differentiated into heterocysts and akinetes (spores). These are truly cosmopolitan organisms occurring in habitats of extreme conditions of light, pH and nutritional resources. They abound various types of natural and artificial aquatic ecosystems.

Fig – 20.5

Chlorophyceae: Chlorophyceae (green algae) constitutes one of the major groups of algae occurring in freshwater habitats. The cells are typically green in colour due to the presence of chlorophyll a and b. The cells contain chloroplast of various shapes, which are dispersed differently in each group of organisms. The chloroplast also contains pyrenoids. In majority of the organisms there is a single nucleus but some genera are multinucleate. Flagellated cells are common either in the vegetative phase or reproductive units. Chlorophyceae is generally divided into several orders based on the diversity of the thallus.

Fig – 20.6

Euglenophyceae: The members are single cells, motile found swimming with the help of usually one prominent flagellum and in some cases with two flagella. In the anterior portion a gullet is visible and there are many chloroplasts in the autotrophic forms and the chloroplasts vary in shape. Euglenoid cells are covered by a proteinaceous pellicle and at times help the organisms attain various shapes. These are widely distributed in all types of water bodies specifically in organically rich aquatic ecosystems.

Fig – 20.7

Bacillariophyceae: The members belonging to this class are popularly known as diatoms. All are basically unicellular, in some cases become pseudofilamentous or aggregated into colonies. The cell wall of diatoms is impregnated with silica and several diatoms have been well preserved as microfossils. The diatom cell is also called as frustule and the classification of diatoms is based on the pattern of ornamentation on the wall of the frustule. The cells have either bilateral or radial symmetry. The frustules are composed of two halves, epitheca and hypotheca and connecting girdle bands. The valve surfaces have several types of markings. Radial symmetry forms are grouped as Centrales and bilaterally symmetric ones are Pennales.

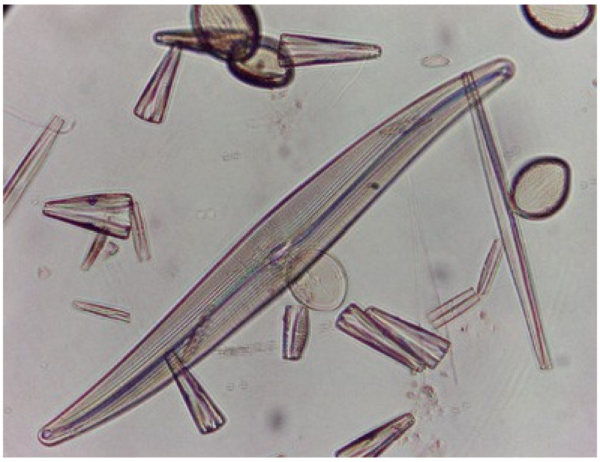

Fig – 20.8

Dinophyceae: The members are unicellular motile cells with two flagella one located in the transversely aligned groove or furrow and other in a longitudinally arranged furrow. One is considered to propel the cell and the other is called the trailing flagellum. The cells while moving forward also get rotated by the flagellar action. The motile cells have a thick pellicle instead of a cell wall, which sometimes becomes very thick, and called theca. Certain genera have thecal plates on their outer covering and called as unarmoured dinoflagellates, while others have horny projections and called armoured dinoflagellates (Anand, 1998).

Fig – 20.9

Zooplankton are the central trophic link between primary producers and higher trophic levels. The freshwater zooplankton comprise of Protozoa, Rotifers, Cladocerans, Copepods and Ostracods. Most of them depend to a large extent, on various bacterioplankton and phytoplankton for food. Many of the larger forms feed on smaller zooplankton, forming secondary consumers. Some of them are detritivore feeders, browsing and feeding on the substrate attached organic matter, phytoplankton or concentrating on the freely suspended organic matter particles or those lying on the bottom sediment. Many of these organisms are also fish food organisms and are consumed by the other aquatic macrofauna. The freshwater zooplankton is mainly constituted of five groups:

Protozoans (first animals): A very diverse group of unicellular organisms are found in this major zooplanktonic community. Most of the protozoans are usually not sampled due to their minute size. Planktonic protozoans are limited to ciliates and flagellates. Among the unicellular protozoa, the heterotrophic nanoflagellates are the major consumers of free-living bacteria and other smaller heterotrophic nanoflagellates. The abundant heterotrophic nanoflagellates (105 to 108 /L in highly eutrophic lentic ecosystems) range in size from about 1.0 to about 20 µm. They include non-pigmented species that structurally have very closely related pigmented species in the phytoplankton. The ciliates are larger in size (8 µm to 300 µm) but are less abundant (102 to 104 /L). While the smallest planktonic ciliates feed on the picoplankton, the larger ciliates feed on the heterotrophic nanoflagellates and small nanophytoplankton. Among the ciliates, those containing captured chloroplasts from the ingested algae or those containing more permanent symbiotic green algae (zoochlorellae) are common. Among the protozoans are two orders of amoebae that are primarily associated with the sediments and littoral aquatic vegetation and large numbers of meroplanktonic species (Edmondson, 1959; Battish, 1992).

Fig – 20.10

Rotifers (wheel bearers): Rotifers, typically an order of magnitude less abundant the protozoans, are the most important soft-bodied metazoans (invertebrates) among the plankton. Their name comes from the apparently rotating wheels of cilia, known as corona, used for locomotion and sweeping food particles towards the mouth. The mouth is generally anterior and the digestive tract contains a set of jaws (trophi) to grasp the food particles and crush them. Relatively few (about 100) ubiquitous rotifer species are planktonic and a much larger number (about 300) are sessile and are associated with sediments and the vegetation of the littoral zones. Planktonic rotifers have a very short life cycle under favourable conditions of temperature, food and photoperiod. Since the rotifers have short reproductive stages they increase in abundance rapidly under favourable environmental conditions (Dhanapathi, 2000).

Fig – 20.11

Crustaceans: This group comprises of members all belonging to the well-known Phylum Arthropoda. This is the largest phylum in terms of number of species and among zooplankton holds the highest position both in terms of systematics and as secondary consumers in the food chain. In healthy habitats wherein external influences of pollution are absent or at least low, members of this group constitute a sizeable population.

Fig – 20.12

Cladocerans (Branched horns): Cladocerans are a crucial group among zooplankton and form the most useful and nutritive group of crustaceans for higher members of fishes in the food chain. Cladocerans are normally covered by the chitinous covering termed as the carapace. The two large second antennae are responsible for giving the cladocerans their common name, water fleas and are used for rowing through the water. Cladocerans are filter feeders as they filter the water to trap the organisms in it. Cladocerans are highly sensitive against even low concentrations of pollutants. The food source of this group is smaller zooplankton, bacterioplankton and algae (Murugan, 1998).

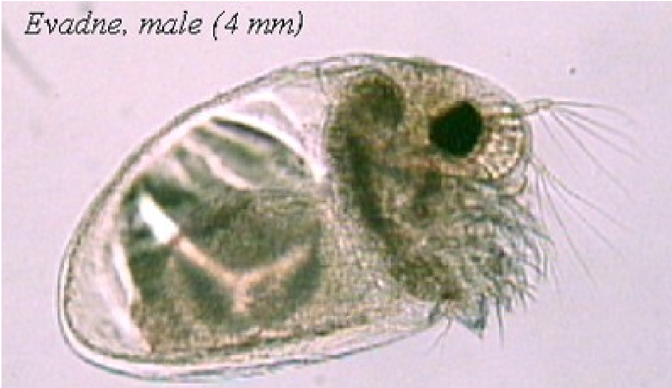

Fig – 20.13

Copepods (Oar foot): The copepods comprise of calanoids, cyclopoids and harpacticoids. The copepods also form important organisms for fish and are influenced by negative environmental factors as caused by excessive human interference in water bodies but to a lesser extent than the cladocerans. Copepods are much more hardier and strongly motile than all other zooplankton with their tougher exoskeleton and longer and stronger appendages. They have long developmental time and a complex life history with early larval stages difficult to distinguish. They are almost wholly carnivorous on the smaller zooplankton for their food needs. Among the three orders of copepods, cyclopoid copepods are generally predatory on (carnivorous) on other zooplankton, and fish larvae. The cyclopoid copepods also feed on algae, bacteria and detritus. The second group of copepods, calanoid copepods change their diet with age, sex, season, and food availability. The calanoid copepods are omnivorous feeding on ciliates, rotifers, algae, bacteria and detritus. The third group harpacticoid copepods are primarily benthic. Copepods, in general can withstand harsher environmental conditions as compared to cladocera (Kalff, 2002).

Fig – 20.14

Ostracods (Shell like): The Ostracods are bivalved organisms and belong to phylum Arthropoda. They mainly inhabit the lake bottom and among macrophytes and feed on detritus and dead plankton. Ostracods are in turn consumed by fishes and benthic macroinvertebrates (Chakrapani, 1996).

Fig – 20.15

Biotic Components

Biotic components refer to the living world of an ecosystem. Different components are connected through food and various other relations. Food is a source of energy to the body to perform functions and is essential for the growth and body building. Initially in all cases the pathway of food in every ecosystem is:

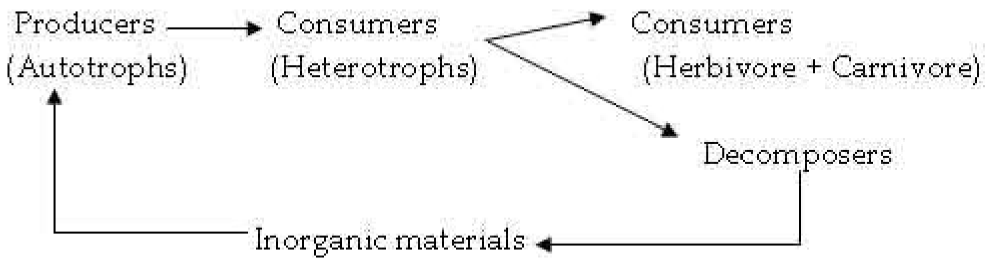

Fig.20.16 Schematic representation of food web

Producers.

Green plants are called producers. They produce carbohydrates by photosynthesis and also synthesize proteins and fats. Producers are also called produce carbohydrates by photosynthesis and also synthesize proteins and fats. Producers are also called transducers as they are able to change radiant energy to chemical form. All the other organisms (heterotrophs) depend upon producers for their survival. Besides this producers also maintain CO_2/O_2 balance of nature.

Consumers.

The animals which consume energy produced by producers as food are called consumers. They are also called phagotrophs. Consumers are differentiated into two categories - herbivores and carnivores.

Trophic Interactions in Aquatic Food Chain :

In most aquatic food chains, the community interactions are often controlled by abiotic factors or predation at higher levels of food chain. The control of primary production by abiotic factors such as nutrients is called "bottom-up control". The control of primary production by the upper levels of food chain is referred to as "top-down control". The idea that predation at upper levels of food chain can have cascading effect down through the food chain is called the "trophic cascade" (Dodds, 2002). The bottom-up hypothesis requires that the biomass of all trophic levels is positively correlated and depend on fertility (limiting resources) of the habitat. The schematic representation of bottom-up control is given in Figure 3.

More available nutrients → more algae → more zooplankton → more planktivorous fish → More piscivorous fish.

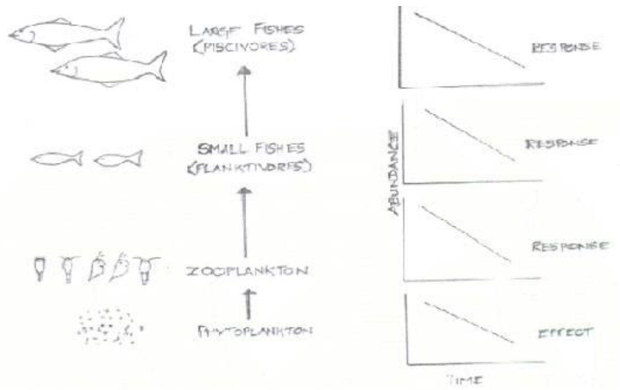

Fig- 20.17 - Bottom up control in the aquatic ecosystem

The top-down hypothesis predicts, however, that the adjacent trophic levels will be negatively correlated. The schematic representation of top-down control is given figure 4.
More piscivorous fish → fewer planktivorous fish → more zooplankton → fewer phytoplankton → more available nutrients

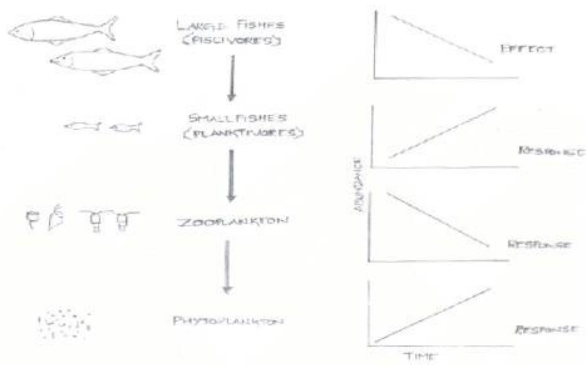

Fig – 20.18 - Top down control in the aquatic ecosystem

Any disturbance to the water body due to over-exploitation of fish resources or due to various anthropogenic activities leads to deterioration of the water quality and hence will have an impact on the communities in the aquatic ecosystem (Lampert and Sommer, 1997). Biomonitoring the water bodies at regular intervals does help to understand the implications of water quality on trophic structure and vice versa.

Monitoring Of Water Bodies:

With the advent of industrialization and increasing populations, the range of requirements for water has increased together with greater demands for higher water quality . Industrialization coupled with intensive agriculture in early 1980's to meet the growing demand of ever increasing populations, the range of requirements for water has increased manifolds. In addition to many intentional water uses, there are several human activities, which have indirect and undesirable, if not devastating, effects on the aquatic environment, which include uncontrolled and unplanned land use for urbanization or deforestation, accidental (unauthorized) release of chemical substances, discharge of untreated waste or leaching of noxious liquids form solid waste deposits. Similarly, uncontrolled and excessive use of fertilizers and pesticides for agricultural purposes has long-term effects on the ground and surface water resources.

In order to protect the water resources from continuing deterioration, and to supply higher quality water for human consumption, there is a need to assess the quality of water. The main reason for assessment of quality of aquatic environment has been to verify whether the observed water quality is suitable for intended use. The overall process of evaluation of physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly the uses which may affect human health and health of the aquatic ecosystem itself is termed as water quality assessment (UNEP, 1996).

Water quality assessment includes the use of monitoring to define the condition of water, to provide the basis of detecting trends and to provide the information enabling the establishment of cause-effect relationship. Thus the water quality assessment program aims:
To provide water quality details to decision makers and public on the quality of freshwater relative to human and aquatic ecosystem health and specifically, to define the status of water quality.

To identify and quantify trends in water quality

To define the cause of observed conditions and trends

To identify the types of water quality problems that occurs in specific geographic areas.

To provide the accumulated information and assessment in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions.

To begin the monitoring of freshwater resources, there is always a need for preliminary survey. A survey of a water body is done with specific objectives. A finite duration, intensive program to measure and observe the quality of the aquatic environment for a specific purpose is termed as a survey. A physicochemical approach to monitor water pollution gives the causes and levels of pollutants in the water body. Biological approach highlights the impact of pollution on the aquatic biota and on the overall status of the water body. However, a combined approach depicts a comprehensive picture of the water quality and aquatic biota enabling effective interpretation and proper decision-making.

Source:
http://nptel.ac.in/courses/120108002/20