Unit I

AQUATIC BIOMES

A) Freshwater Ecosystem

Lakes

Wetlands

Streams

Rivers

B) Estuaries

C) Intertidal Zones

D) Oceanic Pelagic Zone

E) Marine Benthic Zone

F) Coral Reefs

A) Freshwater Ecosystem

Most of the Earth Surface (around 70%) is covered with water, but not all the water is freshwater. Only 3.5% is freshwater, and the rest 96.5% is saltwater in the form of oceans.

The Freshwater is found in the form of ponds, lakes, streams, frozen water, etc. other than oceans and seas. The freshwater ecosystem plays an important role in biodiversity.

Freshwater Ecosystem Definition

An ecosystem characterized by low-salt content, making a suitable environment for various plants and animals is known as a freshwater ecosystem.

Types of Freshwater Ecosystem

The freshwater ecosystem is mainly divided into three types based on its region – **Lotic, lentic, and wetland freshwater ecosystem.**

Lotic Freshwater Ecosystem

In simple terms, the water bodies moving in one direction is known as a lotic freshwater ecosystem. Rivers and streams are common examples of lotic ecosystems.

Lentic Freshwater Ecosystem

An aquatic ecosystem within stagnant or still water like ponds and lakes is known as Lentic Freshwater Ecosystem. Lentic ecosystem found in various sizes ranging from a few square meters to thousands of square km.

Wetland Freshwater Ecosystem

Wetlands are still water bodies that support vascular plants. Marshes, swamps, and bogs are commonly known as wetland ecosystems. Wetlands are quite productive due to the proximity of water and soil.

The plant species found in the wetlands are known as hydrophytes as they have adapted the moist and humid environment of the region. The common hydrophyte plants found in the wetland ecosystem include cattails, tamarack, pond lilies, sedges, black spruce, etc.

As far as animal species are a concern, wetlands provide shelter to various amphibians, reptiles, birds, shrimp, shellfish, etc.

Freshwater Ecosystem Characteristics

- The freshwater ecosystem is a habitat for various plant and animal species. One of the major reasons is that it is quite rich in terms of nutrition and minerals.
- The freshwater ecosystem is less saline, unlike the marine ecosystem.
- The temperature in this ecosystem varies depending on some factors like location, season, and depth from the water surface.
- During summers, the temperature of the freshwater ecosystem generally ranges from 30-71 degrees Fahrenheit. Whereas during winters, the temperature ranges from 35-45 degrees Fahrenheit.
- The size and shape of freshwater ecosystems vary depending on location, an area covered, and depth of water bodies.
- The freshwater ecosystem contains sediments at the bottom. In gentle flowing freshwater bodies or still water bodies, the sediments remain in place.
- The freshwater ecosystem provides a suitable environment for various species of flora and fauna.

Freshwater Ecosystem Animals

The freshwater ecosystem provides a perfect environment for various animal species. Some animals of freshwater prefer moving water bodies like rivers, whereas some others prefer to live in stagnant water like ponds, lakes, wetlands, etc.

Fishes

Fishes are the most common species of the freshwater ecosystem. Some fishes like salmon, trout, etc. prefer to live in moving clean water with a high level of oxygen. On the other hand, small muddy ponds provide an ideal environment for fishes like catfish, carp, etc.

Some freshwater fishes like pike and sturgeon require a large area to live as they grow large. Big lakes are a perfect place for these fishes.

Mammals, amphibians, and Reptile

Various species of mammals are also living in a freshwater ecosystem such as beavers, otters, etc. Most of the mammals live in small water bodies like lakes. This type of ecosystem is preferable for these mammals because they come to shores to reproduce, feed and breathe.

Amphibians like frogs, salamanders belong to wetlands. The freshwater ecosystem is also a home for some species of reptiles like an alligator, turtle, snakes, etc. These reptiles live in a stagnant freshwater ecosystem.

Birds

Some birds are also a part of the freshwater ecosystem. Ducks, geese, etc. are commonly found in lakes, rivers, etc. On the other hand, some birds such as swallows belong to swamps and ponds. The birds like swallows are insect-eating, and swamps are an ideal shelter for these birds. It provides a good source of food.

Insects

This ecosystem is also a home for various species of insects such as mosquitoes, dragonflies, bees, wasps, water spiders, etc.

Freshwater ecosystem not only thrive a wide range of plant and animal species but also plays a vital role in our everyday life. Freshwater is the main source of water for us to fulfill our need for water to perform numerous tasks.

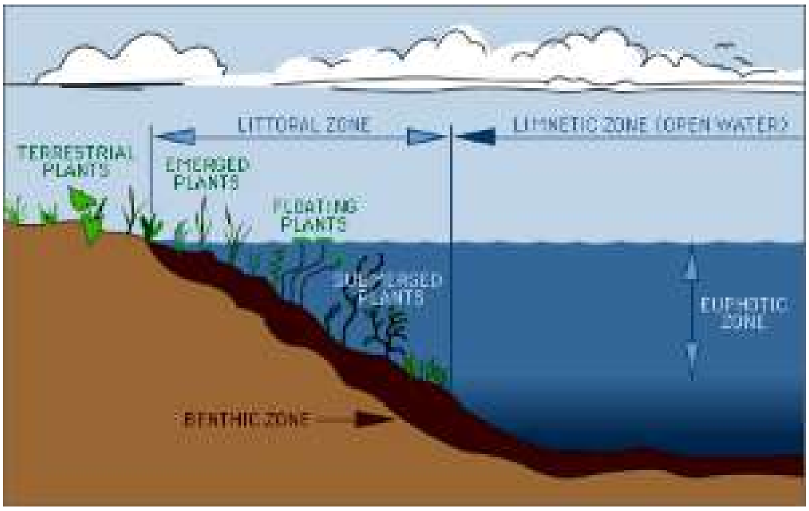
Lakes

Freshwater (FW) pond and lake ecosystems are open water bodies with water depths greater than 2 metres and little to no floating vegetation. The difference between a pond and a lake is size: ponds are smaller than 50 hectares, and lakes are bigger than 50 hectares. Freshwater ponds and lakes are influenced by groundwater, precipitation, stream flow and evaporation.

They often form complex inter-relationships with the linear riparian ecosystems along their shorelines, as well as with wetland ecosystems that are nearby.

Open freshwater ecosystems include both ponds and lakes. A pond or lake ecosystem consists of four distinct habitats: shore, surface film, open water, and bottom water. Each provides conditions that support different kinds of organisms with specific adaptations. There is considerable variability in the available habitats. For example, bottom water conditions are variable as they are greatly influenced by substrate and depth. Shallow sandy bottoms provide a nesting environment for earthworms, snails, and insects, while the more muddy conditions of deep bottom water supports flatworms, rat-tailed maggots, and dragonfly nymphs. All open freshwater ecosystems provide critical breeding habitat for invertebrates, amphibians, and fish. These water bodies are also valuable habitat for many resident birds and also a stopover for migrating species. They are a rich source of nutrients for many aquatic and terrestrial species—and a vital source of drinking water for all.

Ecology of lakes



The biodiversity of lakes can differ greatly, not only between lakes but also within a single lake. Two key factors that determine the biodiversity in lakes are:

1. The physical and chemical conditions within a lake and tolerances of different species to those conditions
2. The abilities of different species to disperse into a lake.

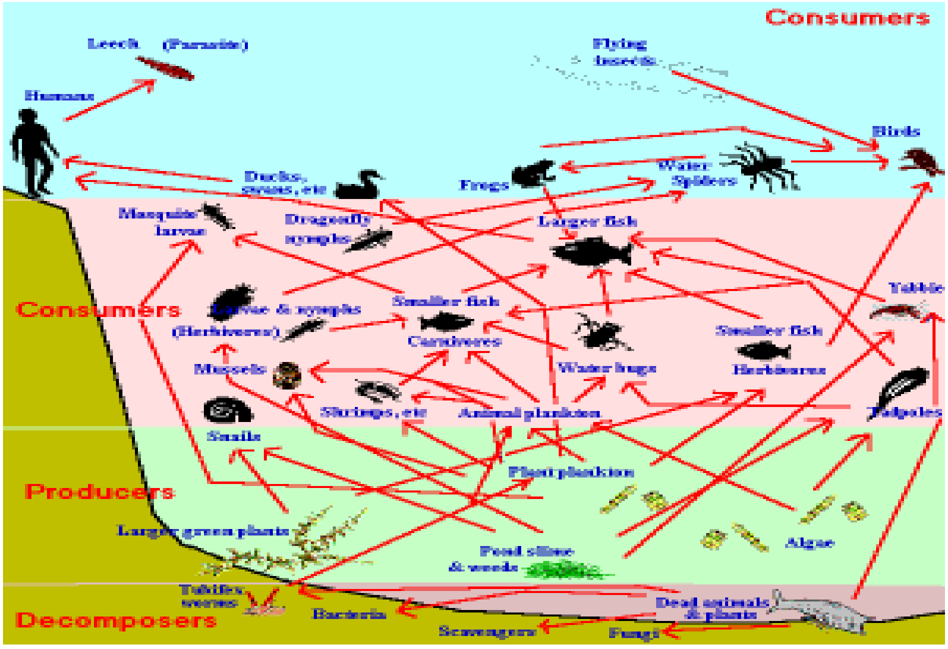
Ecological zones

Generally four major ecological zones are identified in lakes (see figure on zones in standing water), providing different conditions for biodiversity:

- The littoral zone is the nearshore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. The littoral community is considered the most diverse and abundant biological community in lakes.
- The euphotic zone of the lake is the layer from the surface down to the depth at which light levels become too low for photosynthesis. Light intensity usually decreases exponentially with depth, due to absorption and attenuation by phytoplankton, suspended particles and dissolved organic matter. The limit for photosynthesis is the depth where around 1% of the incident light intensity at the water surface is still available.
- The limnetic zone is the open water area where light does not generally penetrate all the way to the bottom.
- The benthic zone is the surface layer of the bottom, with sediments abundant with organisms. This upper layer may be mixed by the activity of the benthic organisms that live there, often to a depth of 2-5 cm in rich organic sediments.

The zonation can be seen to be largely determined by the light extinction curve in the water column. If the light extinction coefficient increases, e.g. due to increased sediment resuspension or to massive algal blooms, the spatial delineation of the major ecological zones will also change: the littoral zone will shrink and the euphotic layer will narrow. Populations of macrophytes, phytoplankton and zooplankton will follow these changes in their distribution. Also fish and benthic life will be affected because the flux of organic matter (food) to the sediment will change.

Lake food webs



Aquatic plants and animals interact with each other through a series of interconnecting pathways called a food web. The various levels in the food web or chain are called trophic levels, each of which represents a different type of productivity. The interconnection between the trophic levels is often very complex and dependent on the local lake situation.

At the basis of the food web in the aquatic environment starts we find the primary producers: phytoplankton (predominantly algae) and macrophytes that use sunlight, water and nutrients for photosynthesis. When either light or nutrients (or both) are in short supply, photosynthesis will be limited. In the littoral zone, where the water is shallow enough for macrophytes to occur, macrophytes and algae are in competition for light and nutrients. Primary production rates of macrophytes and algae, as well as the outcome of their competition, can be fundamentally changed by altering nutrient loading of the lake.

Phytoplankton is the primary food for many species of filter-feeding zooplankton (e.g. Cladocerans) and filter feeding benthos (e.g. Dreissena mussels). Zooplankton in turn is eaten by planktivores that include fish as well as a variety of aquatic insect larvae. The piscivores, fish-eating fish, are at the top of the aquatic food web. Extending the food web to the terrestrial environment, it becomes even more complex, with a multitude of relationships with birds, reptiles, amphibians, mammals, spiders, insects and man.

Food webs of lakes can be fuelled by internal production, i.e. photosynthesis by plants and algae, but also by external production, i.e. carbon inputs from surrounding land.

Macrophytes

Macrophytes (large multicellular plants in lakes) play a very important role in the lake ecosystem. They add structure to the aquatic environment and support an abundance of life. In the littoral zone, many fish build nests in the vegetation and young fish find protection among the plants from predators. A multitude of aquatic insects (food for many fish) live on and feed among the plants. They also produce oxygen, which assists with overall lake functioning.

Macrophytes may be classified into several groups based on whether they are rooted (attached to substrate) or floating, and whether all parts remain submerged or some parts emerge out of the water (emergent).

The absence of macrophytes may indicate water quality problems as a result of excessive turbidity, herbicides or salinization. This may result in a reduced population of (sport and forage) fish and waterfowl (Crowder and Painter, 1991). An overabundance of macrophytes as a result of high nutrient levels may also interfere with the ecosystem services that a lake can provide, e.g. recreational activities (swimming, fishing, boating) and aesthetic appeal.

Microbial organisms

Microbial organisms present in most lakes include unicellular and colonial algae, rotifers, protozoa, bacteria and blue-green algae. Photosynthetic algae that float freely within the limnetic zone are referred to as phytoplankton. Dense blooms of phytoplankton may occur in lakes where nutrients are abundant, turning the lake turbid and green (eutrophic lakes).

Invertebrates

The invertebrate fauna of lakes mainly consists of crustaceans, molluscs, oligochaete worms and adults, larvae or nymphs of insects. The tiny animals suspended in the water column are called zooplankton. Like phytoplankton, these species have developed mechanisms that keep them from sinking to deeper waters, including drag-inducing body forms and the active flicking of appendages such as antennae or spines.

The invertebrates that inhabit the benthic zone are numerically dominated by small species and are species-rich compared to the zooplankton of the open water. They include crustaceans (e.g. crabs, crayfish, and shrimp), molluscs (e.g. clams and snails) and numerous types of insects. These organisms are mostly found in the vegetation of the littoral and euphotic zone, where the richest resources, highly oxygenated water, and warmest portion of the ecosystem are found. The structurally diverse macrophyte beds are important sites for the accumulation of organic matter, and provide an ideal habitat. The sediments and plants also offer protection from predatory fish.

Vertebrates

A variety of vertebrate animals live in and around lakes. Species composition is very much dependent on the local situation.

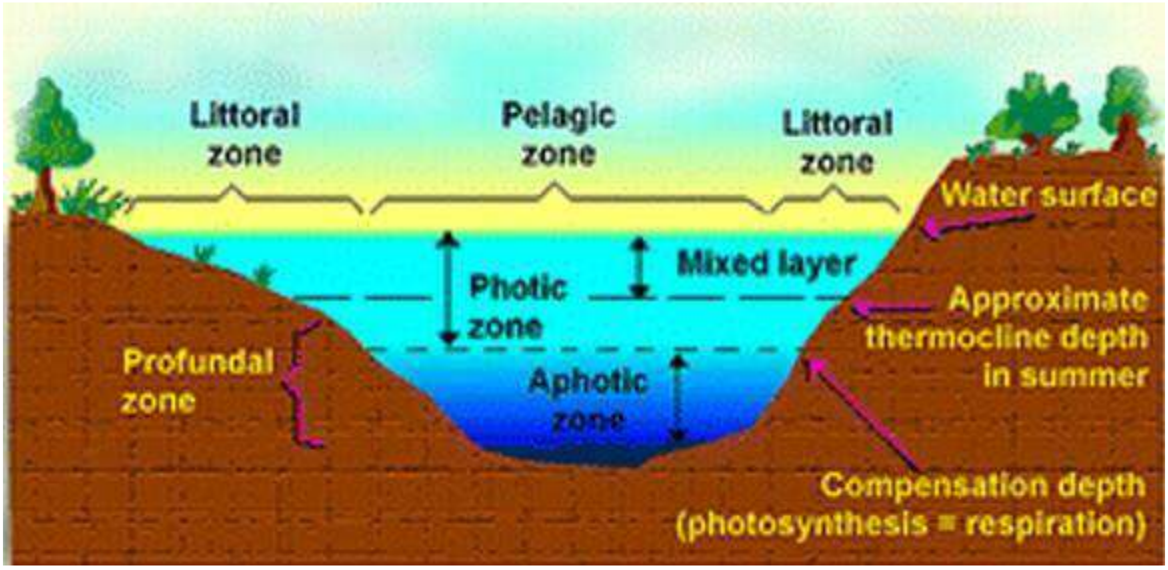
Fish are a notable species group in lakes, and represent an important part of the ecosystem services that lakes deliver. Fish species have specific physiological tolerances and preferences in temperature, dissolved oxygen concentrations, and spawning needs. Because fish are highly mobile, they are able to deal with unsuitable abiotic factors in one zone by simply moving to another.

Other vertebrate taxa of lakes include amphibians (e.g. salamanders and frogs), reptiles (e.g. snakes, turtles, and alligators), and a large number of waterfowl species. Most of these vertebrates spend part of their time in terrestrial habitats and thus are not directly affected by abiotic factors in the lake or pond. However, food shortage in the aquatic environment can severely affect waterfowl, for instance, which are heavily dependent on the food source that delta waters normally provide.

Wetlands

Wetland Ecosystem

- Wetlands are areas of marsh or peatland with water that is static or flowing, fresh, brackish or saline, including areas of marine water the depth of which at low tide does not exceed 6 m.
- Wetlands are **transition zones (ecotone)** between terrestrial and aquatic ecosystems.
- E.g. Mangroves, lake littorals (marginal areas between highest and lowest water level of the lakes), floodplains (areas lying adjacent to the river channels beyond the natural levees and periodically flooded during high discharge in the river) and other marshy or swampy areas.



- These habitats experience periodic flooding from adjacent deepwater habitats and therefore supports plants and animals specifically adapted to such shallow flooding or waterlogging.

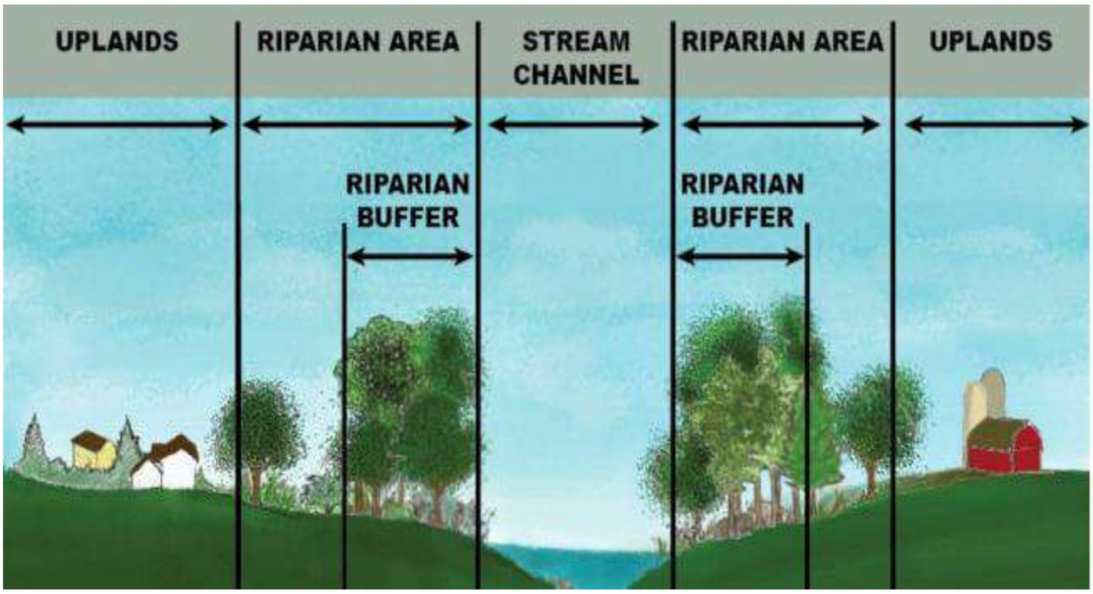
- Waterlogged soil adapted plant life (**hydrophytes**), and **hydric soils (not enough O_2)** are the chief characteristics of wetlands.
- India has over 27,000 wetlands, of which 23,000+ are inland wetlands, and around 4000 are coastal wetlands.
- Wetlands occupy 18.4% of the country's area of which 70% are under **paddy cultivation**.
- Natural wetlands in India range from high altitude wetlands in the Himalayas; flood plains of the major river systems; saline and temporary wetlands of the arid and semi-arid regions; coastal wetlands such as lagoons, backwaters, estuaries, mangroves, swamps and coral reefs, and so on.

Distinction from Lakes

- Lakes are generally **less important** when compared to wetland from the viewpoint of ecosystem and biodiversity conservation.
- There is no clear distinction between lakes and wetlands. Wetlands are shallow water bodies whereas lakes can be deep or shallow.
- National Lake Conservation Programme (NLCP) considers lakes as standing water bodies which have a minimum water depth of **3 m**, generally cover a water spread of **more than ten hectares** and have **no or very little aquatic vegetation**.
- Wetlands (generally less than 3 m deep over most of their area) are usually **rich in nutrients** (derived from surroundings and their sediments) and have **abundant growth of aquatic macrophytes** (an aquatic plant large enough to be seen by the naked eye).
- They **support high densities and diverse fauna**, particularly birds, fish and macro invertebrates, and therefore, have high value for biodiversity conservation.
- Excessive growth of macrophytes (both submerged and free-floating) in wetlands affects the water quality adversely and interfere with the utilisation of the water body.
- However, marginal aquatic vegetation is desirable as it checks erosion, serves habitat for wildlife and helps improve water quality.

Importance of Wetlands

- Wetlands are indispensable for the countless benefits or "ecosystem services" that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation.
- Wetlands are habitat to aquatic flora and fauna, numerous species of native and **migratory birds**.
- Wetlands are an important resource for sustainable tourism.
- They carry out water purification, filtration of sediments and nutrients from surface water.
- They help in nutrients recycling, groundwater recharging and stabilisation of local climate.
- Play an important role in flood mitigation by controlling the rate of runoff.
- Buffer (act as a riparian buffer) shorelines against erosion and pollutants.
- They act as a genetic reservoir for various species of plants (especially rice).



Reasons for depletion

- Excessive pollutants (Industrial effluents, domestic waste, agricultural runoff etc.) are dumped into wetlands beyond the recycling capacity.
- Habitat destruction and deforestation create ecological imbalance by altering the population of wetland species.
- Conversion of wetlands for agriculture and encroachment by public and mafia.

- Overfishing and fish farming (Aquaculture).
- Overgrazing in marshy soils.
- Removal of sand from beds near seas makes the wetland vulnerable to wave action and tidal bore.

Streams

Freshwater Streams & Ecosystem Components

Stream Ecosystem Definition

A stream is a general term as a small channel of freshwater that contains flowing water. They can be both natural and artificial. Many streams are "offshoots" of larger bodies of water like lakes or rivers. Natural streams are further classified as when they flow, where they flow from and if they're continuous.

Perennial streams flow all year long while *seasonal streams* are only seen at certain times of year, usually in wet season or as a result of snow or ice melting.

Continuous streams flow without stopping until they reach an endpoint or another body of water. *Interrupted steams*, on the other hand, may have breaks or different reaches depending on seasonality, barriers and other factors.

Abiotic Factors

Abiotic factors are defined as nonliving things that affect and shape an ecosystem. In a freshwater ecosystem like a stream, the following are going to be some of the most important abiotic factors:

- Temperature
- Sunlight levels
- pH level of the water
- Vitamins and minerals in the water
- Precipitation levels
- Water clarity
- Water chemistry

Chemistry of the water including pH levels along with abiotic nutrients in the water (minerals, chemicals, gases, etc.) are some of the most important factors in a freshwater ecosystem like a stream. Organisms depend on these nutrients in order to live, which is what will keep the stream a balanced and healthy community.

If pH levels are changed, nutrients become imbalanced, pollutants/toxins enter, light levels decrease or if there are any other changes to these abiotic factors, the organisms that have adjusted to their stream environment will no longer be able to survive. This will cause a chain reaction of organismal death and further imbalance of the abiotic factors and the ecosystem overall.

Biotic Factors

Biotic factors are all of the living things and factors within an ecosystem. This includes things as tiny as microscopic bacteria found at the banks of the stream to the huge bears that hunt for fish in the stream's water.

According to the U.S. Geological Survey, there are three key and dominant biotic factors that make up a stream ecosystem: fish, invertebrate species and algae.

Algae is perhaps the most important biotic factor since these autotrophs are responsible for turning the sun's energy that penetrates the water's surface into usable chemical energy and biomass via photosynthesis.

Without this freshwater algae, there would be no way for energy to enter the ecosystem. Other primary producers can exist in these ecosystems as well including trees along the banks, water lilies, duckweed, cattails and more.

Invertebrate Species

Invertebrate species that are important to freshwater ecosystems like streams generally include segmented worms, arthropods and mollusks. Some specific examples include the common earthworm, leeches, water beetles, mayflies, dragonflies, mussels and more.

Fish Species

Fish species are another critical biotic factor that make up stream communities. These fish will eat both the algae and the invertebrate species in the water. They'll also provide food for larger fish as well as other organisms in surrounding communities like bears and foxes.

Other animal species common in streams include crayfish, spiders, frogs, water snakes and bird species (ducks, kingfishers, etc). **Other organisms** like plankton and various species of protists are also biotic factors relevant in a stream ecosystem.

Rivers

River ecosystems are flowing waters that drain the landscape, and include the biotic (living) interactions amongst plants, animals and micro-organisms, as well as abiotic (non-living) physical and chemical interactions of its many parts. River ecosystems are part of larger watershed networks or catchments, where smaller headwater streams drain into mid-size streams, which progressively drain into larger river networks. The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow-moving water of pools. These distinctions form the basis for the division of rivers into upland and lowland rivers.

River ecosystems are prime examples of lotic ecosystems. *Lotic* refers to flowing water, from the Latin *lotus*, meaning washed. Lotic waters range from springs only a few centimeters wide to major rivers kilometers in width.

Abiotic components (non-living)

The non-living components of an ecosystem are called abiotic components. E.g. stone, air, soil, etc.

Unidirectional water flow is the key factor in lotic systems influencing their ecology. Stream flow can be continuous or intermittent, though. Stream flow is the result of the summative inputs from groundwater, precipitation, and overland flow. Water flow can vary between systems, ranging from torrential rapids to slow backwaters that almost seem like lentic systems. The speed or velocity of the water flow of the water column can also vary within a system and is subject to chaotic turbulence, though water velocity tends to be highest in the middle part of the stream channel.

Light

Light is important to lotic systems, because it provides the energy necessary to drive primary production via photosynthesis, and can also provide refuge for prey species in shadows it casts. The amount of light that a system receives can be related to a combination of internal and external stream variables.

Temperature

Most lotic species are poikilotherms whose internal temperature varies with their environment, thus temperature is a key abiotic factor for them. Water can be heated or cooled through radiation at the surface and conduction to or from the air and surrounding substrate. Shallow streams are typically well mixed and maintain a relatively uniform temperature within an area. In deeper, slower moving water systems, however, a strong difference between the bottom and surface temperatures may develop.

Water chemistry in river ecosystems varies depending on which dissolved solutes and gases are present in the water column of the stream. Specifically river water can include, apart from the water itself,

- dissolved inorganic matter and major ions (calcium, sodium, magnesium, potassium, bicarbonate, sulphide, chloride)
- dissolved inorganic nutrients (nitrogen, phosphorus, silica)
- suspended and dissolved organic matter
- gases (nitrogen, nitrous oxide, carbon dioxide, oxygen)
- trace metals and pollutants

Dissolved ions and nutrients

Dissolved stream solutes can be considered either *reactive* or *conservative*. Reactive solutes are readily biologically assimilated by the autotrophic and heterotrophic biota of the stream; examples can include inorganic nitrogen species such as nitrate or ammonium, some forms of phosphorus (e.g., soluble reactive phosphorus), and silica. Other solutes can be considered conservative, which indicates that the solute is not taken up and used biologically; chloride is often considered a conservative solute. Conservative solutes are often used as hydrologic tracers for water movement and transport. Both reactive and conservative stream water chemistry is foremost determined by inputs from the geology of its watershed, or catchment area. Stream water chemistry can also be influenced by precipitation, and the addition of pollutants from human sources. Large differences in chemistry do not usually exist within small lotic systems due to a high rate of mixing. In larger river systems, however, the concentrations of most nutrients, dissolved salts, and pH decrease as distance increases from the river's source.

Dissolved gases

In terms of dissolved gases, oxygen is likely the most important chemical constituent of lotic systems, as all aerobic organisms require it for survival. It enters the water mostly via diffusion at the water-air interface. Oxygen's solubility in water decreases as water pH and temperature increases. Fast, turbulent streams expose more of the water's surface area to the air and tend to have low temperatures and thus more oxygen than slow, backwaters.[3] Oxygen is a byproduct of photosynthesis, so systems with a high abundance of aquatic algae and plants may also have high concentrations of oxygen during the day. These levels can decrease significantly during the night when primary producers switch to respiration. Oxygen can be limiting if circulation between the surface and deeper layers is poor, if the activity of lotic animals is very high, or if there is a large amount of organic decay occurring.

Suspended matter

Rivers can also transport suspended inorganic and organic matter. These materials can include sediment or terrestrially-derived organic matter that falls into the stream channel.Often, organic matter is processed within the stream via mechanical fragmentation, consumption and grazing by invertebrates, and microbial decomposition. Leaves and woody debris recognizable coarse particulate organic matter (CPOM) into particulate organic matter (POM), down to fine particulate organic matter. Woody and non-woody plants have different in stream breakdown rates, with leafy plants or plant parts (e.g., flower petals) breaking down faster than woody logs or branches.

Biotic components

The living components of an ecosystem are called the biotic components. Streams have numerous types of biotic organisms that live in them, including bacteria, primary producers, insects and other invertebrates, as well as fish and other vertebrates.

A biofilm is a combination of algae (diatoms etc.), fungi, bacteria, and other small microorganisms that exist in a film along the streambed or the benthos. Biofilm assemblages themselves are complex, and add to the complexity of a streambed.

The different biofilm components (algae and bacteria are the principal components) are embedded in an exopolysaccharide matrix (EPS), and are net receptors of inorganic and organic elements and remain submitted to the influences of the different environmental factors.

Microorganisms

Bacteria are present in large numbers in lotic waters. Free-living forms are associated with decomposing organic material, biofilm on the surfaces of rocks and vegetation, in between particles that compose the substrate, and suspended in the water column. Other forms are also associated with the guts of lotic organisms as parasites or in commensal relationships.[Bacteria play a large role in energy recycling.

Diatoms are one of the main dominant groups of periphytic algae in lotic systems and have been widely used as efficient indicators of water quality, because they respond quickly to environmental changes, especially organic pollution and eutrophication, with a broad spectrum of tolerances to conditions ranging, from oligotrophic to eutrophic.

Primary producers

Algae, consisting of phytoplankton and periphyton, are the most significant sources of primary production in most streams and rivers. Phytoplankton float freely in the water column and thus are unable to maintain populations in fast flowing streams. They can, however, develop sizeable populations in slow moving rivers and backwaters. Periphyton are typically filamentous and tufted algae that can attach themselves to objects to avoid being washed away by fast currents. In places where flow rates are negligible or absent, periphyton may form a gelatinous, unanchored floating mat.

Insects and other invertebrates

Up to 90% of invertebrates in some lotic systems are insects. These species exhibit tremendous diversity and can be found occupying almost every available habitat, including the surfaces of stones, deep below the substratum in the hyporheic zone, adrift in the current, and in the surface film.

Insects have developed several strategies for living in the diverse flows of lotic systems. Some avoid high current areas, inhabiting the substratum or the sheltered side of rocks. Others have flat bodies to reduce the drag forces they experience from living in running water.

Fish and other vertebrates

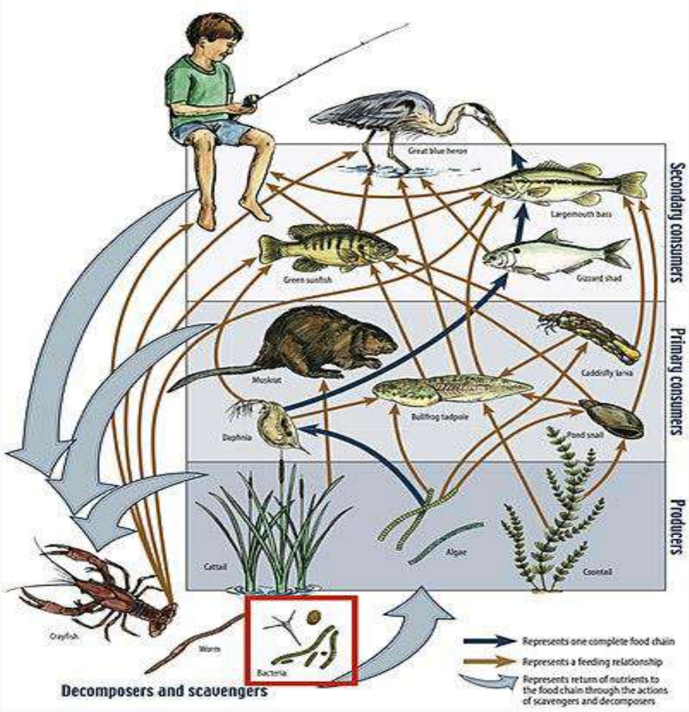
Fish are probably the best-known inhabitants of lotic systems. The ability of a fish species to live in flowing waters depends upon the speed at which it can swim and the duration that its speed can be maintained. This ability can vary greatly between species and is tied to the habitat in which it can survive. Continuous swimming expends a tremendous amount of energy and, therefore, fishes spend only short periods in full current. Instead, individuals remain close to the bottom or the banks, behind obstacles, and sheltered from the current, swimming in the current only to feed or change locations. Some species have adapted to living only on the system bottom, never venturing into the open water flow.

Trophic level dynamics

The concept of trophic levels are used in food webs to visualise the manner in which energy is transferred from one part of an ecosystem to another.[29] Trophic levels can be assigned numbers determining how far an organism is along the food chain.

1. Level one: Producers, plant-like organisms that generate their own food using solar radiation, including algae, phytoplankton, mosses and lichens.
2. Level two: Consumers, animal-like organism that get their energy from eating producers, such as zooplankton, small fish, and crustaceans.
3. Level three: Decomposers, organisms that break down the dead matter of consumers and producers and return the nutrients back to the system. Example are bacteria and fungi.

Food chain



Example of a river food web

Bacteria can be seen in the red box at the bottom. Bacteria (and other decomposers, like worms) decompose and recycle nutrients back to the habitat, which is shown by the light blue arrows. Without bacteria, the rest of the food web would starve, because there would not be enough nutrients for the animals higher up in the food web. The dark orange arrows show how some animals consume others in the food web. For example, lobsters may be eaten by humans. The dark blue arrows represent one complete food chain, beginning with the consumption of algae by the water flea, *Daphnia*, which is consumed by a small fish, which is consumed by a larger fish, which is at the end consumed by the great blue heron.

A food chain is a linear system of links that is part of a food web, and represents the order in which organisms are consumed from one trophic level to the next. Each link in a food chain is associated with a trophic level in the ecosystem. The numbered steps it takes for the initial source of energy starting from the bottom to reach the top of the food web is called the food chain length. While food chain lengths can fluctuate, aquatic ecosystems start with primary producers that are consumed by primary consumers which are consumed by secondary consumers, and those in turn can be consumed by tertiary consumers so on and so forth until the top of the food chain has been reached.

Primary producers

Primary producers start every food chain. Their production of energy and nutrients comes from the sun through photosynthesis. Algae contributes to a lot of the energy and nutrients at the base of the food chain along with terrestrial litter-fall that enters the stream or river. Production of organic compounds like carbon is what gets transferred up the food chain. Primary producers are consumed by herbivorous invertebrates that act as the primary consumers. Productivity of these producers and the function of the ecosystem as a whole are influenced by the organism above it in the food chain.

Primary consumers

Primary consumers are the invertebrates and macro-invertebrates that feed upon the primary producers. They play an important role in initiating the transfer of energy from the base trophic level to the next. They are regulatory organisms which facilitate and control rates of nutrient cycling and the mixing of aquatic and terrestrial plant materials. They also transport and retain some of those nutrients and materials. There are many different functional groups of these invertebrate, including grazers, organisms that feed on algal biofilm that collects on submerged objects, shredders that feed on large leaves and detritus and help break down large material. Also filter feeders, macro-invertebrates that rely on stream flow to deliver them fine particulate organic matter (FPOM) suspended in the water column, and gatherers who feed on FPOM found on the substrate of the river or stream.

Secondary consumers

The secondary consumers in a river ecosystem are the predators of the primary consumers. This includes mainly insectivorous fish. Consumption by invertebrate insects and macro-invertebrates is another step of energy flow up the food chain. Depending on their abundance, these predatory consumers can shape an ecosystem by the manner in which they affect the trophic levels below them. When fish are at high abundance and eat lots of invertebrates, then algal biomass and primary production in the stream is greater, and when secondary consumers are not present, then algal biomass may decrease due to the high abundance of primary consumers.[37] Energy and nutrients that starts with primary producers continues to make its way up the food chain and depending on the ecosystem, may end with these predatory fish.

Food web complexity

Diversity, productivity, species richness, composition and stability are all interconnected by a series of feedback loops. Communities can have a series of complex, direct and/or indirect, responses to major changes in biodiversity.[35] Food webs can include a wide array of variables, the three main variables ecologists look at regarding ecosystems include species richness, biomass of productivity and stability/resistant to change. When a species is added or removed from an ecosystem it will have an effect on the remaining food web, the intensity of this effect is related to species connectedness and food web robustness. When a new species is added to a river ecosystem the intensity of the effect is related to the robustness or resistance to change of the current food web. When a species is removed from a river ecosystem the intensity of the effect is related to the connectedness of the species to the food web. An invasive species could be removed with little to no effect, but if important and native primary producers, prey or predatory fish are removed you could have a negative trophic cascade.[38] One highly variable component to river ecosystems is food supply (biomass of primary producers). Food supply or type of producers is ever changing with the seasons and differing habitats within the river ecosystem. Another highly variable component to river ecosystems is nutrient input from wetland and terrestrial detritus. Food and nutrient supply variability is important for the succession, robustness and connectedness of river ecosystem organisms.

Estuaries

An estuary is a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean. Estuaries, and their surrounding lands, are places of transition from land to sea. Although influenced by the tides, they are protected from the full force of ocean waves, winds and storms by land forms such as barrier islands or peninsulas.

Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland or agricultural land. The sheltered waters of estuaries also support unique communities of plants and animals specially adapted for life at the margin of the sea.

Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and saltwater marshes, swamps, sandy beaches, mud and sand flats, rocky shores, oyster reefs, mangrove forests, river deltas, tidal pools and seagrass beds.

Estuaries provide us with a suite of resources, benefits and services. Some of these can be measured in dollars and cents, while others cannot. Estuaries provide places for recreational activities, scientific study and aesthetic enjoyment. Estuaries are an irreplaceable natural resource that must be managed carefully for the mutual benefit of all who enjoy and depend on them. Below are additional ways in which estuaries are important
Thousands of species of birds, mammals, fish and other wildlife depend on estuarine habitats as places to live, feed and reproduce. And many marine organisms, including most commercially-important species of fish, depend on estuaries at some point during their development.

Because they are biologically productive, estuaries provide ideal areas for migratory birds to rest and refuel during their long journeys. Because many species of fish and wildlife rely on the sheltered waters of estuaries as protected spawning places, estuaries are often called the "nurseries of the sea."

Estuaries have important commercial value and their resources provide economic benefits for tourism, fisheries and recreational activities. The protected coastal waters of estuaries also support important public infrastructure, serving as harbors and ports vital for shipping and transportation.

Intertidal Zones

The intertidal zone is an extreme ecosystem because it constantly experiences drastic changes. It is located on marine coastlines, including rocky shores and sandy beaches. The intertidal zone experiences two different states: one at low tide when it is exposed to the air and the other at high tide when it is submerged in seawater. The zone is completely submerged by the tide once or twice every day. This ecosystem is rife with research opportunities for marine researchers like National Geographic grantee Swapnale Gole, who studies the behavior of sea anemones, crustaceans, and fish in the intertidal zones of the Andaman Islands in India.

Organisms that live in the intertidal zone tend to form their own communities across the zone's elevation gradient. Some species live further up the shore and closer to the high tide line, while others live further down the shore, closer the low tide line. Anything living in the intertidal zone must be able to survive changes in moisture, temperature, and salinity and withstand strong waves. Intertidal zones of rocky shorelines host sea stars, snails, seaweed, algae, and crabs. Barnacles, mussels, and kelps can survive in this environment by anchoring themselves to the rocks. Barnacles and mussels can also hold seawater in their closed shells to keep from drying out during low tide. Intertidal zones richer in sediments are filled with different species of clams, sand dollars, and worms.

At rocky shorelines, tide pools can form in holes, cracks, or crevices where seawater collects as the tide goes out. Organisms that cannot normally survive low tide conditions, like sea stars, shrimp, or fish, can take refuge in these pools. Sandy shores provide sediments in which organisms bury themselves to stay cool and moist during low tide. Where a species lives within the intertidal zone depends on its tolerance of underwater and above-water conditions. The presence of predators and species that compete for the same space and food also impact where an organism will be found.

The intertidal zone can be further divided into three zones: high tide, middle tide, and low tide. The high tide zone is only submerged at high tide and is hotter and drier as a result. The middle tide zone is submerged and exposed for equal amounts of time. The low tide zone is only exposed during low tide and has the greatest biodiversity of the three zones because it provides more favorable conditions for those organisms that cannot tolerate air exposure for long.

While conditions in the intertidal zone can be extreme, it is home to many living things and is also an important feeding spot for both resident and migrating birds. This ecosystem also provides protection against erosion and keeps storm waves from reaching buildings along the shore.

Oceanic Pelagic Zone

Pelagic zone, ecological realm that includes the entire ocean water column. Of all the inhabited Earth environments, the pelagic zone has the largest volume, 1,370,000,000 cubic kilometres (330,000,000 cubic miles), and the greatest vertical range, 11,000 metres (36,000 feet). Pelagic life is found throughout the water column, although the numbers of individuals and species decrease with increasing depth. The regional and vertical distributions of pelagic life are governed by the abundance of nutrients and dissolved oxygen; the presence or absence of sunlight, water temperature, salinity, and pressure; and the presence of continental or submarine topographic barriers.

Pelagic life consists of three categories. The phytoplankton, which constitute the food base of all marine animals, are microscopic organisms that inhabit only the sunlit uppermost oceanic layer, using sunlight to photosynthetically combine carbon dioxide and dissolved nutrient salts. Zooplankton are the marine animals that rely mainly upon water motion for transport, although some forms such as jellyfish are feeble swimmers. Zooplankton subsist on phytoplankton and smaller zooplankton and are dominated in their numbers by small crustacean copepods and euphasiids. Nekton, the free swimmers, are dominated by the bony and cartilaginous fishes, molluscans, and decapods, with rarer mammals and reptiles.

Marine Benthic Zone

Benthic zone is one of the ecological regions found at the lowest level of a water body including lake, ocean or stream. This zone also includes the sediment surface as well as some subsurface layers of the water body. An integral part of the benthic zone is the benthic boundary layer that comprises the bottom layer of water and the uppermost sediment layer which is directly influenced by the overlying water. This benthic boundary layer influences the biological activities that take place over there. Rocky outcrops, coral, bay mud and sand bottom are some examples of the contact soil layers.

Characteristics of Benthic Zone

Some of the important characteristics of benthic zone are as follows:

- **Temperature**

The benthic zone temperature depends upon the benthic zone depth; it ranges from warmer temperature at shallow depth due to close proximity to the water surface and may further drop to 2-3 degree centigrade at the most extreme depths of the abyssal zone. Very few organisms can survive at lower depths and the ones which can grow there move at a very slow rate.

- **Pressure**

The pressure in the benthic region varies from low to high depending upon the depth of the zone. The pressure is lower at shallow depths as compared to hundreds of metres of depth. An example of a very high pressure benthic zone is the Mariana Trench which has a pressure 1000 times more than the normal pressure. An organism of benthic zone living at a higher pressure region is very large in size. Also, at greater depths, there is higher dissolved oxygen and it results in the enlargement of bethos size.

- **Light**

Different Benthic zone depths have different light intensities and it is such that as there is increase in the benthic zone depth, the intensity of the light increases. The intensity of light disappears quickly between 250-1000 meters and it is known as the disphotic zone. As a result, photosynthesis process is difficult to take place in this region and beyond 1000 meters there is no light availability and hence photosynthesis doesn’t take place here.

Benthic Zone Diagram

By observing the below benthic zone diagram, we can segregate a variety of other zones present near a water body. It includes benthic zone, euphotic zone, littoral zone and limnetic zone.

Benthos are the living organisms found in the benthic zone and it includes microorganisms like bacteria, fungi and also larger invertebrates like crustaceans and polychaetes. Crustaceans are large arthropod taxon group organisms that include crabs, crayfish, lobsters, prawns, woodlice, shrimps, krill, etc. Polychaetes are the bristle worms that belong to the class of annelid worms and each of their body segments consists of a pair of fleshy protrusions known as parapodia having many bristles (chaetae) and made up of chitin. Here, we discuss some of the benthos facts.

- Benthos generally live in close relationship with the substrate and most of them are permanently attached to the bottom layer or the benthic boundary layer.
- Most of the benthos lack a backbone and are referred to as invertebrates and may include sea anemones, sponges, corals, sea stars, worms, crabs, sea urchins, and many others.

- Being the lowest level of a marine or freshwater system, it is often characterized by low temperatures and low sunlight.
- Benthic habitats in the oceanic environments can be zoned by its depth. Different zones from the shallowest to the deepest of these include the epipelagic which is less than 200 meters, the mesopelagic which is 200-1,000 meters, the bathyal which is 1,000 to 4,000 meters, the abyssal which is 4,000 to 6,000 meters and the hadal is below 6,000 meters which is the deepest one.
- Benthic zone is important for the health of aquatic ecosystems where tiny microscopic organisms live. A healthy benthic environment serves as a source of food for bottom feeding animals. Benthos or the organisms living in this zone are good indicators of the water quality of the marine ecosystem.
- Benthos depend upon each other for food and generally feed on worms, crabs, lobsters, sponges and other tiny organisms. Depending on the behaviour of food consumption, they can be divided as filter feeders and deposit feeders.
- Unlike the benthic zone, the littoral zone of a lake is the area near the shore area where sunlight can penetrate all the way to the sediment and enable the aquatic plants or macrophytes to survive.

Coral Reefs

Coral reefs are some of the most diverse ecosystems in the world. Coral polyps, the animals primarily responsible for building reefs, can take many forms: large reef building colonies, graceful flowing fans, and even small, solitary organisms. Thousands of species of corals have been discovered; some live in warm, shallow, tropical seas and others in the cold, dark depths of the ocean.

Coral reef diversity

Because of the diversity of life found in the habitats created by corals, reefs are often called the "rainforests of the sea." About 25% of the ocean's fish depend on healthy coral reefs. Fishes and other organisms shelter, find food, reproduce, and rear their young in the many nooks and crannies formed by corals. The Northwest Hawaiian Island coral reefs, which are part of the Papahānaumokuākea National Marine Monument, provide an example of the diversity of life associated with shallow-water reef ecosystems. This area supports more than 7,000 species of fishes, invertebrates, plants, sea turtles, birds, and marine mammals. Deep water reefs or mounds are less well known, but also support a wide array of sea life in a comparatively barren world.

Coral characteristics

Shallow water, reef-building corals have a symbiotic relationship with photosynthetic algae called zooxanthellae, which live in their tissues. The coral provides a protected environment and the compounds zooxanthellae need for photosynthesis. In return, the algae produce carbohydrates that the coral uses for food, as well as oxygen. The algae also help the coral remove waste. Since both partners benefit from association, this type of symbiosis is called mutualism.

Deep-sea corals live in much deeper or colder oceanic waters and lack zooxanthellae. Unlike their shallow water relatives, which rely heavily on photosynthesis to produce food, deep sea corals take in plankton and organic matter for much of their energy needs.

Benefits of coral reef ecosystems

Coral reefs protect coastlines from storms and erosion, provide jobs for local communities, and offer opportunities for recreation. They are also are a source of food and new medicines. Over half a billion people depend on reefs for food, income, and protection. Fishing, diving, and snorkeling on and near reefs add hundreds of millions of dollars to local businesses. The net economic value of the world's coral reefs is estimated to be nearly tens of billionsoffsite link of U.S. dollars per year. These ecosystems are culturally important to indigenous people around the world.

Corals have long been popular as souvenirs, for home decor, and in jewelry, but many consumers are unaware that these beautiful structures are made by living creatures. Fewer still realize that corals are dying off at alarming rates.

Threats to coral reef ecosystems

Unfortunately, coral reef ecosystems are severely threatened. Some threats are natural, such as diseases, predators, and storms. Other threats are caused by people, including pollution, sedimentation, unsustainable fishing practices, and climate change, which is raising ocean temperatures and causing ocean acidification. Many of these threats can stress corals, leading to coral bleaching and possible death, while others cause physical damage to these delicate ecosystems.