Aquatic Ecology, Biodiversity and Disaster Management

- **Content Creator:** RANI.V, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
- **Content Reviewer:** SAHAR MASUD, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Lesson Number	Lesson Name
Lesson 1	Aquatic Ecology-An Introduction
Lesson 2	Aquatic Productivity, Energy flow and food chain in an ecosystem
Lesson 3	Animal associations and its interaction in an aquatic environment
Lesson 4	Aquatic Biodiversity, its types and diversity indices
Lesson 5	Ecological and evolutionary processes, Ecological niche
Lesson 6	Ecological niches – Estuaries, mangroves and coral reefs
Lesson 7	Ecological niches - Flood plains, Coastal wetlands, Bheels and Oxbow lakes
Lesson 8	Threats to biodiversity- Habitat destruction, Introduction of exotic species, Conservation of habitats, Marine parks and sanctuaries
Lesson 9	Conservation programmes for endangered species, ex situ and in situ conservation, captive breeding and management of endangered species
Lesson 10	National and international conventions and regulations concerning Biodiversity and Use of selective gears and Exclusion devices

Fisheries science is the bridge between preserving the oceans and meeting the food needs of the world.

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 1	Aquatic Ecology-An Introduction
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.1 Objectives:

- Aquatic environment: Flora and fauna of an aquatic ecosystem
- Components of an aquatic ecosystems

1.2 .Glossary of terms:

- **Ecology:** The term ecology derived from two Greek words. “Oikos” means home; ‘logy’ means science. Ecology deals with interactions, relationships, distributions & abundance. The study of the relationships of organisms to their environment and one another (Brewer, 1988). According to Odum (1969), Ecology is the study of inter-relationship between organisms and environment.
- **Ecosystem** An ecosystem is a natural unit of living and non-living parts that interact to produce a stable system. The term ecosystem was coined in 1935 by the British ecologist, Arthur G. Tansley.
- **Ecology** is the study of ecosystems, or how living things relate to the environment and to one another. Understanding this relationship is important because living things and non-living things depend upon and impact each other.
- **Population:** All the individuals of a particular species or several related species of plants and /or animals in a unit area and unit time constitutes ecological population.
- **Community** Biotic community is assemblages of several species of population that tend to occur together in various geographical areas

Designed and developed under the aegis of NAHEP Component-2 Project “Investments In ICAR Leadership In Agricultural Higher Education”
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

constitute an ecological community. Example:- Rocky shore community, coral reef community, sandy shore community
algal community etc.

1.3. Ecosystems: An introduction

Ecosystems operate from day to day by exchanging energy. The energy exchanged within an ecosystem is recycled between the physical and biological components. The plants within an ecosystem convert the sun's energy into food, and are in turn grazed upon by animals, which are consumed by predators. Microorganisms within an ecosystem, such as fungi and bacteria, also exchange energy within the ecosystem by breaking down waste material to substances that can be used by plants for food. In this way, each element within the ecosystem depends on the others for survival. Aquatic ecosystems include oceans, lakes, rivers, streams, estuaries, and wetlands. Within these aquatic ecosystems are living things that depend on the water for survival, such as fish, plants, and microorganisms. These ecosystems are very fragile and can be easily disturbed by pollution

1.3.1. Types of ecosystem

- **Natural ecosystem (Open ecosystem):** They are self regulating system without direct human interference and manipulations. Eg: Ponds, lakes, rivers, seas, oceans, forests, grasslands
- **Artificial ecosystem (Closed ecosystem**): There are manmade ecosystems which can be controlled and managed, Eg: Aquarium, ponds, etc. Other terminologies used are

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- **The biosphere**: It is a major ecosystem and comprises all other ecosystem.

  Mega ecosystem: Marine ecosystem -Oceans, seas, estuaries, backwaters etc.

- **Limnetic ecosystem:** Fresh water ecosystem - Ponds, pools, lakes, rivers, streams etc.
- **The habitat** is the specific place in the environment where the organism lives; e.g. rocky or sandy shore, mangrove, coral reefs. Different habitats have different chemical and physical properties that dictate which organisms can live there.
- **Niche:** In ecology, a niche is the role or job of a species in a habitat. The word niche comes from the French word *nicher*, which means "to nest." An ecological niche describes how a species interacts with, and lives in, its habitat. Ecological niches have specific characteristics, such as availability of nutrients, temperature, terrain, sunlight and predators, which dictate how, and how well, a species survives and reproduces

1.4 Principles and concepts of ecosystem

The characteristic features of an ecosystem are the flow of energy, the food supply and the production of all biological resources to drive the ecosystem. Light energy from the sun is captured by green plants and converted to chemical energy. Organisms use and convert this chemical energy for growth and life activities through food chain. A food chain is a succession of organisms in a community that constitutes

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

a feeding sequence in which food energy is transferred from one organism to the other. At the bottom of the chain is a photosynthesizing plant, followed by an herbivore, a successions of carnivores, and finally decomposers. At each step, some of the chemical energy is assimilated and used by the organism and the rest is released in respiration and waste products in an ecosystem.

1.5 Flora and fauna of an ecosystem

1.5.0 Animals and Plants in the Aquatic Biome

The aquatic biomes, or ecosystems, of the world include freshwater and marine biomes. Freshwater biomes comprise rivers and streams, lakes and ponds, and wetlands. Marine biomes consist of oceans, coral reefs and estuaries, wetlands, rivers, streams, ponds, lakes. A huge number of species of plants and animals live in aquatic biomes. Both freshwater and marine biomes contain specific regions, or zones, each exhibiting certain species of plants and animals.

1.5. 1.Flora and fauna in freshwater ecosystem

1.5.2 Plankton organisms occur in open water and move primarily with general water motion. Planktonic communities occur in all lentic ecosystems. In lotic systems they are important only in slow-moving areas. Phytoplankton (plant plankton) comprise at least eight major taxonomic groups of algae, most of which are microscopic. They exhibit a diversity of forms ranging from one-celled organisms to complex colonies algae; Phytoplankton (Bacillariophyceae)

1.5.3 Zooplankton (animal plankton) comprise protozoans and three major groups of eukaryotic organisms: rotifers, cladocerans, and copepods. Most are microscopic but some are clearly visible to the naked eye.

1.5.4 Aquatic fauna (Animals) such as fishes and swimming insects that occur in the water column and can control their position independently of water movement are termed **nekton.** In addition to their importance as a human food source, fishes may affect zooplankton, benthic invertebrates, vegetation, and lake sediments.

1.5.5 Benthic organisms: Benthic animals range from microscopic protozoans and crustaceans to large aquatic insects and fishes.

1.5.6 Bacteria occur throughout fresh-water ecosystems in planktonic and benthic areas and play a major role in biogeochemical cycling. Most bacteria are heterotrophic, using reduced carbon as an energy source; others are photosynthetic or derive energy from reduced compounds other than carbon.

1.5.7 Interactions

Ultimately the conditions in a fresh-water ecosystem are controlled by numerous interactions among biotic and abiotic components. Primary production in a fresh-water ecosystem is controlled by light and nutrient availability. As light diminishes with depth in a column or water, a point is reached where energy for photosynthesis balances respiratory energy demands. In benthic areas, the region where light is sufficient for plant

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

growth is termed the littoral zone; deeper areas are labelled profundal zone

1.6. Flora and fauna in marine ecosystem

Oceans covers 71% of the earth's surface and contains approximately 97% of the planet's water. They generate 32% of the world's net primary production. The marine ecosystem is the largest aquatic system of the planet which includes oceans, coral reefs and estuaries. The two major zones of the ocean are the sea floor, or bottom region, called the benthic realm and the watery region above the sea floor called the pelagic realm. Each of these is further subdivided into different zones according to their environmental conditions. The intertidal zone consists of the coastal regions and contains a great diversity of species of plants and animals. As the tides go in and out, this region is sometimes submerged and sometimes exposed, causing constant change. Seaweeds, algae, snails, crabs, small fishes, mollusks, worms, clams and crustaceans live in the coastal area.

The pelagic zone consists of open ocean farther from the land and contains surface seaweeds, fish, whales and dolphins. The benthic zone lies below the pelagic, and contains bacteria, fungi, sea anemones, sponges and fishes. Deepest ocean is the abyssal zone, where some invertebrates and fish live. Where there are hydrothermal vents, chemosynthetic bacteria find a home.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

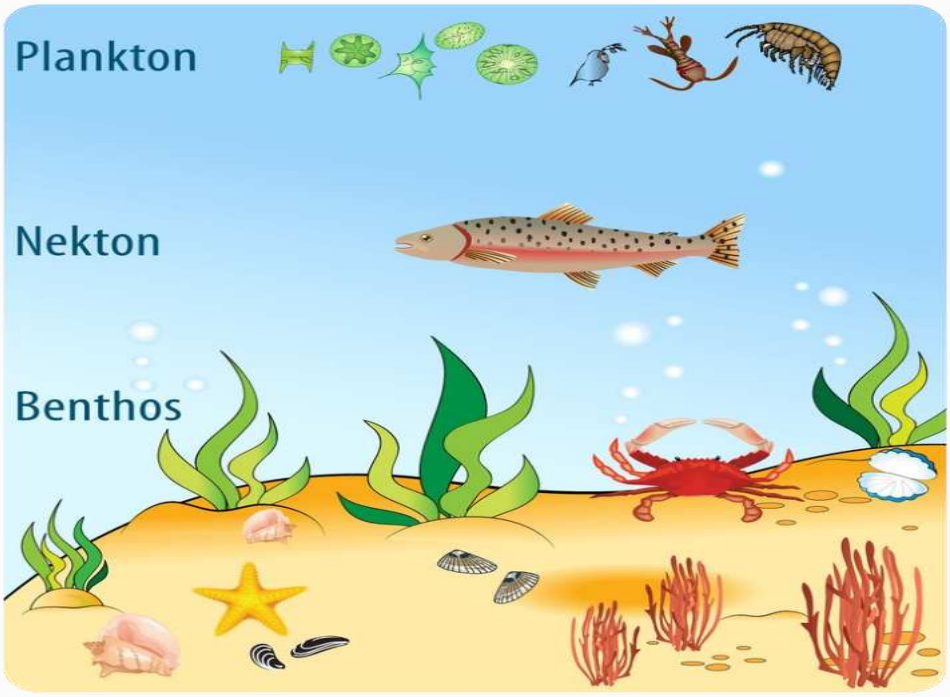


Fig. 1. Components of an aquatic ecosystem

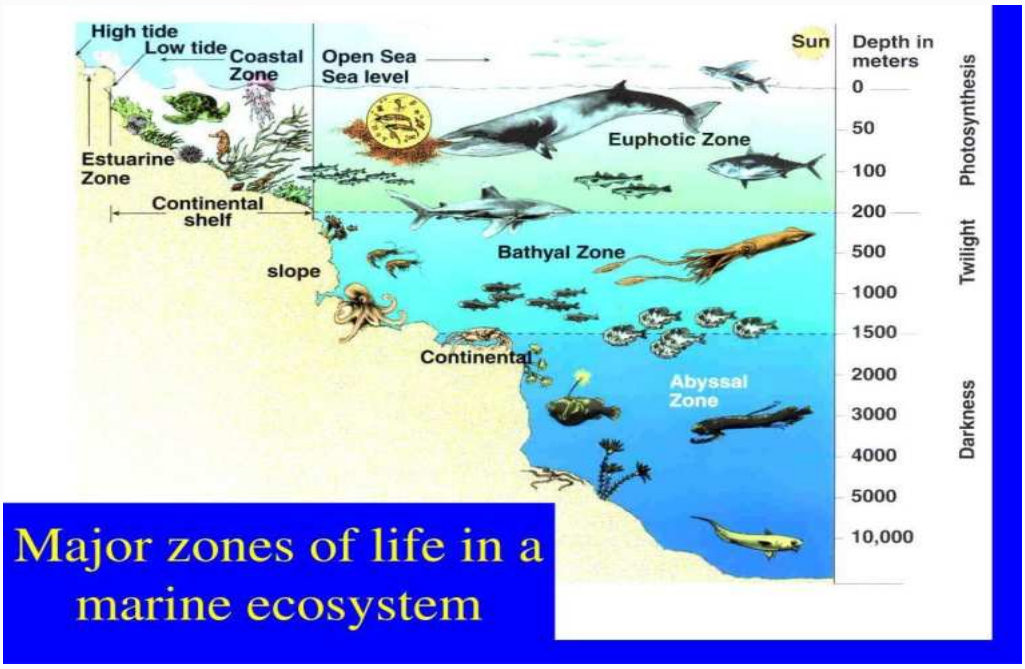


Fig.2 Major zones in marine ecosystem

There are two main components of an ecosystem which are in constant communication with each other. They are the biotic components and the abiotic components

1.7.1 **Biotic Components of Ecosystem**

The living components of an ecosystem are called the biotic components. Some of these factors include plants, animals, as well as fungi and bacteria. These biotic components can be further classified, based on the energy requirement source. Producers, consumers, and decomposers are the three broad categories of biotic components (Fig.1)

1.7.2 Producers are the plants in the ecosystem, which can generate their own energy requirement through photosynthesis, in the presence of sunlight and chlorophyll. All other living beings are dependent on plants for their energy requirement of food as well as oxygen. Organisms that make up the biotic component of an ecosystem are classified as autotrophic organisms and heterotrophic organisms based on how they get their nutrition, food or organic nutrients for their growth, development and survival.

1.7.3 Autotrophs (Producers)

Autotrophs are the organisms that can manufacture the organic compounds from simple inorganic compounds in the environment. In aquatic ecosystems, most of the producers are of various species of floating and drifting forms of phytoplankton and bacteria. In addition, macrophytes also serve as producer in aquatic ecosystems Most producers make their organic nutrients they need through photosynthesis. The overall net chemical change can be summarized as follows:

$$6\ CO_2 + 6\ H_2O + \text{solar energy} \text{-----}> C_6H_{12}O_6 + 6\ O_2$$

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.7.4 Heterotrophs (Consumers): All animals are consumers. These are the organisms which cannot synthesize the organic nutrients they need and get their organic nutrients by feeding on the tissues of producers or other consumers. There are several classes of consumers, depending on their food source. Consumers include the herbivores, carnivores, and omnivores. The herbivores are the living organisms that feed on plants. Carnivores eat other living organisms. Omnivores are animals that can eat both plant and animal tissue.

1.7.5 Primary consumers (herbivores): Feed directly on plants or other producers. e.g. - zooplankton (copepods, cladocerans etc.)

1.7.6 Secondary consumers (primary carnivores) feed on primary consumers. e.g. Aquatic insects, crustaceans etc.

1.7.7 Tertiary consumers (secondary carnivores) feed only on secondary consumers. e.g. small fishes.

1.7.8 Tertiary carnivores: Feed only on animal-eating animals. They are predators. e.g. large fishes like tuna, seer fish, sharks etc.

1.7.9 Decomposers are the fungi and bacteria, which are the saprophytes. They feed on the decaying organic matter and convert this matter into nitrogen and carbon dioxide. The saprophytes play a vital role in recycling the nutrients so that the producers i.e. plants can use them once again.

1.8 Abiotic components

Ecosystems are composed of living organisms and their non-living environment; while the biosphere includes all of the earth's ecosystems

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

taken together. The environment is all the external factors that act on an organism: • Physical (abiotic): temperature, salinity, pH, sunlight, currents, wave action and sediment

1.8.1 Ecological components are

- Species
- Population
- Communities
- Ecosystem
- Biosphere

1.8.2 Species

It is a natural group of actually or potentially interbreeding individuals reproductively isolated from other such groups. Eg. *Sardinella* sp. *Catla* sp.

1.8.3 Population

All the individuals of a particular species or several related species of plants and /or animals in a unit area and unit time constitutes ecological population.

- Nonspecific population (only one species)
- Poly/mixed specific population (Several Species)

Example: - Barnacles population, Mackerel population, oysters population

1.8.4. Community

Biotic community is assemblages of several species of population that tend to occur together in various geographical areas constitute an

ecological community.

Example:- Rocky shore community, coral reef community, sandy shore community

algal community etc.

The community also called as 'Bio Coenoses' (Karl Mobius, 1977)

- Phyto Coenosis – Plant Community
- Zoo Coenosis – Animal Community

1.8.5. Ecosystem

Ecosystems are dynamic interactions between plants, animals and microorganisms and their environment working together as a functional unit. Ecosystems in nature, work as all the parts work together to make a balanced system. An ecosystem is a community of living and non-living things that work together. It can be as large as a desert or a lake or as small as a pond or a puddle. No community can carry more organisms than its food, water and shelter that can accommodate. Food and territory are often balanced by natural phenomena such as fire, disease, and the number of predators. Each organism has its own niche or role to play. The major parts of an ecosystem are soil, atmosphere, heat and light from the sun, water and living organisms

1.8.6. Biosphere

The biosphere is the biological component of earth systems, which includes the lithosphere, hydrosphere, atmosphere and other spheres. The biosphere includes all living organisms –plants, animals, bacteria, fungi etc. on earth, together with the dead organic matter produced by them.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 2	Aquatic Productivity, Energy flow and food chain in an ecosystem
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

2.1 Objectives

- Concept of aquatic productivity and Aquatic productivity in the oceans
- Study on nutrient cycles in ecosystem
- Energy flow in ecosystem
- Food chain in aquatic ecosystem

2.2 Glossary terms

1. **Autotrophs:** Autotrophs are organisms that can produce their own food, using materials from inorganic sources.
2. **Primary productivity:** The rate at which energy is converted to organic substances by photosynthetic producers (photoautotrophs), which obtain energy and nutrients by harnessing sunlight, and chemosynthetic producers (chemoautotrophs), which obtain chemical energy through oxidation**.**
3. **Secondary productivity:** The rate at which these consumers convert the chemical energy of their food into their own biomass is called secondary productivity.
4. **Ecological efficiency:** The efficiency at which energy is transferred from one trophic level to another is called ecological efficiency.
5. **Assimilation efficiency:** The efficiency by which animals convert the food they ingest into energy for growth and reproduction is called assimilation efficiency.
6. **Compensation depth:** Depth at which light intensity reaches a level at which oxygen evolved from a photosynthesizing organism equals that consumed by its respiration.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

7. **Critical depth:** The depth above which total integrated photosynthetic rate equals total integrated respiration of photosynthesizers.
8. The depth at which the average light intensity of the water column equals the compensation light intensity.
9. **Upwelling:** Divergence of water currents or the movement of surface water away from land can lead to a `welling-up' of cold nutrient-rich water from the ocean depths, often associated with great production of fish and fisheries.
10. **Trophic level:** Position in the food chain, determined by the number of energy-transfer steps to that level.
11. **Biomass:** The mass of living tissues in either an individual or cumulatively across organisms in a population or ecosystem.

2.3 Aquatic productivity

2.3.1 Concept of productivity

Life in the sea is due to the photosynthetic activity of aquatic plants. Plants convert the light energy into chemical energy (sugar). Phytoplankton is the dominant primary producers of the pelagic environment. They convert inorganic materials (NO_3, PO_4) into new organic compounds (lipid, protein, CHO's) by the process of photosynthesis and transfer through food chain in an ecosystem. Autotrophs are called as primary producers. They can able to manufacture complex organic molecules from simple inorganic compounds (water, CO_2, nutrients).

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

2.3.2 Primary production

The term **"production"** is the creation of new organic matter by the process of photosynthesis. **Primary production** is the synthesis and storage of organic molecules during the growth and reproduction of photosynthetic organisms.

Photosynthesis is the process by which plants, some bacteria, and some protists use the energy from sunlight to produce sugar which cellular respiration converts into ATP, the "fuel" used by all living things. The conversion of unusable sunlight energy into usable chemical energy is associated with the actions of the green pigment chlorophyll. We can write the overall reaction of this process as:

$$6H_2O + 6CO_2 \text{ ----------> } C_6H_{12}O_6 + 6O_2$$

2.3.3 Pattern of primary production

Seasonal and regional variations are common phenomenon in nature. In temperate latitudes, seasonal variations are distinct and regular compared to constant, irregular production in tropical environments

2.3.4 Factors influencing primary production

- Light
- Temperature
- Salinity
- Nutrients
- Minor nutrients
- Organic substances
- Grazing of zooplankton

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

2.3.5 Relationship between composition, light, depth, critical depth and the depth mixing

Plant growth or net production occurs when photosynthesis exceeds respiration the depth at which photosynthesis and respiration equal is called **compensation depth** (CD). It is the production of organic material by photosynthesis which exactly balances the breakdown of organic materials by respiration. Below the CD there is no net production even though photosynthesis still occurs; the CD varies with incident radiation and transparency. The area above the CD is often referred to as **euphotic zone** with an average depth of 80 m (varied between 0 and 100m) depending upon the suspended particles matter load.

2.3.6 Compensation depth

It is the depth at which the amount of respiration exactly balances the amount of photosynthesis is referred to as **compensation depth**.

2.3.7 Critical depth

The depth at which a population of phytoplankton cells can be mixed until photosynthetic gain is balanced by respiratory losses ($P_W = R_W$)

2.3.8 Nutrients

- Productivity represents the amount of carbon fixed per unit time. Also productivity can be represented by the assimilation index in which growth is expressed as mg of carbon produced per mg chlorophyll ‘a’ per hour. Growth rates phytoplankton is as an increase in cell numbers.
- Phosphate and Nitrates are the two major nutrients recognized as one of the major factors limiting primary productivity.

Designed and developed under the aegis of NAHEP Component-2 Project “Investments In ICAR Leadership In Agricultural Higher Education”
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Phytoplankton absorbs nutrients from the solution during photosynthesis for the formation of particulate organic matter. Sometimes nutrient are absorbed for the synthesis of RNA, DNA, cell wall, spines etc.
- The effect of nutrients conservation on the growth of plankton can be described by Growth rates - Nutrient uptake velocity

2.3.9 Measurement of primary production

2.3.9.1 Gross primary production (GPP)

GPP is the total amount of CO_2 that is fixed by the plant in photosynthesis. Net primary production: NPP is the net amount of primary production after the costs of plant respiration are included.

Therefore, NPP = GPP - R respiration: R is the amount of CO_2 that is lost from an organism or system from metabolic activity.

Respiration can be further divided into components that reflect the source of the CO_2

2.3.9.2 Methods of measurement of primary production

1. Light and dark bottle method
2. Carbon ^{14}C method

2.4 Secondary production

- The energy stored by the consumers is called **secondary production**. Secondary production is the generation of biomass of heterotrophic organisms in aquatic ecosystems. This is driven by the transfer of organic material between trophic levels and represents the quantity of new tissue created through the use of assimilated food. Secondary production is sometimes defined to only include consumption of

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

primary producers by herbivorous consumers (with tertiary production referring to **carnivorous** consumers but is more commonly defined to include all biomass generation by heterotrophs.

- Organisms responsible for secondary production include animals, protists, fungi and many bacteria.
- Secondary production can be estimated through a number of different methods including increment summation, removal summation, the instantaneous growth method and the Allen curve method. The choice between these methods will depend on the assumptions of each and the ecosystem under study

2.5 Aquatic Productivity in the oceans

2.5.1 Polar region: In polar open oceans, primary production is wildly fluctuating. There is little to **no sunlight,** which means that for most of the year, there is **no primary production** taking place.

- During **spring,** when sunlight becomes ample and day lengths increase, an incredible burst in production occurs. This is also caused by the fact that there is typically **no thermocline** layer in polar regions. Thus, both nutrients and sunlight are abundant and non-limiting. This spike in productivity lasts 3–4 months before returning to a dormant phase the rest of the year.

2.5.2 Tropical region

The primary productivity of tropical ocean regions is **so low** throughout the year that they are commonly referred to as '**marine deserts'**. This is because the **thermocline layer is a permanent feature in**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

the tropics, which limits the deeper nutrient rich water from mixing with surface water.

2.5.3 Temperate region

- In temperate regions, the productivity is generally more moderate.
- During the **winter**, the thermocline layer is fully broken down, which allows for nutrient rich water to mix with the surface water. However, light levels are low throughout winter, which constricts the productivity to relatively low levels. In spring, productivity increases as sunlight becomes stronger. This creates a brief period of productivity increase (similar to Polar Regions, but not as dramatic).
- When **summer** rolls around, light becomes plentiful again. However, the temporary thermocline becomes re-established, which limits production to very low levels.
- In **autumn**, there is another small spike in production that occurs when the thermocline starts to breaks down again, creating a small period of time where sunlight and nutrients are both plentiful.

2.5.4. Factors influencing primary productivity

- Primary productivity in the oceans is limited by the available **nutrients, nitrates, phosphates,** and **iron.**
- Large areas in the centre of oceanic gyre circulation (e.g., the Sargassso Sea around Bermuda) have very low productivity.
- Upwelling zones bring nutrients from depth and stimulate productivity.
- Upwelling zones occur from prevailing winds along the west sides of continents, in equatorial regions, in the southern ocean, and seasonally

in other regions (coastal, Somalia, Oman). These upwelling zones have very high primary and export productivity.

2.6 Nutrient Cycles in an ecosystem

- Al1 organisms require a variety of organic and inorganic nutrients for their survival.
- These chemicals enter into the biotic components from the environment and released into the environment by the organisms. Hence, these chemicals tend to circulate in a definite path from the organisms to the environment and vice versa.
- This cycling of chemical elements from the biotic to environment and back to the living organisms is called biogeochemical. (i.e.biogeochemical cycles are the pathways by which chemicals circulate through the biotic and abiotic components of an ecosystem).
- As these chemicals are essential to the living organisms as food for their survival or for any other metabolic life processes, these cycles are also known as nutrient cycles.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

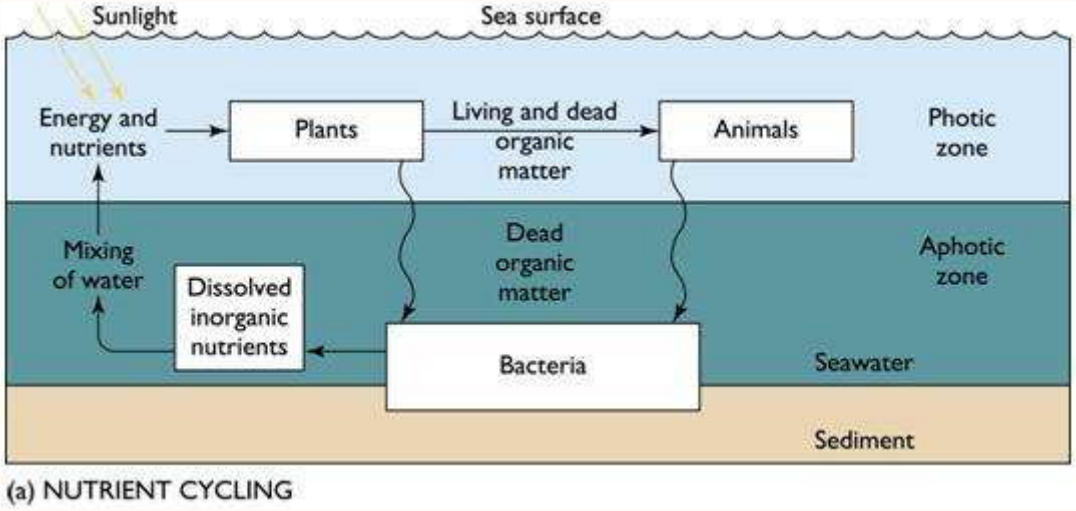


Fig.1 Nutrient cycling

Biogeochemical cycles have two phases, namely

- The biotic phase and
- The abiotic phase

- In biotic phase, the chemicals flow through the living components, whereas in the abiotic phase, the chemicals flow through the non-living components of the ecosystem.
- That is in the biotic phase of the nutrient cycle, the chemicals flow through a path or links of the various levels of the food chains aquatic ecosystems.

The biogeochemicals are of two types viz.,

- **Gaseous cycles and**
- **Sedimentary cycles or mineral cycles**

In a gaseous cycle, elements move through the atmosphere. For gases, main reservoirs are the atmosphere and the ocean. These include the oxygen cycle, carbon cycle and nitrogen cycle

In a sedimentary cycle, elements move from land to 'water to sediment. For the mineral elements, main reservoirs are the soil and

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

sedimentary rocks i.e. earth's crust. These include phosphorous and sulphur cycles

Carbon, nitrogen and phosphorus cycles are known to limit the productivity of the aquatic systems and other elements are not considered as limiting the productivity, in aquatic systems.

2.6. Carbon cycle

2.6.1 Importance of Carbon in life

- Carbon is the basic constituent of living organisms. It is present as carbohydrates, fats, proteins and nucleic acids.
- In the atmosphere, it is present as CO_2, at the rate of 0.03 – 0.04%.
- Cycling of carbon through a path of atmosphere, lithosphere, hydrosphere and biosphere is called the carbon cycle.
- The carbon cycle naturally consists of two parts, the **terrestrial** and the **aquatic carbon cycle.**
- The aquatic carbon is concerned with the movements of carbon through marine ecosystems and the terrestrial carbon cycle is concerned with the movement of carbon through terrestrial ecosystems.
- The carbon cycle is based on carbon dioxide (CO_2), which can be found in air in the gaseous from, and in water in dissolved form

2.6.2 Cycling of Carbon in aquatic ecosystem

Aquatic plants also generate oxygen, but they use carbon dioxide from water. The process of oxygen generation is called **photosynthesis**. During photosynthesis, plants and other producers transfer carbon dioxide and

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

water into complex carbohydrates, such as glucose, under the influence of sunlight. The overall reaction of photosynthesis is

$$6CO_2 + 6H_2O + \text{Solar energy} + \text{Nutrients} + C_6H_{12}O_6 + 6O_2$$

(Glucose)

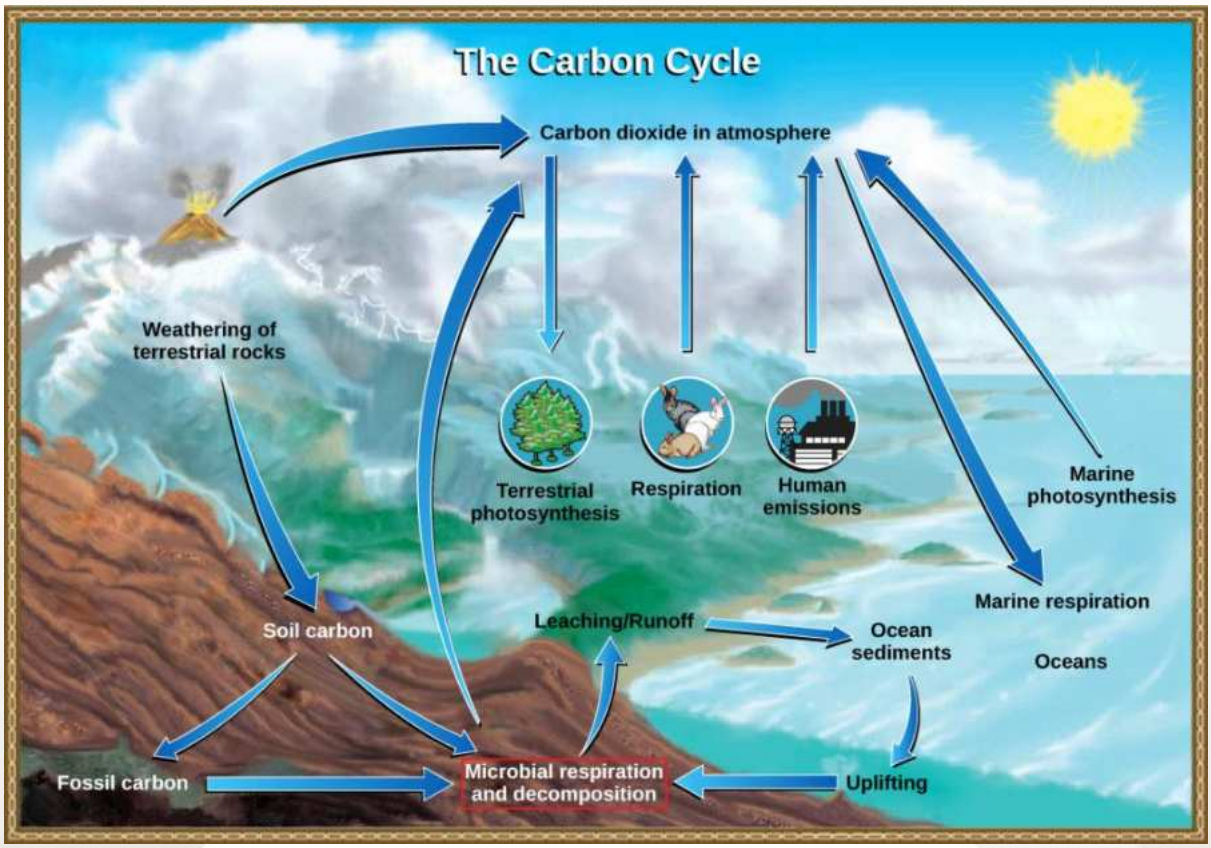


Fig. 2. Carbon cycle

- Carbon that is used by producers, consumers and decomposers cycles fairly rapidly through air, water and biota
- In the aquatic ecosystems, carbon dioxide can be stored in rocks, skeletons of living organisms, particularly corals and mollusc in the seas, and sediments. It will take a long time before this carbon dioxide will be released, through weathering of rocks, biogenic deposits or geologic processes that bring sediment to the surface of water.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Carbon dioxide that is present in water will be present as either carbonate or bicarbonate ions.
- These ions are an important part of natural buffers that prevent the water from becoming too acidic or too basic. When the sun warms up the water, carbonate and bicarbonate ions will be returned to the atmosphere as carbon dioxide.

2.6.3 Nitrogen cycle in an aquatic ecosystem

2.6.3.1. Nitrogen processes in an aquatic ecosystem

- Nitrogen exists in a variety of forms in natural systems and its compounds are involved in numerous biological and abiotic processes.
- Nitrogen, in its gaseous form of N_2, makes up almost 80 percent of the atmosphere. This constitutes the major storage pool in the complex cycle of nitrogen through ecosystems. Some of this gas is converted in the soils and waters to ammonia (NH_3), or many other nitrogen compounds. The process is known as **nitrogen fixation**, and in the absence of chemical fertilizers, is the primary source of nitrogen to all living things.
- Biological nitrogen fixation is mediated by special nitrogen-fixing bacteria and algae. On the land, these bacteria often live on nodules on the roots of legumes where they use energy from plants to do their work.
- In freshwater and, possible, in marine systems, cyanobacteria fix nitrogen. Once nitrogen has been fixed in the soil or aquatic system, it can follow two different pathways. It can be oxidized for energy in

process called **nitrification** or assimilated by an organism into its biomass in a process called **ammonia assimilation**.

- Plants incorporate the appropriate forms of fixed nitrogen into their tissues through their root systems.
- The plants then use it to manufacture amino acids and convert it into proteins. Nitrogen, fixed as proteins in the bodies of living organisms, eventually returns via the nitrogen cycle to its original form of nitrogen gas in the air.
- The process of **de-nitrification** starts when plants containing the fixed nitrogen are either eaten or die.
- Fixed nitrogen products in dead plants, animal bodies, and animal excreta encounter denitrifying bacteria that undo the work done by the nitrogen-fixing bacteria.
- Generally, nitrogen is the end-product of denitrification, but nitrous oxide (N2O) is also produced in much smaller quantities (up to ten present) and the fee nitrogen released in to the atmosphere.

2.6.3.2. Human impact on Nitrogen cycle

The disruption of the nitrogen cycle by human activity plays an important role in a wide-range of environmental problems ranging from the production of tropospheric (lower atmosphere) smog to the perturbation of stratospheric ozone and the contamination of groundwater. Nitrous oxide is a greenhouse gas like carbon dioxide and water vapour can trap heat near the earth's surface. It also destroys stratospheric zone. Eventually nitrous oxide in the stratosphere is broken down by ultraviolet light in to nitrogen dioxide (NO_2) and nitric oxide (NO),

which can catalytically reduce ozone. Nitrogen oxides are chemically transformed back to either N2 or to nitrate or nitrite compounds, which may later get used by plants after they are washed by the rain back to the earth's surface. Nitrate rain is acidic and can cause ecological problems as well as serve as a fertilizer to vegetation.

2.7 Phosphorus cycle in an aquatic ecosystem

2.7.1 Importance of Phosphorus cycle in an aquatic life

- Phosphorus is an important and necessary chemical for both plants and animals as it is an essential constituent of DNA, RNA, fats such as phospholipids, bones and teeth of animals.
- Phosphates are also a critical component of ATP, the cellular energy carrier as they serve as an energy 'release' for organisms to use in building proteins or contacting muscles.
- Like calcium, phosphorus is important to vertebrates; in the human body, 80% of phosphorous is found in teeth and bones.

2.7.2 Phosphorus cycle

- Phosphorus circulates through water, the earth's crust, and living organism.
- It is **not** present in the **atmosphere** and is most likely to enter food chains following the slow weathering of phosphate rock deposits.
- Some of the released phosphates become dissolved in soil water which is taken up by plant roots.
- Phosphates are not very soluble in water, and not found in many types of rocks.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Phosphorus is therefore the main limiting factor for plant growth in most soils and aquatic ecosystems.
- Animals obtain phosphorus by eating plants and/or herbivores.
- Dead organisms and animal wastes return phosphorus to the soil, to streams, and eventually to ocean floors as rock deposits.

People disrupt the phosphorus cycle by mining large amounts of phosphate rock for fertilizers and detergents; and through run off of such substances plus animal waste and sewage into aquatic ecosystems.

2.8 Sulphur cycle in aquatic environment

- Sulphur is one of the components that make up proteins and vitamins.
- Proteins consist of amino acids that contain sulphur atoms.
- Sulphur is important for the functioning of proteins and enzymes in plants, and in animals that depend upon plants for sulphur.
- Plants absorb sulphur when it is dissolved in water. Animals consume these plants, so that they take up enough sulphur to maintain their health.
- Most of the earth's sulphur is tied up in rocks and salts or buried deep in the ocean in oceanic sediments. Sulphur can also be found in the atmosphere. It enters the atmosphere through both natural and human sources.
- Natural resources can be for instance volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- When sulphur enters the atmosphere through human activity, this is mainly a consequence of industrial processes where sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) gases are emitted on a wide scale.
- When sulphur dioxide enters the atmosphere, it will react with oxygen to produce sulphur trioxide gas (SO_3), or with other chemicals in the atmosphere, to produce sulphur salts.
- Sulphur dioxide may also react with water to produce sulphur acid (H_2SO^4). Sulphuric acid may also be produced from dimethylsulphide, which is emitted to the atmosphere by plankton species.
- All these particles will settle back into earth, or react with rain and fall back into earth as acid deposition.
- The particles will then be absorbed by plants again and are released back in to the atmosphere, so that the sulphur cycle will start over again.

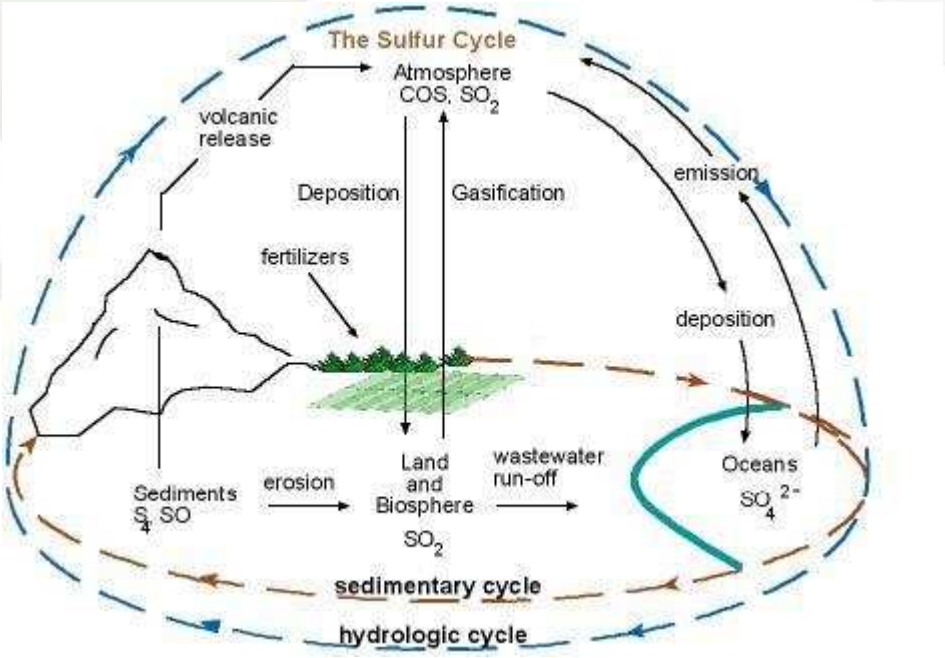


Fig. 3. Sulfur cycle

2.9 Energy Flow in an Ecosystem

2.9.1. Energy sources

All ecosystems must have a source of energy (usually the sun) because all organism functions such as growth and reproduction require energy. Energy moves through the ecosystem by a series of events that link organisms together. Ecosystem functions mainly comprise the interactions of various components in an ecosystem. They are interconnected by energy, nutrients and minerals.

The survival of an ecosystem depends on Flow of energy-- Non cyclic food chain

Biogeochemical cycle –Cyclic food chain - circulation of nutrients and minerals

Plants have green pigments, called chlorophyll which captures energy from the sun (solar energy) to split carbon dioxide atoms and then combine the carbon atoms with oxygen and hydrogen (photosynthesis) to make sugars (food).

2.9.2. Photosynthesis

Carbon dioxide + water + Sunlight + nutrients = Simple sugar + oxygen

(energy) (food)

Some sugars produced during photosynthesis are broken down during respiration to release energy needed by the plant for growth and reproduction. Others are used to make “building blocks” that are combined to make plant cells, hence plant parts.

2.9.3 Respiration

Designed and developed under the aegis of NAHEP Component-2 Project “Investments In ICAR Leadership In Agricultural Higher Education”
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Simple sugar (food) + oxygen + carbon dioxide + water + energy (heat)

Animal that eat plants (herbivores) use them to make animal parts or burn them to produce energy for their cell functions. Any compounds not used immediately are combined and stored as fats. Tissues of animals eaten by other animals (predators/carnivores) are broken down and re-combined into new parts for that animal, and so on. Thus, all animals depend on plant for food.

2.9.4 Trophic levels

The different feeding levels in the food chain are called trophic levels. Food chains comprised of many feeding or nourishing levels, and each level is called trophic level. The first trophic level in the food chain is called primary producers, the second trophic level is the primary consumers (herbivores), and the third level is occupied by the primary carnivores. The number of trophic levels in a food chain is always restricted to 3 to 5. Lower the number of trophic levels higher the transfer of energy to the top level organisms in the food chain. The energy transfer will be very less to the top predator, if the food chain is having more than three levels of trophic tiers.

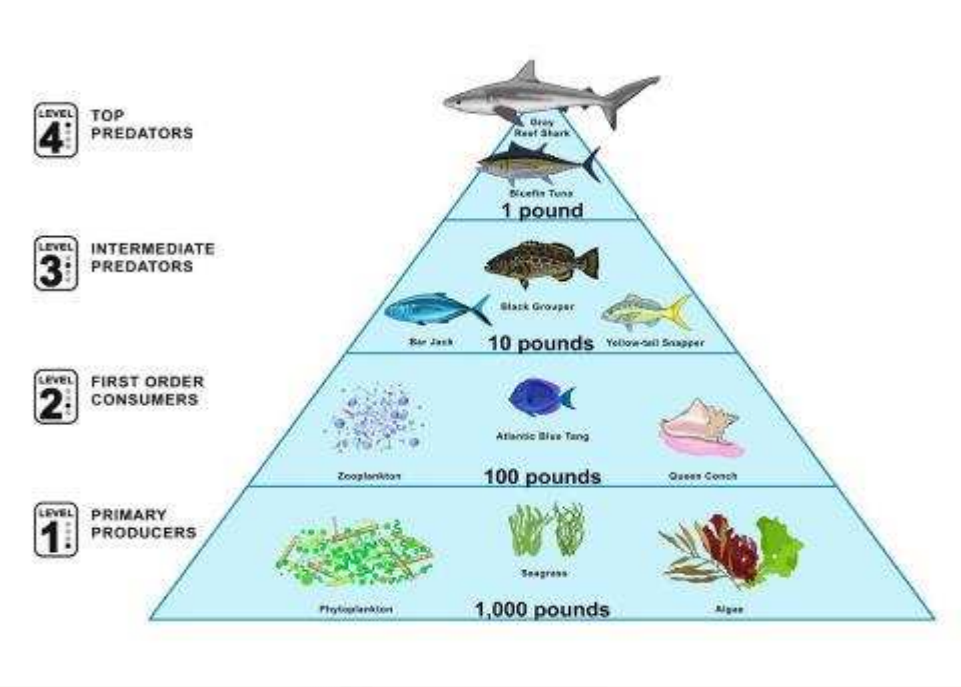


Fig. 4 Trophic levels in an aquatic ecosystem

2.9.5 Energy Flow

The transfer of energy from one trophic level to another is called **energy flow**. This flow of energy is always unidirectional and never returns back, like nutrients, which cycles in the ecosystems. So, energy can be utilized once in the ecosystem and otherwise it will go as waste heat.

2.9.5.1 Energy flow is based on two important Laws of Thermodynamics which are as follows:

(1) The first law of Thermodynamics

- It states that the amount of energy in the universe is constant.
- It may change from one form to another, but it can neither be created nor destroyed. Light energy can be neither created nor destroyed as it passes through the atmosphere. It may, however, be transformed into another type of energy, such as chemical energy or

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

heat energy. These forms of energy cannot be transformed into electromagnetic radiation

(2) The second law of Thermodynamics:

- It states that non-random energy (mechanical, chemical, radiant energy) cannot be changed without some degradation into heat energy.
- The change of energy from one form to another takes place in such a way that a part of energy assumes waste form (heat energy).
- In this way, after transformation the capacity of energy to perform work is decreased. Thus, energy flows from higher to lower level.

2.9.6 Energy flow in an ecosystem

- Through these series of steps of eating and being eaten, energy flows from one trophic level to another.
- Green pants or other photosynthesizing organisms use light energy from the sun to manufacture carbohydrates for their own needs. Most of this chemical energy is processed in metabolism and dissipated as heat in respiration.
- Plants convert the remaining energy to biomass. Ultimately, this material, which is stored energy, is transferred to the second trophic level, which comprises grazing herbivores, decomposers, and detrital feeders.
- Most of the energy assimilated at the second trophic level is again lost as heat in respiration; a fraction becomes new biomass.

- Organisms in each trophic level pass on as biomass with much less energy than they energy than they receive. Thus, the more steps between producer and final consumer, the less energy remains available.
- Seldom are there more than four links, or five levels, in a food web. Eventually, all energy flowing through the trophic levels is dissipated as **heat.** The process whereby energy loses its capacity to do work is called **entropy.**

2.10. Food chain in an aquatic ecosystem

- The biotic components of any ecosystem are linked with each other by food. This food relationship with other organisms is termed as **food chain**.
- In any ecosystem the primary producers from the food source for the primary consumers or herbivores, which will from food source to the secondary consumers or carnivores.
- The sequence of eaters being eaten is called food chain. A simple food chain may start with microscopic green algae. Microscopic zooplankton will serve as food for the small fishes

Primary producers (Phytoplankton and macroplants) → Primary consumers (Zooplankton and herbivorus fishes) → Secondary consumers (Small fishes and predatory fishes)

2.10.1 Types of food chain

Two basic types of food-chain are recognized:the grazing and detritus food chain.

2.10.1.1. Grazing food chain

The grazing food chain starts with green plants and ends with carnivores via herbivores. The producers are green plants, which prepare their own food in the presence of sunlight. So, they are also called as Autotrophs. The herbivorous animals eat the plants (autotrphs/primary producers). The carnivores eat the herbivorous animals. Thus, the grazing food chain starts with primary producers and ends with carnivores.

Plants (Phytoplankton)	→	Herbivores (zooplankton)	→	Primary carnivores (Zooplankton feeding fish)	→	Secondary carnivores (predatory fish / aquatic snakes)

This grazing food chain is further divided into preadator food chain and parasitic food chains.

2.10.1.2 Predator food chain

In this food chain one animal kills and eat the other animals. The animal which kills other animals for food is called a predator. This act of hunting is called predation. Animals that are caught and eaten by a predator are called prey. Predators that only eat the meat of prey are carnivores.

2.10.1.3 Parasitic food chain

The plants and animals of the grazing food chain are affected by parasites. Parasites derive their energy from their hosts.

Detritus food chain: it starts from the dead organic matter and ends with inorganic matter. This consists of decomposers like fungi and bacteria. These live on the dead matter of the organism and decompose the organic matter and convert to inorganic matter, which is helpful for plants to prepare their food.

However, these two food chains cannot function separately and are interconnected with each other at different levels. The organisms of detritus chain may serve as food for the organism of grazing food chains.

2.11. Food web

Food web is a set of interconnected food chains by which energy and materials circulate within an ecosystem. The food web is divided into two broad categories:

- **2.11.1 The grazing web** which typically begins with green plants, algae, or photosynthesizing plankton, and materials typically pass from plants to plant eaters (herbivores) to flesh eaters (carnivores).
- **2.11.2 The detrital web**, which begins with organic debris. These webs are made up of individual food chains. The materials pass from plant and animal matter to bacteria and fungi (decomposers), then to detrital feeders (detritivores), and then to their predators (carnivores).

2.8.3 Ecological pyramid

- An ecological pyramid (or trophic pyramid) is the graphical representation of the trophic structure such as number, biomass and

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

energy of an ecosystem. The use of this ecological pyramid was fist proposed by Charles Sutherland Elton (1927), and hence these ecological pyramids are called **Eltonian pyramid**.

- Ecological pyramids begin with producers on the bottom and proceed through the various trophic levels, the highest of which is on top. There are three types of ecological pyramids, viz.

  i) Pyramid of numbers,

  Ii) Pyramid of biomass and

  Iii) Pyramid of energy.

2.8.3.1 Pyramid of number

A pyramid of numbers shows the number of organisms at each trophic (relating of nutrition) level. In pyramids of numbers, the number of individuals at the trophic level decreases from the producer level to the consumer level. In an ecosystem, the number of producers is far high and the number of consumer in the subsequent trophic levels, are lesser than that of the producers.

Example: In a pond ecosystem, the number decreases in the following order

Phytoplankton - Zooplankton - Small fishes - Large predatory fishes / snakes

2.8.3.2 Pyramid of biomass

- Biomass refers to the total weight of the living organisms in a unit area. An ecological pyramid of biomass shows the relationship between biomas and trophic level by quantifying the amount of biomass present at each trophic level.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- In the pyramid of biomass, there will be a clear cut decrease in the biomass from the lower to the higher trophic levels. Generally, the pyramid of biomass is an upright one (the apex is pointed upwards) in all terrestrial ecosystems. In certain ecosystems like pond ecosystem, the pyramid of biomass is an inverted type of pyramid (apex is pointed downwards). In this type of ecosystem, which contain less amount of biomass of producers and more amount of biomass of consumers (fishes).

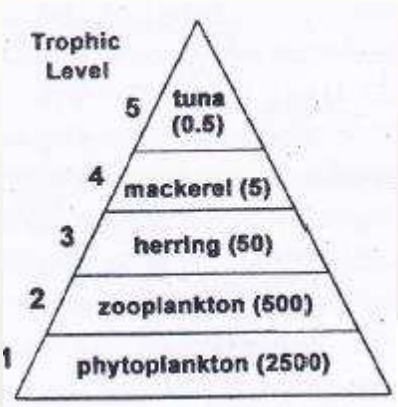


Fig.5 Food pyramid

Example: An Ocean Food Pyramid: it takes about 2500 pounds (1136kg) of phytoplankton to support 0.5 pound (0.2276kg) of tuna. The decrease from 2500 to 500 is 80 percent. The other trophic levels in this pyramid are decreased by 90 percent. It is an upright pyramid of biomass.

2.8.3.3 Pyramid of energy

At each trophic level in the food chain, energy that was originally stored by the autotrophic plants is dissipated along the food chain. When the links or levels in the food chain are more, the dissipated or unusable energy will also be more. There is generally a **90 percent loss at each level**

of the food chain, creating a pyramid-shaped diagram that is wider at the bottom and narrow at the top.

Example: In a pond, maximum energy is stored by the phytoplankton. Then, the energy decreases when it is transferred to the subsequent consumer levels.

2.9. References

1. Howard T. Odum (1953) *Fundamentals of Ecology*.
2. Introduction to Marine Biology-semester programs OCB 1001 Chantale Bégin, Jessica Fry, Michael Cucknell Version 3.6 Pp:1-321
3. A teaching manual on “Aquatic Environment and Biodiversity”. 2007. A.Srinivasan, Baskaran Manimaran, P.Padmavathi, and N.Jayakumar, Department of Fisheries Environment, Fisheries College and Research Institute, Tamilnadu Vetrerinary and Animal Sciences University, Thoothukudi
4. e-Courses –Aquatic Ecology and Biodiversity- in Agriculture and Allied Sciences – ICAR developed during the year 2012

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 3	Animal associations and its interaction in an aquatic environment
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

3.1 Objectives

- Symbiosis
- Commensalism
- Parasitism
- Prey-predator relationship
- Host- parasite relationship

3.2 Glossary of terms

1. **Commensals -** A **commensal** is an organism that uses food supplied in the internal or external environment of the host, without establishing a close association with the host, for instance by feeding on its tissues.
2. **Epizoism** – A non-parasitic relationship between animals in which one animal lives on the surface of the other.
3. **Endoecism** - Where one animal habitually shelters in a tube or burrow of another. Prime benefit = shelter, Ancillary benefit = food sharing
4. **Inquilinism** - Where one organism lives within another, using it as a refuge. Prime benefit = shelter.
5. **Coral bleaching** - whitening of coral that results from the loss of a coral's symbiotic algae *(Zooxanthellae*) or the degradation of the algae's photosynthetic pigment.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

3.3 Introduction

- In any environment, no organism can be able to live alone without having interaction with other organisms. Animals may have interactions with other animals, plants with other plants, animals with plants and even some plants are dependent upon animals.
- The interaction of one species with another is essentially important for the purposes of obtaining food and shelter and for meeting other necessary requirements.
- The interaction or inter-dependence or inter-relationship between the individuals of the same species is known as **intra-specific relationship** and the relationship between the organisms of different species is termed as **inter-specific relationship**.
- Inter-specific relations are divided into two types:
  i) Symbiosis
  ii) **Antagonism**

In symbiosis either one or both the species are benefited but neither species is harmed while in antagonism, any one of the partner species is harmed.

3.4 Symbiotic relationship in an aquatic environment

Symbiotic relationship is defined as close ecological relationships between the individuals of two (or more)

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

different species. Symbiotic relationships are divided into two categories:

i) **Mutualism**

iii) **Commensalism**

3.4.1 Mutualism

- A relationship between two dissimilar organisms that are mutually beneficial is called **mutualism**. The term mutualism literally meaning **'living together'** was first coined by De Bary 1877.
- The association may be **obligatory or continuous**, **facultative or transitory**. While in continuous or obligatory mutualism, the individuals or symbionts cannot live apart, in facultative mutualism the individuals can successfully live apart from each other.

3.4.1.1 Obligate Mutualism

This is a permanent type of relationship in which two symbionts are in close contact and interdependent on each other. It is also referred as Mutualism with continuous contact. Examples are given below

3.4.1.2. Coral and Zooxanthellae

A marine mutualism involves unicellular algae known as zooxanthellae and corals, a type of coelenterate animal. In this mutualism, the coral provides the algae with shelter and inorganic nutrient, while the pigmented algae provide photosynthate. Sometimes, this mutualism is upset by

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

environmental stresses associated with unusually warm or cool water temperature, a change in salinity, or excessive exposure to sunlight or shading. The leads to expulsion of the zooxanthellae by the coral, a phenomenon known as ''bleaching" which may lead to death of the coral unless it can re-establish another same algal species.

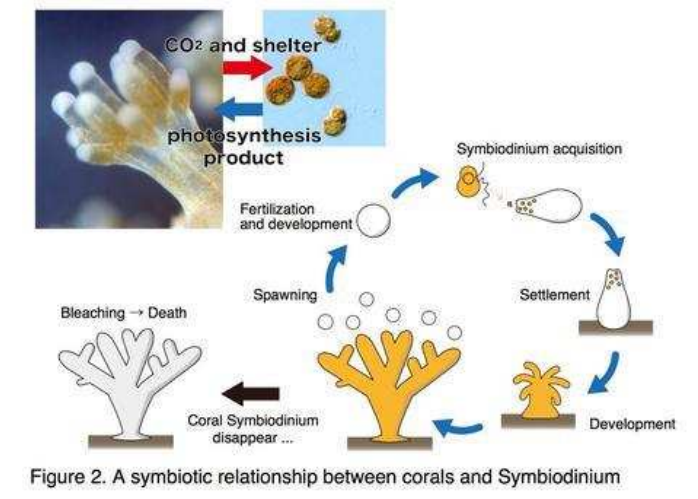


Fig.1 Symbiotic relationship between corals and microalgae

3.4.1.3 Clown fish and Sea anemone

Anemone fish (*Amphiprion frenatus*) lives its entire adult life among the tentacles of Bulb – Tentacle Sea Anemone (*Entacmae quadricolor*). Anemone fish do not get stung by the anemone as would most other fish, and so gain protection from predators. They drop food particles which anemone can eat. The anemone fish is known to live and spawn only in the bodies of the sea anemone and this will not live in the absence of the sea anemone. The anemone gets benefits from the

clown fish as it aerates the tentacles as well as removing the parasites from the bodies of the anemone.

Fig. 2 Clown fish and Sea anemone

3.4.1.4 Hermit crab and Sea Anemone

Hermit crab (*Eupagurus*) lives in the empty shell of a snail. The outer surface of the shell is inhabited by the sea anemone (*Adamsia*). The hermit crab is protected from the enemies by the nematocysts of anemone. The sea anemone derives food from hermit crabs and gets transported from one place to another.

Fig. 3 Hermit crab and Sea Anemone

3.4.1.5 Giant clam and Zooxanthellae

Gaint clam, *Tridacna gigas* lives in the well-lighted shallow coastal water and its mantle cavity harbours huge population of the algal symbiotic dinoflagellates species, which is commonly called Zooxanthellae (*Symbiodinium microadriaticum*). Since the clam shells are very thick, the shells cannot be closed and this helps the symbiotic algae to receive good sun light and carry out photosynthesis. Some of the older cells of these algae are in turn consumed by this giant clam

Fig. 4. Giant clam and Zooxanthellae

3.5 Facultative mutualism

- In this type of mutualism partners or symbionts are rarely attached to each other and it is only for a short duration. It is also called as **mutualism without continuous contact**. Though both the partners are benefited from each other but the nutritional need is

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

primary at least for one of the species. A commonly cited example of this type of mutualism is found in crocodile (*Crocodylus* spp.) and crocodile-bird (*Pluvianusae gyptius*), which removes leaches from around the teeth of the crocodile which allows the bird to enter its mouth for the search.

Fig.5 Crocodile (*Crocodylus* spp.) and crocodile-bird (*Pluvianusae gyptius*)

3.6 Commensalism

- Commensalism is an interaction between two different species of living organisms, where one partner or species benefits and the other species is neither benefited nor harmed.
- The term commensalism derives from the Latin word ***commensa*,** meaning sharing a table as guest messmates. The term commensalism was coined by **Van Beneden**
- In this relationship, there is no physiological inter dependence among the partners and the partners are referred as **commensals**.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- The purpose of this relationship is to get food, space, shelter, defence and transport. Commensalism divided into two types based on the level of association between the commensals.

3.6.1. Permanent commensalism

3.6.2. Temporary commensalism

Further based on the position or location of the commensal on the host species, it is

grouped into:

3.6.2.1 Endocommensals

3.6.2.2 Ectocommensals

3.7. Permanent commensalism

- In this type of commensalism, the commensals remain more or less in permanent contact with their hosts. E.g. Barnacles are permanently attached on the body surface of whales and these barnacles are not obtaining any food from the tissues of the whales (host).
- The barnacles are called as **ectocommensals** as they do not obtain any nourishment from whales and in turn the whales are helping barnacles in providing substratum for attachment.
- Some plants live as attached epiphytes on the surfaces of animals e.g. green alga that grows on the long, grooved hairs of the sloth. Abundance of alga gives green colour to the host.

- It is advantageous to the sloth in concealing it on the trees *Basicladia,* another green alga, is seen growing on the back of freshwater turtles many micro-organisms such as protozoa and saprophytic bacteria and fungi live within the tissues or cavities of higher plants and animals without causing any harm to the host. These are known as **endocommensals**

3.8 Temporary Commensalism

- In this type of association, the commensals remain only in temporary contact with each other. This intermittent contact between the animals for food, shelter or for breeding sites is seen in many marine animals. Examples are given below

3.8.1 Suckerfish and shark

Temporary association or contact between two animal commensals is seen in sucker-fish and the sharks or whales. Sucker-fish *(Echnesis*) is found attached by means of its dorsal sucker to the underside of a shark or other large animal.

Fig. 6 Suckerfish and shark

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.8.2 *Chaetopterus* (Poychaete worm) and *Polyonx* (crab)

The decapods crustacean, Polynex lives in the U-tube of the marine annelid, *Chaetopterus* sp., It obtains food particles and oxygen supply from water entering the tube due to the pumping action of the worm's parapodia.

3.8.3 *Fierasfer* (Pearl fish) and Seacucumber

A small tropical fish, *Fierasfer*, lives within the cloacal chamber of sea cucumber. The fish usually comes out to feed in the surrounding. Here the sea cucumber allows the fish to enter into the cloacal opening with their tail first.

Fig. 7 Pearl fish and Seacucumber

3.8.4 Portuguese man-of-war and fish

Physalia physalis (Jelly fish) is commonly known as Portuguese man-of-war. It is capable of killing almost all small sized fishes with the help of its tentacles and consuming them. But the small fish*, Nomeus sp*. lives and moves in between the tentacles of the Portuguese man-of-war freely without getting affected. It also takes shelter, protection and food from the Portuguese man-of-war.

Fig.8 Jelly fish and *Nomeus sp*

3.9 Antagonism

- The association between two different species in which one or both are harmed is called **antagonism**. It includes antibiosis, exploitation (parasitism and predation) and competition.

3.9.1 Antibiosis

- It is an inter-specific relationship in which one partner inhibits or kills the other partner.
- The inhibition is mainly effected by the production of toxic substance, which does not affect the partner which is producing but it will kill or inhibit the other partner. The production of harmful secretions of substances is a typical example of this type of relationship.
- Fungi are the chief sources of different kind of antibiotic substances such as *penicillin, streptomycin* and *aureomycin.*

- Another example for the antibiosis is that the blue-green algae, *Microcystis* sp., produce a toxic substance called hydroxylamine, which causes fish kill as well as the death of the cattle which drink the bloom affected water. Similarly, the toxic dinoflagellates bloom of different species, causes red-tide in seawater and produce toxin in the water which causes mass mortality of fishes.

3.10. Exploitation

- A form of competition wherein organisms indirectly compete with other organisms for resources by **exploiting** resources to limit the resources availability to other organisms.
- In this type of relationship, one exploits the other for its own benefits. So this is the one sided relationship.
- Two types of exploitations are distinguished in animals, namely parasitism and predatism.
- In **parasitism**, the parasites exploit the conditions found in the host by gaining support as well as shelter for it-self while in predatism one species prevails over the other for the sake of nourishment.

3.11. Competition

- Competition is an interaction between organisms or species in which both the

organisms or species are harmed

- It is a common feature found in animals and it adversely affects the other species with reference to food, space, light, oxygen or any other common need
- It divided into two types, viz. intra-specific **competition** and **inter-specific competition**
- In intra-specific competition, there is competition between the individuals of the same species, e.g. some of the larger fishes preying on smaller fishes.
- In inter-specific competition, there is a competition between two different species. E.g. Fishes eating the mosquito larvae and Carnivores feeding on the herbivores.

3.12. Parasitism

- Relationship between two species of plants or animals in which one benefits (the parasite) at the expense of the other (the host), sometimes without killing the organisms. The benefited partner is called as parasite and the affected partner is a host.

3.12.1. Parasite

- A parasite is an organism which exploits another organism for the purpose of nourishing from its tissues.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Some parasitic relationship are harmless, while in other cases a parasite can damage or even kill its host. It lives in or on the body of the host.
- A number of organisms also go through a parasitic stage at some point during their lives and afterwards they lead a different life. Hence, based on the duration of parasitic mode of life, parasites are classified as permanent and temporary parasites.

3.12.2 Temporary parasites

- Those organisms which spend only a portion of their life as parasites on the host are called temporary parasites. E.g. Lamprey *(Petromyzon*) and marine fish.
- The lamprey sucks the blood from the large fishes with its sucker and leaves the host. This type of parasitic forms is also known as facultative parasites.
- The *Glochidium* larva of freshwater mussel attaches to the host fish by its hooks till it attains a young stage and leads a permanent benthic life.

3.12.3 Permanent parasites

- Those organisms which spend their entire life as parasites are called **permanent parasites.**
- The permanent parasites of plants are called the **Phytoparasites,** and those of animals as **Zooparasites.** These are also called as obligatory parasites, which must need a host.

- The permanent parasites can be divided into two categories, viz**. Ecto-parasites and endo-parasites**, the former referring to external parasites, and the latter internal parasites.
- The endoparasites are further divided into **intracellular parasites** and **intercellular parasites**. Parasites which live inside the host cell are called intracellular parasites (e.g. *Trypanosoma*) and those which live in between the cells of the host are inter cellular parasites (eg. flukes, isopods, etc.).
- Another marine example is that the male angler fish of very small size is attached to the large sized female fish, *Antennarius hispidus*. This attachment of male fish with female is to get nourishment as well as for reproduction. This type of parasitism is also termed as **sexual parasitism.**

3.12.4 Hyper parasitism

- Sometimes, parasites themselves are parasitized by other organisms. Such parasites are known as **hyperparasites**. For example*, Nosema notabilis* is a hyper parasite on Myxosporidian, *Sphaerospora polymorpha* a common parasite of the urinary bladder of the toadfish.

3.13 Prey- predator relationship

- The prey-predator relationship is well known relationship in the ocean. "**Predators"** are hunting animals that capture and kill their "**prey**".
- A convenient starting point in the study of predator prey interactions is to consider the factors influencing the state of predation.
- One such factor is the abundance of the prey. If the prey is dense, a predator will be able to capture as many as it needs with a minimum of effort and time. If the prey is sparse, the predator will have to seek persistently even to catch only a few.

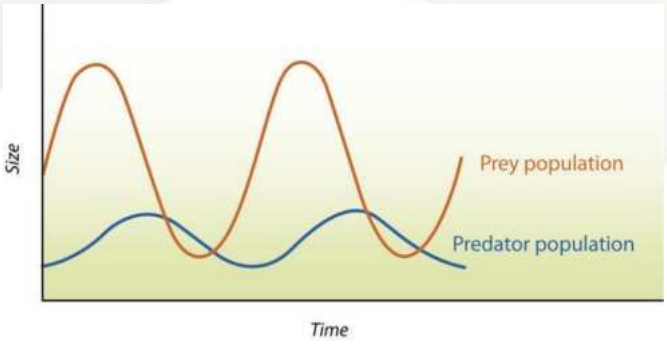


Fig.9. Predator prey relationship curve

3.14. Host and parasite relationship

- The study of parasites and their relationship to their hosts is one of the most fascinating and rewarding phase of ecology.

- The concept of parasitism is complete in relationship between the parasite and its host.
- The term parasitism is the condition of life normal and necessary for an organism that lives on or in its host and that nourishes itself at the expenses of the host without destroying it as a predator does its prey but after influence some degree of injury affecting its welfare

Table.1 The interspecific relationships between animal can be graphically represented as shown below: Inter-specific relationships among organisms

S. No	Type of Relationship	Species A	Species B	Effect of relationship
1.	Neutralism	0	0	Neither species affects the other.
2.	Mutualism	+	+	Favourable to both.
3.	Commensalism	+	0	Favourable to A, the commensal, but not to B, the host.
4.	Exploitation or Parasitism	+	-	Favourable to A, the parasite but harmful to B, the host.
5.	Predation	+	-	Beneficial to A, the predator but harmful to B, the prey
6.	Competition	-	-	Harmful to one species or the other.

The symbol '+' denotes the fact that both members of the partnership are benefited, while the symbol '-' refers to the harmful nature of the association and symbol '0' denotes the fact that there is no significant effect as a result of partnership on the partners.

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 4	Aquatic Biodiversity, its types and diversity indices
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

4.1 Objectives:

- Aquatic biodiversity-an introduction
- Different types of biodiversity and its indices
- Adaptations of organism in different habitat

4.2 Glossary of terms:

- **Biodiversity** is the variation among living organisms from different sources including terrestrial, marine and desert ecosystems, and the ecological complexes of which they are a part. E. O. Wilson first used the term “biodiversity” in 1988
- **Biodiversity** is that part of nature which includes the differences in genes among the individuals of a species, the variety and richness of all the plant and animal species at different scales in space, locally, in a region, in the country and the world, and various types of ecosystems, both terrestrial and aquatic, within a defined area
- **Species diversity** relates to the number of the different species and the number of individuals of each species within the community. It comprises of Species richness and Species evenness
- **Habitat** is the specific place in the environment where the organism lives; e.g. rocky or sandy shore, mangrove, coral reefs. Different habitats have different chemical and physical properties that dictate which organisms can live there
- **Species richness** is the number of species that live in a certain location

Designed and developed under the aegis of NAHEP Component-2 Project “Investments In ICAR Leadership In Agricultural Higher Education”
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- **Biodiversity indices** are quantitative measures that reflects how many different types (such as species) are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types.

4.3 Aquatic biodiversity

- Aquatic biodiversity encompasses freshwater ecosystems, including lakes, ponds,

  reservoirs, rivers, streams, groundwater and wetlands.
- It also consists of marine ecosystems, including oceans, estuaries, salt marshes, sea grass beds, coral reefs, kelpbeds of seaweeds and mangrove forests.

In summary, aquatic biodiversity includes all unique species and habitats and the

interaction between them. Fishes exhibit enormous diversity in size, shape, biology and in

the habitats.

4.3.1. Threats to aquatic biodiversity

Anthropogenic activities are causing species to disappear at an alarming rate. It has been estimated that between 1975 and 2015, species extinction will occur at a rate of 1 to 11 percent per decade. Aquatic species are at a higher risk of extinction than mammals and birds. Freshwater and marine ecosystems face similar threats.

4.3.1.1Invasion of exotic species

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Exotic species are introduced into marine areas by means of transplanting or commercial shipping. It has been reported that ship ballast water is responsible for the transport of approximately 3,000 species worldwide each day. Exotic species can have many negative impacts on the environment, the economy and human health. When species are introduced into an area, they may cause increased predation and competition, disease, habitat destruction, genetic stock alterations and even extinction.

4.3.1.2. Habitat loss and degradation

Marine ecosystems are experiencing high rates of habitat loss and degradation. Shoreline stabilization, development of large ports, mangrove deforestation, coral and sand mining and the existence of densely populated coastal cities all contributed to this loss. The introduction of structures such as fishing harbours, jetties and other structures has interrupted important longshore current movements. As a result, beach fronts and marsh communities are becoming eroded and experiencing increased sand loss.

4.3.1.3 Construction of dams

Construction of dams across the rivers leads to the destruction of feeding and breeding grounds of many freshwater fishes and also the migratory fishes to a greater extent. Excess release of water from the reservoir and diversion of river water for agricultural and industrial purposes may also results in the destruction or degradation of freshwater fish habitats.

4.3.1.4 Human bias

Losses to aquatic biodiversity are also linked to pests or threats towards species that

are either unobserved or whose existence and importance to aquatic ecosystems are

unknown. Often times "pest" or "threat" species such as sharks have been hunted to

near extinction upsetting the natural balance of their associated ecosystem. Purposeful

usage of dynamiting and fish poisons may also cause severe fish biodiversity loss.

4.3.1.5 Overexploitation of species

Overexploitation of species affects the loss of genetic diversity and species abundance

of both individual and /or groups of interacting species. Modifications of gear and vessel efficiency have caused a significant decrease in fish populations. Incidental by-catch from fisheries operations also contribute to the decline in aquatic biodiversity.

4.3.1.6 Aquaculture

Aquaculture production has increased greatly in partial response to the decline in fisheries. Certain types of aquaculture can also contribute to the degradation of natural environments in many parts of the world. For example, it can contribute to the accidental release of non-native species, habitat conversion, pollution, as well as actual elimination of more fish than is being produced.

4.3.1.7 Pollution

Oceans have historically been the dumping grounds for the wastes from society. Pollution has been considerably damaging to aquatic ecosystems and may consists of agricultural, urban and industrial wastes containing contaminants such as sewage, fertilizer, and heavy metals, pesticides and other harmful substances that have proven to be very damaging to the loss aquatic habitats and species.

4.3.1.8 Sedimentation

Land management practices including urbanization, farming, forestry practices and industrialization have all contributed to the increased flow of sediments, in turn impacting aquatic resources. As a result of these activities, sediment runoff into rivers, lakes, streams, and estuaries has increased and is adversely affecting the biodiversity of these areas in a number of ways.

4.3.1.9 Climate change

Global climate change poses serious threats such as sea level rise, increase of sea surface temperature, ocean acidification, etc. to many aquatic ecosystems. In the last century, increased global temperature has caused sea levels to rise approximately 15 - 20 cm (6 - 8 inches) worldwide, and is expected to continue to rise at an average rate of 1 – 2 mm/year. At this rate, low lying areas and coastal aquatic ecosystems such as estuaries, marshes, and mangrove forests are being threatened.

4.3.2 Benefits of biodiversity

- Species diversity is the source of food, building materials, energy and medicines and services such as pollination, waste assimilation

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

and water filtration.

Genetic diversity that makes species possible, breeding of high yielding species and disease-resistant plants and animals and allows for adaptation to changing climatic conditions.

- Ecosystem diversity, in addition to aquatic species and genetic diversity enhances the quality of life through recreation, aesthetic enjoyment and spiritual enrichment opportunities.

4.4 Types of biodiversity

There are the following three different types of biodiversity:

I. Species diversity
II. Genetic diversity
III. Habitat diversity

4.4.1.0 Species Diversity-An introduction:

- Species is a basic unit of classification and is defined as a **group of similar organisms** that mate and produce offspring's with one another and thus, share a common lineage.
- The numbers of species of plants and animals that are present in a region constitutes its species diversity.

4.4.1.1. Species diversity is defined as the number of species and abundance of each species that live in a particular location. The number of species that live in a certain location is called **species richness**.

- The richness of a species tells about the extent of biodiversity of a site and provides a means for comparing different sites. The species richness depends largely on climatic conditions. When a

species is confined entirely to a particular area, it is termed as **endemic species**.

- Areas that are rich in species diversity are called **'hotspots' of diversity**.
- India is among the world's 15 nations that are exceptionally rich in species diversity.

4.5.0. Genetic Diversity:

- It refers to the variations among the genetic resources of the organisms.
- Each member of any animal or plant species differs widely from other individuals in its genetic makeup because of the large number of combinations possible in the genes that give every individual specific characteristic.
- This genetic variability is essential for a healthy breeding population of a species.
- Genetic diversity refers to the diversity (or genetic variability) within species.
- Each individual species possesses genes which are the source of its own unique features.

4.5.1 Importance of Genetic Diversity:

(i) It helps in speciation or evolution of new species;

(ii) It is useful in adaptation to changes in environmental conditions;

(iii) It is important for agricultural productivity and development.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

4.6.0 Habitat diversity: Habitat diversity is the number of different habitats that one particular region can provide. Examples are given below:

4.6.1 Lentic habitat

4.6.1.1 Ponds

Ponds are very shallow in nature and its average depth may be about 8-10 feet with some exceptions. Since the ponds are shallow, the light penetrates up to the very bottom. In ponds, water temperature is fairly uniform from top to bottom. There is little wave action, because the water is shallow. Based on the origin, the ponds can be of natural types and artificial types. Natural ponds are formed either due to the ageing of the lakes or filled with accumulation of rain water in the natural depressions that occur on the earth surfaces, whereas the artificial ponds are man-made ones.

4.6.1.2 Lakes

Lakes are bigger than ponds and too deep to support rooted plants except near the shore. Some lakes are deep enough and wide enough for waves to form. For example, the Lake Superior is the largest freshwater lake in the world, with a water spread area of 31,000 square miles. Similarly, the Lake Baikal in the Southern Siberia, is the deepest lake in the world, which has a depth of 1,700 meters.

4.6.1.3 Zonation of lakes and ponds

Lakes and ponds are divided into three different "zones" namely littoral, limnetic and profundal zones, which are usually determined by depth and its distance from the shoreline.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

4.6.2 Lotic habitat

4.6.2.1 River habitat

Rivers are called running water systems. River waters are characterized by movement of water and it is the unique characteristic of river waters. The interchange between the soil and water is higher in the river waters than the pond waters. Dissolved oxygen content is more and uniformly distributed in running waters and there is no physical and chemical stratification. Depending on the water movement in different zones, the nature of bottom materials is changing with sandy, muddy, rocky or pebbles.

4.6.2.2 Adaptations of organisms

The living organisms of the running water systems possess a variety of adaptations to maintain their position against the fast moving waters. The plants and animals are permanently attached to the hard substratum like stones and pebbles. Most of the animals inhabiting the streams and rivers are positively rheotatic and they are capable of moving against the water flow or currents. Freshwater animals body fluids are hypertonic to their environment and constantly take in water by osmosis which is referred as endosmosis. Special types of adaptations for respiration are seen in the freshwater animals.

4.6.2.3 Estuarine habitat

Estuaries are partially enclosed bodies of water along coastlines where fresh water and salt water meet and mix. Estuary is acting as a transition zone between oceans and continents. It has a free connection with the ocean. Fresh water input from land sources dilutes the estuary's

salt content. They characerstic feature or the estuary is the mixing of fresh and salt water Pritchard (1967) defined as"An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage."

4.6.2.4 Mangrove habitat

Mangroves are salt-tolerant aquatic ecosystems found mainly in tropical and sub-tropical inter-tidal regions. They are trees or shrubs, common in shallow and muddy salt water or brackish waters, along quiet shorelines and in estuaries. This eco-system is highly fragile, subjected to physiological and morphological stresses, salinity effect, aeration and wave action. Mangroves are also called as mangal, mangrove forest biome, mangrove swamp, mangrove forest etc. Mangroves protect coastal areas from erosion, storm surge (especially during hurricanes), and tsunamis. Of the recognized 110 mangrove species, only about 54 species in 20 genera from 16 families constitute the "true mangroves".

4.6.2.5. Adaptations of mangroves

Mangroves have **Pnuematophores (aerial roots),** allow mangroves to absorb gases directly from the atmosphere and other nutrients such as iron from soil. The roots also contain wide aerenchyma to facilitate transport gas within the plant.

4.7.0 Biodiversity indices

It is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

account how evenly the basic entities (such as individuals) are distributed among those types. Species diversity relates to the number of the different species and the number of individuals of each species within the community. It comprises of - Species richness and Species evenness.

4.7.1 Simpson Index:

Also known as Index of Dominance derived by Edward H. Simpson in 1949. This index gives an idea regarding the magnitude of stress in a particular community.

$$D=\Sigma\, n(n-1)/N(N-1)$$

where, n - number of individuals of particular species.

N - total number of individuals.

D is the measure of dominance, so as D increases, diversity (in the sense of evenness) decreases.

- It is less sensitive to richness and more sensitive to evenness.
- The scale ranges from 0 – 1, with 1 representing the lowest biodiversity.

4.7.2 Shannon Wiener Index:

Most commonly used index in ecological studies for comparing diversity between various habitats. It is dimensionless, independent of sample size and expresses the worth of each species.

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where,

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

p_i - total individuals in a community.

- More sensitive to evenness than richness.
- Increased values indicate increased diversity.
- This index has no units; value only as comparison between at least two communities.
- Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4.

4.7.3 Evenness Index:

It is a measure of the uniformity of different species in a community.

$$E = \bar{H}/\log_e S$$

Where,

$\bar{H}$ -shannon wiener species diversity index

S - number of species.

The value increases as the environment becomes favourable.

4.7.4 Jaccard's Index

For comparing biodiversity levels across different sites this index is used.An intuitive measure of similarity between two samples can summarize the fraction of species they share.

$$J=s_c/s_a+s_b+s_c$$

Where, Sa and Sb are the numbers of species unique to samples a and b, respectively, and Sc is the number of species common to the two samples.

Jaccard's index only utilizes the richness component of diversity, and it does not entail any information on abundance.

4.7.5 Richness Index:

The mathematical expression of richness index is,

$RI = S\text{-}1/\log_e N$ OR

$RI = S/\sqrt{N}$

Where,

S- number of species and

N- total number of individuals of all species.

- This index reflects the suitability of a particular habitat for successful thriving and growth of different species.
- The value decreases when environment becomes unfavourable or stressful due to intrusion of some foreign matter.

4.7.6 Importance of Biodiversity Indices:

- Diversity indices provide important information about rarity and commonness of species in a community.
- The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure.

4.8 Reference:

1. Begon, M., J. L. Harper, and C. R. Townsend. 1996. Ecology: Individuals, Populations, and Communities, 3rd edition. Blackwell Science Ltd., Cambridge, MA.
2. Magurran, A. E. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton, NJ.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 5	Ecological and evolutionary processes, Ecological niche
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

5.0. Objectives:

- Importance of Ecological Processes in an aquatic ecosystem
- Evolution of aquatic organisms in the ocean
- Ecological niche – lagoons

5.1. Glossary of terms

- **Evolutionary ecology** lies at the intersection of **ecology and evolutionary** biology. It approaches the **study of ecology** in a way that explicitly considers the **evolutionary** histories of species and the interactions between them
- **Ecological niche:** In ecology, a **niche** is the fit of a species living under specific environmental conditions. The ecological niche describes how an organism or population responds to the distribution of resources and competitors (for example, by growing when resources are abundant, and when predators, parasites and pathogens are scarce) and how it in turn alters those same factors (for example, limiting access to resources by other organisms, acting as a food source for predators and a consumer of prey)
- **Ecological processes** are the interactions between plants, animals and the non-living components of the environment like climate or rocks. These processes are crucial for maintaining healthy ecosystems and supporting the long-term persistence of biodiversity.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- **Evolution:** Biological evolution refers to the cumulative changes that occur in a population over time.
- **Lagoon:** A lagoon is a shallow body of water that may have an opening to a larger body of water, but is also protected from it by a sandbar or coral reef

5.2 Importance of Ecological Processes

- Chemical processes, including primary production (conversion of the sun's energy into organic matter through photosynthesis), and the associated cycling of carbon, nutrients (nitrogen, phosphorus), hydrogen/oxygen, and other elements from the physical environment (air, water, land) through biological organisms and back into the physical environment.
- Collectively, ecological processes produce organic matter, transfer carbon and nutrients, drive soil formation, and enable organisms to reproduce.
- They also play an important role in providing ecological services—for example, providing natural resources, such as food, fiber, and timber, and regulating air and water quality.

5.2.1 **Factors influence Ecological processes** are **primary production, influence the extent,**

distribution and **biodiversity** of systems

- **Primary producers** include everything from microscopic organisms to the larger animals of the oceans
- **Primary production** is influenced by the availability of nutrients.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- If primary production declines, energy flow to higher trophic levels is diminished, potentially compromising the sustainability of animal populations dependent on plants for food.
- Too much primary production can also cause problems, such as when lakes experience an overload of **nutrients**. Such eutrophic conditions can alter the composition of animal and plant life and result in reduced oxygen levels as organic matter decomposes.
- The "dead zone" in the Gulf of Mexico is an example of the effects caused by excess nutrients and too much primary production.

5.2.2 Impacts of human activities on ecological processes

- Ecological processes can be impacted by both natural forces and human activities happening over different temporal and spatial scales.
- With respect to natural forces, ecological processes are affected by both small-scale natural events such as seasonal changes in temperature, precipitation, and stream flows and large-scale events such as climate change.
- Other impacts of human activities such as including pesticide use, chemical use, waste generation, land use changes, and water quality management, among others—on the rates, types, and timing of ecological processes.
- **Many pesticides, chemicals used in industry, pollutants, and waste products** can interfere with species reproduction, one of the most important ecological processes.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- **Changes in land use** that alter the extent and distribution of ecological systems can directly affect ecological processes in particular areas, often causing associated changes in primary production, nutrient cycling, and erosion and sediment transport.
- **Water quality management** is affected by the activities that upset the balance between primary production and respiration (such as wastewater treatment plant discharge, nutrients from fertilizers and animal manure, and ultraviolet radiation).
- In aquatic systems, temperature is the ultimate factor determining species distributions although multiple proximate factors are involved in setting range limits, particularly dispersal capability, habitat quality and the outcomes of biological interactions themselves are modulated by temperature.
- Dispersal ability shapes distributions of aquatic organisms, alongside ecological traits that facilitate successful colonization, such as adult body size and anti-predator behaviour
- Past environmental changes have altered availability of essential habitat and driven extinctions

5.2.3.3 The three main **research** ecological **methods** commonly used to assess ecological

processes are

- Observation,
- Modelling and
- Experimentation

An evolutionary and ecological processes is required to understand broader patterns of

species distribution and to predict responses to global change.

5.3. Evolution of aquatic organisms in the ocean

5.3.1 Evolution

Biological evolution refers to the cumulative changes that occur in a population over time. These changes are produced at the genetic level as organisms' genes mutate and/or recombine in different ways during reproduction and are passed on to future generations. This process of differential survival and reproduction is known as **natural selection**.

5.3.2 Evolution of life in the ocean

- The biological evolution in the marine environment plays a crucial role in understanding the origin of life on Earth.
- Evidence shows that life probably began in the ocean at least 3.5 billion years ago. Photosynthesis began more than 2.5 billion years ago—**The Great Oxidation Event**. But it took hundreds of millions of years for enough oxygen to build up in the atmosphere and ocean to support complex life.
- The first organisms were **single-celled microbes** for nearly 2.3 billion years ago, life consisted of these alone.
- About 1.2 billion years ago, more **complex multi-celled organisms evolved**. Since then, life forms have grown much more diverse—though not continuously. The record reveals bursts of evolution and expansion interrupted by massive extinctions.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

5.3.3 The Paleozoic Era - 542 Million to 250 Million Years Ago

- **Plants** were the first to make the move, followed by **invertebrates.**
- Many new species appeared and thrived.
- Worms, snails, star fish, trilobites, and many other kinds of sea animals evolved.
- Lampreys, small jawless fish-like animals, were the first fish in the oceans and the first animals with a notochord (a type of spine).
- Fish did not have jaws until the Silurian and by the Devonian they had evolved into huge forms like Dunkleosteus
- Not long afterward, **vertebrates t**ook to the land.
- The end of the Paleozoic Era came with the largest mass extinction in the history of life on Earth, wiping out 95% of marine life and nearly 70% of life on land.

5.3.4 The Mesozoic Era-250 Million to 65 Million Years Ago

- During the Triassic, some **reptiles** took to the water.
- The sea reptiles diversified during the Triassic and some become strange-looking. Tanystropheus looks a lot like a small Sauropod, but it was only distantly related to dinosaurs.
- The plesiosaurs from the Jurassic had taken on large sizes, like Elasmosaurus.
- All the dinosaurs and many other animals, especially herbivores, died off, leaving niches to be filled by new species in the coming era.

5.3.5 The Cenozoic Era- 65 Million Years Ago to the Present

- The final time period on the Geologic Time Scale is the Cenozoic Period.
- With large dinosaurs now extinct, **smaller mammals** that had survived were able to grow and become dominant.
- With the rise of so many carnivorous land mammals moved into the water.
- The massive carnivorous whale Basilosaurus had taken over the ocean.
- When Megalodon came along 28 million years ago, it became the largest shark in existence at 50 ft long. It hunted the small whales and seals like Odobenocetops.
- Megalodon died out 1.5 million years ago and the **whales became the largest animals in the ocean.**
- Today, the **Blue Whale** *(Balaenoptera musculus*) is the largest mammal in the world
- All species of life—including humans—evolved into their present-day forms over the course of this era, which hasn't ended and most likely won't until another mass extinction occurs.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

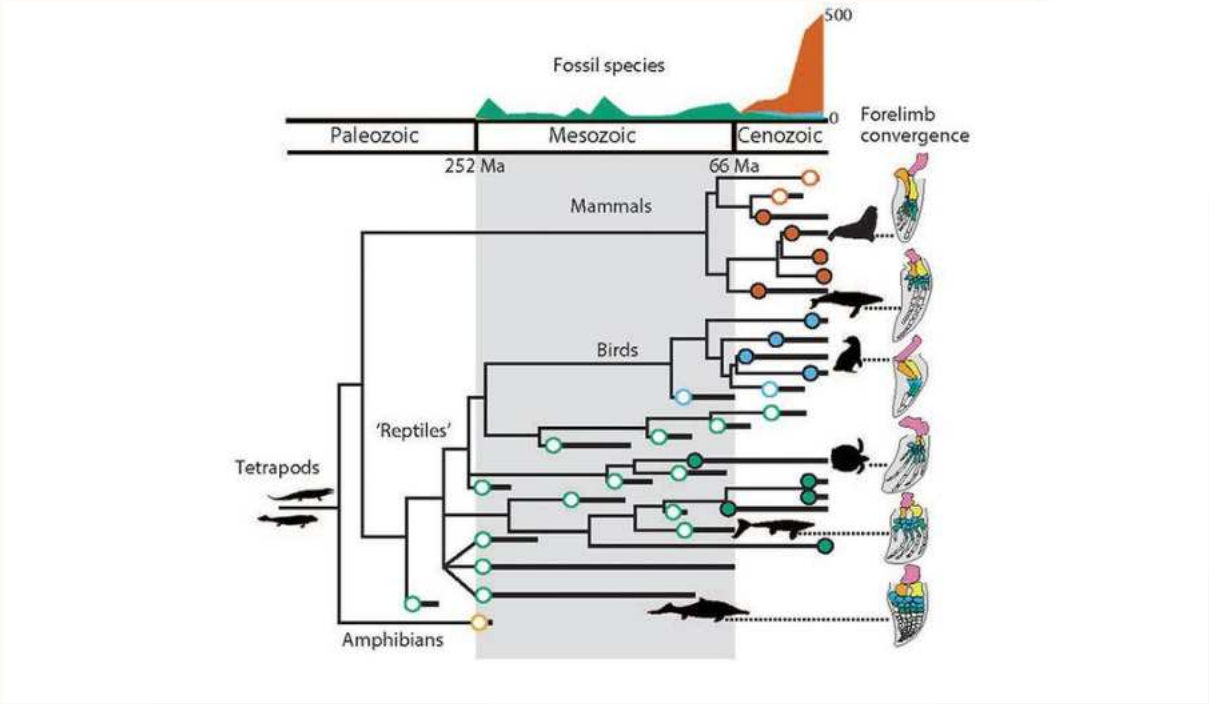


Fig.1 Evolution of life in the ocean

Over a period of 300 million years, many kind of species ranging from seals to mosasaurs independently developed similar streamlined forelimbs (for swimming) as they transitioned from living on land to the ocean.

5.4. Ecological niche- Lagoons

- **A lagoon is** a shallow body of water separated from a larger body of water by barrier islands or reefs.
- Lagoons are commonly divided into coastal lagoons and atoll lagoons. They have also been identified as occurring on mixed-sand and gravel coastlines.
- Lagoons are common coastal features around many parts of the world.
- Lagoons can also be man-made and used for wastewater treatment, as is the case for e.g. **aerated lagoons** and **anaerobic lagoons**

5.4.2.0 Types of lagoons

5.4.2.1 Coastal lagoon

A coastal lagoon is a shallow, coastal body of water, separated from the ocean by a barrier. This barrier can be formed by a barrier islands, a sand bar or spit, shingle or less frequently rocks.

5.4.2.2 Atoll lagoon

An oceanic or atoll lagoon is a circular coral reef or string of coral islands surrounding a lagoon. Atoll lagoons are much deeper than coastal lagoons, sometimes about 20 m deep.

5.4.2.3 Choked lagoon

Choked lagoons usually have a narrow channel to the sea and form in areas where the energy of waves in the sea is high. The narrow inlet mostly prevents the tides from entering, and also prevents much mixing of water. In arid areas, high evaporation rates and reduced tidal inflow result in this type of lagoon becoming temporarily or permanently hypersaline.

Mundel Lagoon and Rekawa Lagoon in Sri Lanka, the Songkhla Lake in Thailand and the Lagoa dos Patos, Brazil are examples of choked lagoons

5.4.2.4 Restricted lagoon

Restricted lagoons have more than one channel to the sea. Temporarily 'restricting' water exchange, but in reality there is good water exchange, and a net transport of water to the sea. Wind plays a role in restricted lagoons, as surface currents can develop because of the wind and result in mixing of water.

5.4.2.5 Leaky lagoon

Leaky lagoons have wide channel(s) to the sea. Unhindered interchange of water and fast water currents are the key features of leaky lagoons.

Example: The Mississippi Sound, USA

5.4.2.6 Ecological characteristics of lagoons

- Coastal lagoons are highly productive ecosystems. They contribute to the overall productivity of coastal waters by supporting a variety of habitats, including salt marshes, seagrasses and mangroves.
- They also provide essential habitat for many fish and shellfish species. For example, seagrass beds are a common feature of soft-substrate lagoons.
- Where seagrass beds occur, *Zostera marina* (eelgrass) is the most dominant species followed by *Thalassia testudinalinum* (turtle grass) is the most dominant species.
- Such beds play an important role in influencing the shape and stability of the shoreline, regulating dissolved oxygen, and filtering suspended matter.
- They can enhance the biodiversity of a lagoon by providing a physical refuge from predation and also serve as nursery and feeding habitats for a variety of organisms.
- Nutrients are transported to lagoons from surface water and groundwater flows and through exchange with the ocean. Because nutrient availability often limits primary productivity, coastal lagoons can foster high rates of primary production, thereby supporting high rates of secondary production compared to other aquatic ecosystems.

5.5. References

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 6	Ecological niches – Estuaries, mangroves and coral reefs
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

6.1 Objectives

- Estuaries- Classification, habitats and its biota
- Mangroves - Importance, adaptations and its biota
- Coral reefs - Importance, types and fauna of coral reef ecosystem

6.2 Glossary terms

- **Estuary:** An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage
- **Positive estuaries** is a salt-wedge estuary is highly stratified. Salt water moves into it in the shape of a wedge, with fresh water flowing over it
- **Mangroves:** Various types of salt-tolerant plant species (trees or shrubs) that occur in intertidal zones of tropical and subtropical sheltered coastlines.
- **Pneumatophores:** Commonly found in mangrove species that grow in saline mud flats, are lateral roots that grow upward out of the mud and water to function as the site of oxygen intake for the submerged primary root system
- **Fringing reef:** It is the most common and widespread of the coral reef structural types, usually found below the low tide level. Develop along the shores of tropical and subtropical islands or continental mass, anywhere the hard substrate

6.3 0. Ecological niche – Estuaries

- Estuaries are partially enclosed bodies of water along coastlines where fresh water and salt water meet and mix.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Estuary act as a transition zone between oceans and continents.
- An estuary has a free connection with the ocean.
- Fresh water input from land sources (usually rivers) dilutes the estuary's salt content.
- They must feature the mixing of fresh and salt water to be a true estuary.

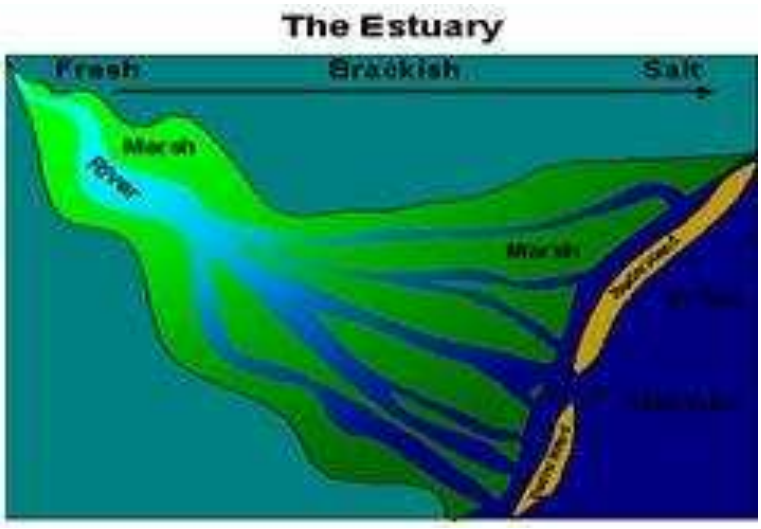


Fig.1 The estuary

6.3.1 Ecological characteristics of estuaries

- Estuaries have large amounts of organic matter, large numbers of organisms, and high secondary productivity.
- The detritus forms a substrate for a rich bacterial and algal growth, which is an important food source for various suspension and detritus-feeding animals. This accumulation of detritus forms an important source of food for many estuarine organisms.
- Estuaries are vital habitats for many marine and fresh water species. They are called the "**nurseries of the sea**" because the protected

environment and abundant food provide an ideal location for fish and shellfish to reproduce.

6.3.2 Classifications of estuaries

6.3.2.1. Estuaries based on geomorphology:

i. **Coastal Plain Estuaries** are formed by sea level rising and filling an existing river valley.

ii. **Tectonic Estuaries** are caused by the folding or faulting of land surfaces.

iii. **Bar-built Estuaries** form when a shallow lagoon or bay is protected from the ocean by a sand bar or barrier island.

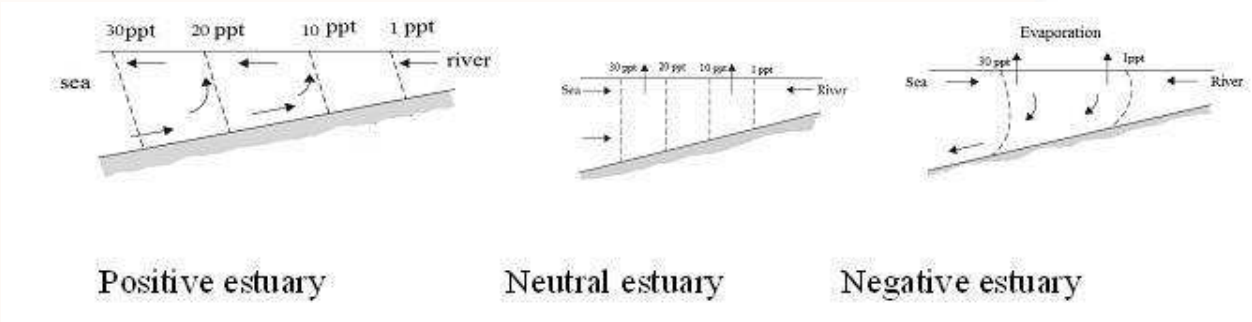
iv. **Fjords** are U-shaped valleys formed by glacial action. Fjords are found in Northern Europe, Alaska and Canada.

6.3.3 Estuaries based on circulation:

i) Salt-wedge estuary or Positive estuaries - A salt-wedge estuary is highly stratified. Salt water moves into it in the shape of a wedge, with fresh water flowing over it. The Mississippi River estuary is an example of this type

ii) Well mixed estuaries or Neutral estuaries - The vertically homogenous or well-mixed estuary is characterized by low inflow of fresh water and large tidal ranges.

iii) Evaporate estuaries or Negative estuaries - In desert climates where the amount of freshwater input to the estuary is small and the rate of evaporation high, a negative or evaporate estuary results.



Fig,2 Types of estuary based on circulation

6.3.4. Characteristics of estuary

These biotic and abiotic factors play an important role on the distribution and diversity of organisms in the estuary

a) **Salinity:** Variations in salinity are affected by temperature, dissolved gases, density and viscosity. Salinity in the estuary varies with depth, flux of fresh water, and changes with the tide. Floods result in reduced salinity and drought can result in higher salinity.

b) **Temperature:** Shallow estuarine waters exhibit great temperature changes. The sun heats up the estuary during the day and cools at night due to influx of water from rivers and the sea. Tides also affect estuarine temperatures at high tide, the deeper, lower reaches of the estuary remain cool, and only the top layers are heated by the sun.

c) **Oxygen:** Some estuaries have very low oxygen levels. In highly stratified estuaries, the level of biological activity in the lower levels can deplete oxygen levels. When mixing is low and tidal effects are minimal, replenishment of oxygen in the estuary may be minimal.

d) **Sediment:** Particle size and chemistry of estuarine sediments can make a difference in the organisms that can survive. Infiltration of the estuarine sediments by nutrients, trace elements, sewage and industrial waste can influence the productivity of the estuary.

e) **Wave action:** This effect is very minimal in estuaries and hence more amounts of sediments are settled along the bottom of the estuaries. This reduced wave action in turn promotes the deposition of sediments and development of rooted plants in the estuarine regions.

f) **Turbidity:** As this region is having good amounts of fine sediments or particles, turbidity of the estuarine waters is very high in most of the periods. The highest turbidities are known to occur during the maximum freshwater discharge into the estuaries.

6.3.5. Classification of estuarine organisms

The estuarine organisms are classified based on the **salinity tolerance levels** as follows:

i) Oligohaline organisms

These organisms include most of the freshwater forms inhabiting rivers which cannot tolerate variations in salinity of more than 0.1 ppt and which are not found at the head of the estuary. Some oligohaline species at the head may tolerate salinities up to 5 ppt and a few even as high as 19 ppt.

ii) True estuarine organisms

These organisms are euryhaline forms and are restricted to estuaries only. These are adapted to the wide variations of salinity and are known to live both in the upper and middle reaches of the estuaries with low saline conditions.

iii) Euryhaline marine organisms

These organisms extend their distribution from the sea to the upper reaches of the estuary. They can tolerate salinity as low as 15

ppt and a few even 5ppt.These organisms form the majority of the total estuarine biota.

iv) Stenohaline marine organisms

These organisms live on the open sea shore and at mouths of the estuaries. They do not enter the estuaries below salinities of 25 ppt.

6.3.6. Estuarine habitats

Estuaries enclose a diverse range of habitats from subtidal areas to intertidal areas.

- Sheltered upper estuary mangroves, seagrass beds and marshes
- Highly energetic beaches on the ocean side of the estuary
- Rocky reefs
- Wave built bars in estuary mouths
- Deep estuarine channels where swift tidal currents flow
- Shallow open salt water and fresh water
- River deltas
- Tidal pools
- Muddy fringing marshes
- Mid-estuary sand banks
- Intertidal flats
- Estuarine beaches

6.3.8.0. Biota of estuaries

6.3.8.1. Estuarine Flora: Diatoms, seaweeds, seagrassess, and mangroves

6.3.8.2. Fauna viz., protozoa, Coelenterata, Rotifera, annelida, arthropoda, finfishes, aquatic mammals like dolphins, sea cow and

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

manatee, terrestrial mammals like rodents, rabbits, tigers, etc., reptiles such as crocodile, sea snake, tree snakes, birds viz.,cormorants, pelicans, etc

6.3.9. Estuarine habitats of India

i) Hooghly-Matlah estuary in West Bengal

ii) Mahandi estuary in Orissa

iii) Godavari estuary in Andhra Pradesh

iv) Adayar Estuary

v) Vellar estuary

vi)Cauver yestuary Apart from these, there are brackish water lakes such as Chilika Lake in Orissa, Pulicat Lake in Tamilnadu and the Vembanad and Kadinamkulam backwaters in Kerala are important.

6.4.0. Ecological niche - Mangroves

- The term mangrove refers to an ecological group of halophytic plant species found along sheltered tropical and subtropical shores.
- It is a diverse group of plants that are adapted to wet, saline intertidal habitats.
- Terms such as mangrove community, mangrove ecosystem, mangrove forest, mangrove swamp, and mangal are used to describe the entire mangrove community.
- Healthy mangrove forests are key to a healthy marine ecology.
- The mangroves make an enormous contribution to the food chain that supports the coastal fisheries.

. Distribution of mangroves

- Mangroves are commonly found throughout the world between latitudes 32°N and 38°S.
- According to the report of the World Resources Institute, mangroves cover an area of 190,000 to 240,000 km^2, occupying about one-quarter of the world's coastal line. Mangroves extend over 18 million hectares worldwide, covering a quarter of the world's tropical coastline.
- Largest mangrove areas occur in Indonesia (30%) followed by Nigeria (10%), Australia (8%) and Mexico (7%).
- India contributes approximately 3% to the world mangrove area.
- Mangroves in India are spread over an area of about 4,500 km^2 along the coastal States/Union Territories of the country.
- Sunderbans in West Bengal accounts for a little less than half of the total area under mangroves in India.

6.4.2 Mangrove habitat

- Mangrove distribution is determined primarily by sea level and its fluctuations and secondarily by air temperature, salinity, ocean currents, storms, shore slope, and soil substrate.
- Most mangroves mostly live on muddy soils, but they can also grow on sand, peat
  and coral rocks
- Zonation often characterizes mangrove forests. Some mangrove species occur close to the shores, fringing islands, and sheltered bays. Others are found further inland in the estuaries influenced by tidal action.

- The roots of some mangrove species such as *Rhizophora* spp. (red mangrove) contain the **pneumataphores**- the unique breathing roots and **Avicennia** spp. (black mangrove) contain many small "breathing" pores, called "**lenticels**." These allow oxygen to diffuse into the plant and down to the underground roots by means of air space tissue in the cortex, called "**parenchyma.**" The lenticels are inactive during high tide.
- Certain species of mangroves exclude salt from their systems while, others actually excrete the salt via their leaves, roots, or branches.

6.4.3 Adaptation of mangroves

i) Salinity : Mangroves are capable of living in the salt water by reverse osmosis at the root level. Some species can exclude more than 90% of salt from the body. Another method is to secrete salt through the use of special glands on the leaves of the tree, which are among the most active salt-secreting systems known. Leaves with thick, waxy cuticles and stomata found only on their lower surfaces are examples of such modification.

ii) Survival in the anoxic soil - The red mangroves, *Rhizophora*, the root system is kept above the loose, anoxic soils so as to have contact with air for respiration as against keeping the roots below the soil in other plants. In black mangroves, *Avicennia* spp. the presence of respiratory roots or pneumatophores extending above the anoxic mud surface of the mangrove habitats so to have gaseous exchange is a special adaptation for efficient respiration mechanisms.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

iii) Production of a propagule - Many mangrove species show **vivipary reproduction**, (Eg. *Rhizophora*). The seed is germinated on the parent tree and grows by combination of photosynthesis and acquisition of nutrients from the parent. This structure, which is neither a seed nor a fruit, which usually termed a **propagule**, then falls to the ground and propagate and grow.

iv) Succulent stem- Some mangrove plants are known to have succulent stem to conserve water in its body.

6.4.5 Importance of mangroves

- Protect coastlines against erosive wave action and strong coastal winds, and serve as natural barriers against tsunamis and torrential storms.
- Refuge and nursery grounds - mangrove areas are excellent nursery grounds for a variety of commercially important prawns, crabs and fin-fishes, as they provide necessary food and shelter for living organisms. These ecosystems also provides food, roosting, nesting site and shelter to a large varieties of birds.
- Are important breeding ground for many fishes, crabs, prawns and other marine animals
- Fallen leaves and branches from mangroves contribute to the detritus and provide nutrients for the marine environment. These ecosystems are quite productive (350 – 500 g C m^{-2} yr^{-1}).
- Prevent salt water from intruding into rivers.
- Retain, concentrate and recycle nutrients and remove toxicants through a natural filtering process.

- Provide resources for coastal communities who depend on the plants for timber, fuel, food, medicinal herbs and other natural products

6.4.6.0 Flora and fauna of mangroves

6.4.6.1. Mangrove flora

About 50 mangrove species that are found worldwide belong to 20 genera in 16 families, although two families, Avicenniaceae and Rhizophoraceae dominate in terms of number of species and abundance.

The most common genera include *Rhizophora* (red mangrove), *Avicennia* (balck mangrove), *Aegiceros, Laguncularia, Lumnitzera, Bruguiera, Ceriops, Sonneratia, Xylocarpus, Heritiera*e.

6.4.6.2. Microalgae: Mangroves are rich in phytoplankton species such as *Navicula, Thalassiothrix, Pleurosigma, Ceratium, Peridinium,* etc.

6.4.6.3 Mangrove fauna including zooplankton groups Foraminiferans, copepods, rotifers, cladocerans etc., Polychaete (*Arenicola* sp.) worms, *Penaeus* spp., *Metapenaeus* spp., *Acetus indicus*, snapping prawn, *Alpheus* spp., mud shrimp, *Upogebia* sp., and mud crab *Scylla* spp. (*S. serrata*); Ghost crab *Dotilla* sp., Fiddler crabs like *Uca* spp. hermit crab *Clibanarius* sp; Mangrove crab *Aratus* sp., mud lobster, *Thalassina anomala,* barnacles *Balanus* sp, *Lepas* sp., insects, molluscs, gastropods *(Nerita, Littorina, Telescopium , Cerithidea,)*, bivalves (oysters, clams, cockles, fishes like Sea bass, grouper, mudskippers, mangrove archer fish, Amphibians like tree frogs, marine turtles like Olive Ridley (*Lepidochelys olivacea*), Green Sea Turtle (*Chelonia mydas*), Hawksbill Turtle (*Eritmochelys imbricata)*, snakes like water snakes, mangrove pit-

viper, mangrove cat snake, Crocodile (*Crocodilus porosus*), Birds - Brahminy kite (*Haliastur indicus*), kingfishers, woodpeckers, herons, (*Egretta garzetta),* Mammals including long-tailed monkey (*Macaca fascicularis*), fruit bats, *(Macroglossus minimus, Eonycteriss pelaea)*, otters and river dolphins (*Platanista gangeticus),* etc.

6.5. 0. Ecological niche - Coral reef

- Coral reefs are living animal colonies, found in marine waters.
- They are often called "**rainforests of the sea",** coral reefs are most diverse ecosystems on earth.
- They occupy less than 1% of the world ocean surface and they provide a home for 25% of all marine species, including fishes, molluscs, echinoderms and sponges.
- They are commonly found at shallow depths in tropical waters.
- Coral reefs are fragile ecosystems, as they are very sensitive to water temperature.

6.5.1 Importance of coral reef

- Protect coastlines from the damaging effects of wave action and tropical storms
- Provide habitats and shelter for many marine organisms
- Important source of nitrogen and other essential nutrients for marine food chains
- Assist in carbon and nitrogen fixing
- Help with nutrient recycling.
- Suppliers of sand to beaches
- Supporters of subsistence and commercial fisheries

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- A source of recreation and tourism

6.5.2.0 Types of coral reef

6.5.2.1 Fringing reef: Develop along the shores of tropical and subtropical islands or continental

mass, anywhere the hard substrate.

- It is the most common and widespread of the reef structural types, usually found below the low tide level.
- Their inshore distribution renders them more susceptible to degradation from coastal activities than other reef types.

6.5.2.2 Barrier reefs – are similar to fringing reefs but are separated from the landmasses and

these are associated with lagoons or deep waters.

- "Barrier" reefs are linear, offshore reef structures that run parallel to coastlines and arise from submerged shelf platforms; the water area between the shore and reef is often termed a "lagoon".
- The **world's largest barrier reef** system, the **Great Barrier Reef**, occurs off the **Queensland coast of Australia**.

6.5.2.3 Atoll: Usually elliptical in shape, arise out of deep water and have centrally located

lagoon and most common in Indo-West Pacific, usually far from land, little influence from freshwater runoff, sedimentation and range in size from <1 to 20+ miles

in diameter, often influenced by trade winds

6.6.3 Structure of coral reef

6.6.3.1 Fore reef zone - closest to the ocean, has two zones,

i) **Deep fore reef zone** - edge of the reef drops off into the depths, sponges, sea fans and solitary corals are found.

ii) **Buttress Zone-** The shallow part of the outer reef is exposed to wave action from the open ocean. Buttresses help stabilize the reef.

6.6.3.2. Reef crest - This zone forms a ridge between the fore reef and the lagoon. Few coral colonies can live on the reef crest because it experiences strong wave action and is often exposed to the air at low tide. They provides a protective home for crabs, shrimps and other animals.

6.6.3.3. Reef flat zone- The reef flat zone is a very sheltered area located on the landward side of the reef which has two zones

i) **Back Reef** - The landward side of the reef is protected from the open ocean and forms one wall of the lagoon (with the land forming the other side).

ii) **Lagoon** - Lagoons are shallow pools of seawater with a substrate of coral rock and sand which may be exposed at low tide

6.6.4. Factors limiting the distribution of coral reefs

- Temperature
- Depth
- Light
- Salinity
- Sedimentation
- Wave action

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Exposure to air
- Nutrient loading and contaminant inputs

6.6.5. Fauna of coral reef ecosystem

- Coral reefs provide habitats for a large variety of organisms.
- Some organisms that use corals through mutualism, commensalism and parasitism are within the taxonomic groups Porifera, Polychaeta, Mollusca, Crustacea, Echinodermata and Pisces (butterfly fishes – Chaetodontidae, puffer fishes – Tetraodontidae, parrotfishes – Scaridae etc.).
- Sponges (Porifera) are found inhabiting cavities in the reef. These sponges, such as *Cliona,* cause bio erosion in corals.
- Polychaetes such as *Hermodice carunculata* and Gastropods in the family Trochidae depend on corals for food.
- The giant clam (Bivalvia), *Tridacna* sp commonly occur in coral reef areas. They feed on corals such *as Porites* and *Agaricia.*
- Decapod crustaceans such as shrimps and crabs depend on corals for shelter. Xantid crabs form cavities in the coral *Acropora palmata.*
- Echinoderm such as *Acanthaster planci* (this is a starfish, commonly called as **crown-of-thorns)** are coral's **top most predator**, which feeds exclusively on coral polyp and devastate the entire reef areas if swarming of this predatory star fish occurs.
- Other organisms that inhabit the coral reefs include variety of fin fishes, sea urchins, jellyfish, oysters, clams, turtles, and sea anemones.

6.7. References:

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 7	Ecological niches - Flood plains, Coastal wetlands, Bheels and Oxbow lakes
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

7.1 Objectives

- Flood plains - Formation, types, flora and fauna and its importance
- Coastal wetlands - Types and its importance
- Bheels - Formation, classification, degradation of bheels
- Oxbow lakes - Formation, types, biota of oxbow lakes and their adaptations

7.2 Glossary terms

- **Open flood plains:** The main channels of flood plains usually retain waters through the year, but the levee region and the flats are seasonally inundated but remains dry for at least some parts of the year.
- **Wetlands**: wetlands as are area of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres
- **Oxbow lake**: A crescent shaped lake (U shaped or horse shoe shaped) that is formed

  when a wide meander from a stream or river is cut off from the main channel to form a lake.
- **Bheels:** are freshwater wetlands with very rich in nutrients and have a great production potential, Bheels are formed by inundation of

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

low-lying lands during flooding, where some water gets trapped even after flood water recede back from the flood plains.

7.3.0 Ecological niche - Flood plains

- Floodplains is an alluvial surface adjacent to a channel that is frequently inundated. It is a depositional features.
- Flood plains are associated with coastal lowlands and often found in estuaries and deltas. They can also spread out into large deltas at a considerable distance from the coast.
- The flood plains are either permanent or temporary water bodies associated with rivers that constantly shift their beds especially in the potamon regimes.
- The frequency with which a river changes its course depends on a number of variable like flow velocity, sedimentation rate, slope channel pattern, water and sedimentation rate, slope, channel, pattern, water and sediment yield, texture and lithology of soil etc.

Fig.1 Flood plains

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

7.3.1 Types

Based on the flow of water, the flood plains can be divided into the following two groups.

i. Plain (lotic environment)/open
ii. Standing water (Lentic environment)/closed

i) Plain/ Open flood plains:

- The main channels of flood plains usually retain waters through the year, but the levee region and the flats are seasonally inundated but remains dry for at least some parts of the year.

ii) Standing waters / closed flood plains:

- Receding flood leaves permanent of semi-permanent standing waters in the form of slough, meander scroll depression, back swamp or the residual channel (oxbow lakes).
- These water bodies expend or contract in area according to annual flood cycle and tend to merge into a continuous sheet or water covering the whale plain during the highest floods.

7.3.2 Formation

Floodplains are formed into two ways:

i) By erosion
ii) By aggradation

The three ways in which floodplains may be formed:

- By vertical accretion
- By lateral accretion
- By island formation and channel abandonment

7.3.3 Importance of flood plains

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Mostly used for agriculture
- Prevents flooding and effective retention of floodwaters.
- Helps in effective cycling of nutrients.
- Effective sewage treatment systems
- Buffer against flooding, erosion and nutrient loss.
-

Fig.2 Uses of flood plains for agriculture purposes

7.3.4 Biota and their adaptations

- Floodplains in general are rich in biodiversity. Similar to oxbow lakes, live floodplains are generally highly productive.
- Due to continuous recruitment a sustained high primary productivity both in terms of phytoplankton and macro vegetation. But the macro vegetation is in optimal amount.
- They ultimately upon death contribute to the detritus pool of the bottom soil. The floodplains support all the three aquatic macro vegetation.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

i. **Emergent macrophytes** are *Typha anqustata, Cyperus procerus, Polygonus sp.*

Commelina longifolia

ii. **Floating macrophytes** are *Nymphaea* sp*, Myriophyllum sp., Pistia stratiotis.,*

Eichhronia crassipes

iii. **Submerged Macrophytes**, examples are *Vallisneria spiralis, Hydrilla verticillata, Ceratophyllum sp., Najas sp.*

Apart from that, gastropod species like *Gabia sp., Lymnaea sop., Pila gibbose.,*

Segmentina sp., bivalves like *Lamellidens marginallis., Piscidium sp., Corbicula sp* and

in addition to that fishes, aquatic insects are also prevalent because of their partial

aquatic adaptations. In India, Assam has the largest number of floodplains.

7.4.0 Ecological niche - Coastal wetlands

- The **Ramsar Convention** defines **wetlands** as are area of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres.
- Every year **February two** is observed **World Wetlands Day.** It marks the date of the signing of the Convention on Wetlands on 2 February 1971, in the Iranian city of Ramsar on the shores of the Caspian Sea.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Therefore, this Convention came to be known as the Ramsar Convention (1971).

- **Coastal wetland** as defined as land areas covered by salt water at least part of the year are called coastal wetlands. There are three main types of wetlands viz., salt **marshes, swamps** and **estuaries**.

7.4.1 Salt marshes

- **Salt marshes** are coastal wetlands which are flooded and drained by salt water brought in by tides. They are marshy because the soil may be composed of deep mud and peat.
- **Marshes** that are almost always flooded and have a mixture of cattails, reeds and other water plants.

Fig. 3 Salt marshes

7.4.2 Swamps

- Low land that is seasonally flooded and has more woody plants than a marsh

- Swamps are actually slowly flowing shallow rivers which look like flooded forests. Although not all wetland areas are covered by water year round, they still have enough moisture content and the correct soils to support their specific aquatic plants and animals.

Fig. 4 Swamps

7.4.3 Importance of coastal wetlands

- Flood protection
- Erosion control
- Wildlife food and habitat
- Commercial fisheries
- Like filters for water quality
- Recreational activities
- Carbon sequestration
- Nurseries and spawning ground
- Storm surge buffers
- Recreation
- Research

7.5.0. Ecological niche - Bheels

- Bheels are freshwater wetlands. All natural wetlands are called bheels in Assam.
- Bheels are very rich in nutrients and have a great production potential.
- Based on eco-energy studies, Jhingran and Pathak (1987) estimated the production potential of bheels at 1,80,00,000 Kcal of energy/ha/yr or 1500 Kg/ha/yr.

Fig.5 Bheels

7.5.1 Formation of bheels

- Bheels are formed by inundation of low-lying lands during flooding, where some water gets trapped even after flood water recede back from the flood plains.
- Bheels may also be caused by filling up of low lying areas during rains, especially during the monsoon season.

7.5.2 Classification of Bheels

i. Open bheels

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

ii. Closed bheels

7.5.2.1 O**pen bheels**

- Some bheels retain their riverine connection for a reasonably longtime which are relatively free form weed infestation.
- Basic approach is to allow recruitment of conserving and protecting the brooder and juveniles.
- These measures have the dual advantage of conserving the natural habitat of the bheels along with extending the benefits of conservation to the lotic ecosystem of the parent stream.

7.5.2.2 C**losed bheels**

- Management of completely closed bheels or those with a very brief period of connection with river is more like small reservoir.
- The basic strategy will be stocking and recapture fish.
- In a culture based fishery, the growth is dependent on stocking density and survival is dependent on size of the stocked fish.
- Growth varies from one water body to another depending on the water quality and food availability.

7.5.3 Bheels in Assam

- Assam is gifted with many extensive water bodies commonly known as bheels that are only source of fish for the poor people in in the surrounding villages.
- Historically there have been three distinct groups of people involved in organized fishing in bheels:
- Those who catch fish for their own daily consumption

- Those belonging to the fisher community and depend on fishing for their livelihood
- Rural entrepreneurs (lease holders)

7.5.3.1 Classification of bheels in Assam

- Lake/ pond
- Oxbow lake/ cut-off-meander
- Water logged areas
- Swamp/marsh
- Reservoir
- Tank

7.5.4 Ecological degradation of bheels

- Fast growing weed of water hyacinth obstructs the penetration of sunlight, inhibiting planktonic growth and contributing to eutrophication by slowing down water currents and depositing debris at the bottom.
- The second phase of enhanced eutrophication resulted from the construction of embankments along almost the entire length of the river Brahmaputra and many of its tributaries.
- These levees substantially reduced the periodic flushing by monsoon floods.
- At last, the major destruction on bheels done by human activities such as buffalo and cattle rearing, agriculture and horticulture and overfishing. These have resulted in further siltation and damage to the micro flora and water quality.

- Undesirable use of pesticides in farming activities has resulted in the accumulation of residue through surface run-off, leading to the problem of Bio-magnification.
- Biodiversity can be an important component in the economic valuation of bheels. The change in biodiversity has implications for the food security and livelihood of the population that depends on the bheels.

7.6.0 Ecological niche - Oxbow lake

- A crescent shaped lake (U shaped or horse shoe shaped) that is formed when a wide meander from a stream or river is cut off from the main channel to form a lake.
- These basins are relatively narrow, long, and deep and have either bend or straight shapes.
- They receive water from the parent river through the old channel or neighbouring catchment areas.

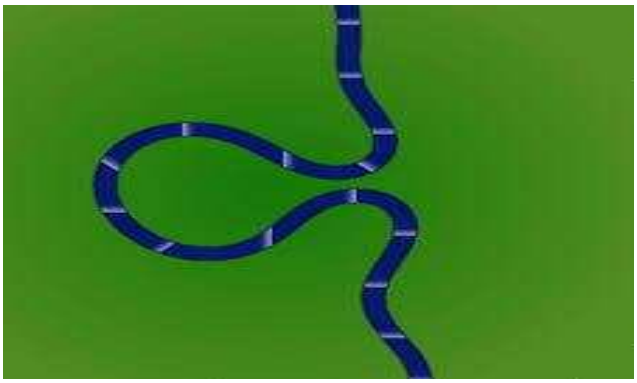


Fig.6. Oxbow lake

7.6.1 Types

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Oxbows are the following two types on the basis of their reverie connection. They are

i. Open / Live oxbow Lakes
ii. Closed / Dead Oxbow Lakes

- In addition to this semi closed oxbow lakes are present, which are open by nature and get closed during certain seasons.

7.6.2 Open / Live Oxbow Lakes

- Open oxbow lakes have free connection with the parent river through a narrow channel.
- These lakes are open year around except during summer.
- In summer, the water level usually falls and the oxbow losses its connection. As the oxbow is open, nutrient income both autochthonous too.

7.6.3 Closed / Dead Oxbow Lakes

- Closed oxbow lakes have no connection with the parent river. But they may get connection with parent during monsoons. Later they lost it.
- Largest Oxbow in the world: **Lake Chicot**
- Lake Chicot is formed along river Mississippi River of North America. It is about 21 miles long and ¾ miles wide.
- Largest Oxbow in the India: **Lake Kanwar Taal**
- Lake Kanwar Taal is formed along a tributary of Ganges, Bihar. It is not only the largest oxbow of India but also of Asia.

Table. 1 Merits & demerits of open oxbow lakes

Merits	Demerits

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

• Influx of flood water during monsoon helps in uprooting of aquatic macro vegetation. Thus, favour other bio communities. • Influx of allochthonous energy input through flood water is possible. Thus, helps to enhance productivity • Allows natural recruitment of fishes from river water.	• Influx of silt loaded along with flood waters, thus making the lake shallower every year. • Benthic community is affected by silt load.

Table 2 Merits & demerits of closed oxbow lakes

Merits	Demerits
• As the system is closed, silt load is greatly prevented. • The life of closed/dead oxbows are comparatively long	• Weed infestation • No allochthonous energy input almost except during monsoons. • No natural recruitment of fishes from river • Less productive and comparatively greater BOD

- In addition to these two types, partially fluviatile' oxbows are present. These have similar properties of open/live oxbow lakes,

but they silt at a faster rate. Thus they disappear almost in monsoons.

7.6.4 Formation of Oxbow lakes

- In general, oxbow lakes are formed by subsequent erosion and deposition.
- By river flow, erosion of soil in concave banks and deposition of eroded material in convex banks occurs, leading to the formation of an oxbow.
- However, the formation of oxbow lakes in tedious process.
- It takes few hundreds to thousands of years to form an oxbow lake. Thus oxbow lakes were formed by many natural and manmade activities.
- The natural factors includes:
    i) Landslides
    ii) glacial activity
    iii) tectonic activities volcanic activity
    iv) drifting activity
    v) fluviatile activity etc.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

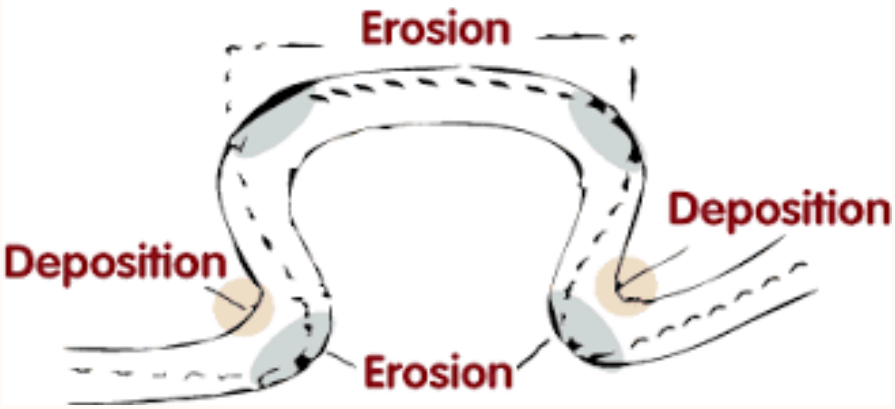


Fig. 7 Formation of Oxbow lakes

7.6.5 Flora fauna of oxbow lakes their adaptations

- The nutrient budget of open and closed oxbow lakes are dynamic and static in nature respectively.
- These closed oxbow lakes are adversely affected with the greater infestation of macrophytes. This macrophyte infestation greatly affect the primary productivity.
- While on the other hand, open oxbow lakes show good amount of primary productivity.
- Apparently all the three types of vegetation are floating, submerged and emerged and emergent vegetation were present. Eg: *Chara* spp, *Valliseneria* spp., *Najas minor*, *Certophyllum demersum* etc. This macrophysics infestation later leads to eutrophication. This later develops leading to swampification. The macrovegetations limit the growth of planktonic algae either by shading or by competing for nutrients.

- Macrophyte grazers are less efficient than planktonic grazers thus they cannot control accumulation of distributes at the bottom. The impact of this phenomenon is reflected in the low efficiency of zooplankton production leading to low fish yield.
- In oxbow lakes, detritus food chain seems to be more prominent due to massive growth & subsequent decay of macrophytes than pelagic food chain organisms. The shallow depth and low turbidity allow the light to have access up to the bottom which promotes macrophytic growth further and thus enrich the detritus fool continuously.
- As oxbow are almost isolated from the parent river, the fishes that came from parent river only exists.
- The fishes that were in the river are locked in oxbows. However, in open oxbow lakes introduction of new species from parent and stock enhancement happens. While in closed oxbow lakes introduction happens only at times of flood.
- As the lotic river turns into lentic oxbows, only fishes which were capable of adapting themselves to the lentic environment survives and other were eliminated.
- Indian Major Carps, air breathing catfishes (*Clarius batrachus, Heteropneustes fossilus*)
- *Wallogo attu, Channa striatus, Channa marulis* and minor carps found a prominent part in the ichthio faunal group of Indian oxbow lakes.

7.7. References

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 8	Aquatic Ecology-An IntroductionThreats to biodiversity- Habitat destruction, Introduction of exotic species, Conservation of habitats, Marine parks and sanctuaries
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

8.1 Objectives

- **Threats to biodiversity :** 1. Habitat destruction
  2. Introduction of exotic species
- **Conservation of habitats:** 1. Marine parks and sanctuaries

8.2 Glossary terms

1. Habitat: Habitat refers to the place or the location where an organism (or a biological population) lives, resides or exists. The term *habitat* came from the Latin *"habitātus",* meaning "having been inhabited".

2. Invasive species: Invasive species, also called introduced species, alien species, or exotic species, any non-native species that significantly modifies or disrupts the ecosystems it colonizes. Such species may arrive in new areas through natural migration, but they are often introduced by the activities of other species.

3. Migratory species: A species or lower taxon of wild animals of which the entire population or any geographically separate part of the population cyclically and predictably cross one or more national jurisdictional boundaries.

4. Marine parks: Marine national parks are areas of the marine environment where the seabed, waters and all plants and animals are fully protected by law, offering an insurance policy against environmental impacts. Marine parks are established over tidal lands and waters to protect and conserve the values of the natural marine environment while allowing forits sustainable use.

5. Sanctuary: Wildlife sanctuaries are the regions where animals kept protected from any sort of disturbance to their habitat and their surroundings.They are also aimed at providing suitable and comfortable living conditions to the animals. Killing, poaching or capturing of animals is strictly prohibited in these regions.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

8.3 Habitat destruction

Anthropogenic activities are causing species to disappear at an alarming rate. It has been estimated that between 1975 and 2015, species extinction will occur at a rate of 1 to 11 percent per decade. Aquatic species are at a higher risk of extinction than mammals and birds. Losses of this magnitude impact the entire ecosystem, depriving valuable resources used to provide food, medicines and industrial materials to human beings.

- Marine ecosystems are experiencing high rates of habitat loss and degradation.
- Shoreline stabilization, the development of large ports, mangrove deforestation, coral and sand mining and the existence of densely populated coastal cities all contributed to this loss. This has led to the destruction of important coastal ecosystems.
- The introduction of structures such as groins, jetties and other structures has interrupted important long shore current movements. As a result, beach fronts and marsh communities are becoming eroded and experiencing increased sand loss.
- Construction of dams across the rivers lead to the destruction of feeding and breeding grounds of many freshwater fishes and also the migratory fishes to a greater extent.
- Excess release of water from the reservoir and diversion of river water for agricultural and industrial purpose may also results in the destruction or degradation of freshwater fish habitats.

8.4 Introduction of exotic species

A leading cause of biodiversity loss in many aquatic ecosystems is the introduction of exotic species. An **exotic species** is a non-native plant or animal deliberately or accidentally introduced in to a new habitat. Such species include plants, fishes, algae, molluscs, crustaceans, bacteria, and viruses. Such species that are above to reproduce and survive outside of

the habitats where they evolved are also referred to as alien, introduced, invasive, non-native or non-indigenous.

- There are many ways that exotic species are introduced into freshwater areas including the release of pet fish or foreign species brought in for entertainment in public or commercial aquariums or for education.
- Exotic species are introduced into marine areas by means of transplanting or commercial shipping. It has been reported that ship ballast water is responsible for the transport of approximately 3,000 species worldwide each day.
- Exotic species can have many negative impacts on the environment, the economy and human health. When species are introduced into an area, they may cause increased predation and competition, disease, habitat destruction, genetic stock alterations and even extinction.
- The invasion of exotic species has been found to cause the economy to suffer through the obstruction of industrial and municipal water pipes and the displacement or elimination of important commercial and sport fishing species.
- Public health may also be negatively impacted.

8.5 Conservation of habitats

Habitat conservation for wild species is one of the most important issues facing the environment today — both in the ocean and on land. As human populations increase, land use increases, and wild species have smaller spaces. Species cannot survive outside of their natural habitat without human intervention, such as the habitats found in a zoo or aquarium, for example. Preserving habitats is essential to preserving biodiversity. Migratory species are particularly vulnerable to habitat destruction because they tend to inhabit more than one natural habitat. This creates the need to not only preserve the two habitats for migratory

species, but also their migratory route. Altering a natural habitat even slightly can result in a domino effect that harms the entire ecosystem.

Habitat destruction is a huge problem in the marine environment.

Habitats are destroyed by:

- **Destructive fishing activity**: bottom trawling and dynamiting coral reefs destroy entire ecosystems.
- **Coastal development**: habitats are destroyed when marshes are dredged for real estate development. Soil runoff and erosion result in excess nutrients from fertilizers and domestic sewage, which then leads to harmful algae blooms that block sunlight and deplete the water of oxygen. It also causes silt to build-up on coral reefs, which blocks sunlight necessary for coral to grow.
- **Pollution:** development near coastal waters contaminates the ocean with toxic substances, such as industrial chemicals, pesticides, and motor oil.
- **Dredging ship channels**: Removes accumulated sediment and pollutants, re-suspending them into the water. Dredging can also destroy sea grass beds and other habitats that provide food, shelter, and breeding grounds. The dredged material must be disposed of, and is often dumped into salt marshes, damaging very productive marine habitats in the process.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Fig. 1 Components for conservation of biodiversity

8.6 0. Marine parks and sanctuaries

- **A marine park** is a protected sea or a lake area which consists of many species of marine life. Such marine parks are usually found in the coastal areas.
- There are 6 established marine national parks in India.
- These are the protected reserves and are the breeding grounds of several aquatic animals. A marine park is a type of marine protected area (MPA). An MPA is a section of the ocean where a government has placed limits on human activity.
- Marine parks are multiple-use MPAs, meaning they have different zones allowing different types of activities.

- Marine parks usually allow recreational activities, such as boating, snorkelling, and sport fishing.
- Most marine parks also include zones for commercial fishing, sometimes called open zones.
- They may also include no-take zones, which prohibit extractive activities, such as fishing, mining, and drilling.

8.6.1 Important Marine Parks and Sanctuaries in India

8.6.1.1 Marine National Park, Gujarat

- Established in the early 1980s, Marine National Park was the first one of its kind in India. This **163 sq. km.** marine park, located on the Jamnagar coast along the Gulf of Kutch, is part of a larger protected marine sanctuary.
- It is the first National Marine park of India.
- The archipelago of 42 islands is home to a diverse range of marine habitats that support 52 species of corals, seven kinds of mangroves and species of birds such as painted stork, darter and black-necked ibis.
- The area is also inhabited by colonies of dolphins, green sea turtles and the endangered whale shark.

8.6.1.2 Mahatma Gandhi Marine National Park, Andaman and Nicobar Islands

- Spread over almost **282sq. km.**, this marine park covers 15 rocky islands with white sandy beaches and tropical vegetation, open seas and smaller bodies of water that are home to diverse marine life.
- The marine park was set up in 1983 to protect the local turtle population and unique corals you won't find anywhere else.
- Coral reef of this area are fringing reef and famous for the breeding ground of turtle.
- Area is famous for variety of coral reefs, colourful fishes, molluscs, shells, starfish, turtles, salt-water, and crocodile.

8.6.1.3 Gahirmatha Marine Sanctuary, Odisha

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- In 1997, the Odisha government declared **1,435sq. km.** of the coastline by Gahirmatha a protected marine park.
- This is mainly because it happens to be the only preferred nesting spot of the **Olive Ridley turtle** anywhere by the Indian Ocean.
- The turtles migrate all the way from the South Pacific to the Odisha coast every year for breeding.
- From October till May, the sandy shores are full of hundreds of thousands of them in various stages of the birthing process.
- Owing to the mangroves around these parts, the waters are nutrient rich, making them ideal for this species of the tiniest of all sea turtles.
- After they hatch, the young ones head from their shelves straight to the waters to begin their long swim to the South Pacific.
- The park is 75km from Bhubaneswar.

8.6.1.4 Gulf of Mannar Marine National Park, Tamil Nadu

- Located inside the larger Gulf of Mannar Biosphere Reserve between Tamil Nadu and Sri Lanka, the **560 sq. km.** marine national park that gets its name from the gulf is composed of 21 islands and coral reefs.
- It stretches across the 160-km distance between Thoothukudi and Dhanushkodi.
- In terms of marine biodiversity, this is one of the richest regions in the world and has been likened to an underwater tropical rainforest.
- It is the shelter of all the species of Mangroves and the indigenous mangrove species home of *Pempis acidula.*

8.6.1.5 Rani Jhansi Marine National Park, Andaman and Nicobar Islands

- Located on three islands of the eastern Ritchie's Archipelago, this marine park was established in 1996.
- The protected area is home to a diverse species of coral, mangroves, terrestrial moist forest, crocodiles and dugong.

8.6.1.6 Malvan Marine Wildlife Sanctuary, Maharashtra

- This **3.2 sq. km.** marine park in the southern reaches of the state was established in 1987.

- The Malvan Wildlife Sanctuary includes Padamged island and other submerged rocky structures.
- The main flora of the sanctuary includes mangrove vegetation.
- The marine flora and fauna of the place comprise seaweed, coral Pearl oyster, egret, black headed gulls.
- More than 30 species and sub species of fishes are found in water bodies.
- It was declared as a wildlife sanctuary on 13th April 1987.

8.7. References

1. Mathew, A. N. P. 2008-2009. Marine Fisheries Conservation and Management in India.

United Nations -The Nippon Foundation Fellowship Programme

2. A teaching manual on “Aquatic Environment and Biodiversity”. 2007. A. Srinivasan,

Baskaran Manimaran, P.Padmavathi, and N.Jayakumar, Department of Fisheries

Environment, Fisheries College and Research Institute, Tamilnadu Veterinary and

Animal Sciences University, Thoothukudi

3. NSW Marine parks education kit, Life on Rocky Shores. Batemans marine park,

Module-2, Teacher Fact Sheet, pp:1-29

1.1

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 9	Conservation programmes for endangered species, ex situ and in situ conservation, captive breeding and management of endangered species
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

9.1 Objectives

- Programmes for conservation of endangered species
- Ex situ and in situ conservation of endangered species
- Captive breeding and management of endangered species

9.2 Glossary terms

1. **Endangered species:** In general, any animal or plant in danger of extinction in the relatively near future. In formal or technical use, this refers to an animal or plant protected under a federal law called the Endangered Species Act.
2. **Game Farming**: The endangered species can be reared in protected areas and then they can be released in their natural habitat.
3. **Poaching**: Poaching is the illegal exploitation of wild species.
4. **In situ conservation**: It is the on-site conservation of genetic resources in natural populations of plants or animal species such as forest genetic resources, in natural populations of tree and animal species.
5. ***Ex situ* conservation:** It means the conservation of components of biological diversity outside their natural habitats.
6. **Biodiversity**: The variability among living organisms on the Earth, including the variability within and between species and within and between ecosystems.

9.3 Conservation programmes for endangered species

9.3.1 Endangered species

- Endangered species are species which are in danger of becoming extinct.

- Endangered species are Blue whale, Fin Whale –Baleen whales, Sperm whale, Bowhead whale, Dolphin Sharks, Sea turtle, Seals, Sea lions, Waters Sea birds, Giant clams, Sea snakes etc.
- Species need conservation in nature. International Union for Conservation of Nature and Natural Resources (IUCN) and survival service commission (SSC) have published two volume of animal that have in need for conservation **"Red Data Book"**

9.3.2 Categories of Species

- **Endangered species (E):** Species which are in danger of becoming extinct
- **Vulnerable species(V):** Species which likely move into the endangered category, if present situation continues.
- **Rare species (R):** Species restricted to specific geographic location or thin by scattered
- distribution.
- **Threatened (T):** Species are small in numbers .Whales, Porpoises, Fish, Turtles and

Seals that are currently endangered and/or threatened with extinction. It is essential to prevent the further decline of fish germplasm.

It is identified that **five principal elements or tasks** in the recovery programmes such as

(i) habitat management

(ii) habitat development and maintenance,

(iii) native fish stocking,

(iv) non-native fish and sport-fishing and

(v) Research data management and monitoring. Indian Fisheries Act 1897 (modified in 1956) along with the following measures would positively help in restoration of the threatened fish fauna.

9.3.3 Steps involved in protecting endangered habitats and species

a) Knowledge of wild life:

For proper management of wild life, a thorough knowledge of the ecology of wild animals is essential.

b) Appointment of officials:

The management of wild life is made effective by appointing suitable officials.

These officials should have inherent love for wild life and they should be given required

training

c) Protective laws:

India was the first country to enact a Wild Life Protection Act. The following

acts have been framed so far.

a. The wild birds and Animals Protection Act of 1887.
b. Forest Act XVI, 1927: It was enacted for the protection of games.
c. Indian Board of Wild Life 1952
d. The Wild life Protection Act 1972:

This act prohibits the hunting of females. Chief Wild Life Wardens and authorized

officers are appointed to watch.

a. The procession, trapping and the shooting of wild animals alive or dead.
b. The serving of their meat in eating houses
c. Their transportation and export.

9.3.4 Measures for endangered species conservation

(1)Restriction of hunting

(2)Poaching: Poaching is the illegal exploitation of wild species.

(3)Habitat improvement

(4)Restoration of habitats: Disturbances caused to wild life must be removed. Polluted rivers can be made clean by treating the effluents.

(5)**Clonal bank**: The cells of rare species of plants are collected and stored safely. In case, these plants become extinct the preserved cells can be cultured and grown into plants. This is called clonal bank system.

(6)**Provision for shelter and cover**: The survival of wild animals can be encouraged by providing natural shelter and cover. This can be achieved by rearing herbs and shrubs.

(7)Artificial stocking

(8)**Game Farming**: The endangered species can be reared in protected areas and then they can be released in their natural habitat.

Eg: The marine turtles lay their eggs on the sea shore. The eggs can be collected and

hatched in the laboratories and the young ones are released into the sea.

(9)**Epidemic control**: veterinary experts should be appointed to take care of wild life

(10) Census

(11) **Educating the public**: Common men should be properly educated about advantages

and disadvantages of wild life

(12) Establishment of Sanctuaries and National Parks

(13) **Main conservation projects for restoration of habitats are**

- **Marine parks**
- **Sanctuaries**
- **Protected areas**

9.3.5 Conservation of Marine turtles

Marine turtles are mostly inhabited in the tropical and subtropical ocean waters throughout the world. They are available in all oceans except the Arctic Ocean. Marine turtles are split into two families;

i) *Cheloniidae*, which are marine turtles with shells covered with scutes (horny plates)

ii) *Dermochelyidae* with only one modern species, the leatherback turtle, which are covered with leathery skin.

Table 1. Status of some common turtles

S. No	Turtle species	Common name	Status
1	*Chelonia mydas*	Green sea turtle	Endangered
2	*Eretmochelys imbricata*	Hawksbill	Critically Endangered
3	*Caretta caretta*	Loggerhead	Endangered
4	*Lepidochelys olivacea*	Olive-Ridley	Vulnerable
5	*Dermochelys coriacea*	Leatherback	Critically Endangered

9.3.5.1 Threats to Marine Turtle

The major threats to the survival of the marine turtles are from natural predators like shark, pollution and their illegal hunting. Marine turtles are caught worldwide for the food industry. In many parts of the world, marine turtles are considered as a fine dining for their flesh. In many coastal communities marine turtles are considered as best source of protein.

Also the important turtles habitats like coral reefs, sea grass beds, mangrove forests and nesting beaches has changes drastically due to which they are under serious threat. Accidental drowning of turtles in fishing gear, over-harvesting of turtles and eggs, and predation of eggs and hatchlings by foxes, feral pigs, dogs and goannas are also considered as a major threat to the existence of the marine turtles.

9.3.5.2 Ecological importance of turtles

Turtles are important because they fulfil an important role within the marine ecosystem, by maintaining healthy seagrass beds and coral reefs, providing habitats (their carapaces) for other marine life, balancing marine food webs and facilitating nutrient cycling from water to land. When sea turtles graze on seagrass it leads to an increase in the seagrasses productivity and nutrient content. Without this grazing, seagrass beds can begin to decompose, as overgrown seagrass blades shade the plants underneath and reduce the flow of currents through the beds. Some turtle species eat sponges which compete with corals for space to grow on reefs. By removing sponges from reefs, turtles allow coral species top grow instead of sponges dominating.

9.3.5.3 Conservation of Marine Turtles in India

Indian government is also taking strict actions to protect these five endangered species of marine turtles found in India under the Indian

Wildlife Protection Act (1972), and in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna & Flora (CITIES).

- The Department of Environment and Forests is giving pivotal importance to the conservation and management of marine turtles in collaboration with the various NGO's and Coast Guard.
- To enhance the population of the marine turtles in India, it is necessary to promote the Sustainable fisheries with use of bycatch reduction devices specially Turtle Excluder Devices (TEDs).
- Also to facilitate the conservation in nesting sites, community participation is essential. Even WWF- India has also proposed some essential interventions for the preservation of marine turtles in India

9.3.6 Conservation of Horseshoe crabs

9.3.6.1 Distribution

- Horseshoe crabs are "living fossils", the last survivors of a group of organisms that first appeared in the fossil record some 30 million years ago.
- Horseshoe crabs *Tachypleus gigas* and *Carcinoscorpius rotundicauda* are distributed along the northeast coast of India extending from the extreme north of West Bengal through Orissa to the northern coast of Andhra Pradesh.
- High congregations of these animals are found along the breeding beaches of Orissa and West Bengal during full moon and new moon high tides.

9.3.6.2 Ecological Importance of Horseshoe Crabs

Horseshoe crabs play an important ecological role in the food web. Shorebirds primarily feed on horseshoe crab eggs exposed on the surface, but sufficient surface eggs are available only if horseshoe crabs are spawning at high densities. Sea turtles feed on adult horseshoe crabs, but their diet depends on relative abundance of the prey species.

9.3.6.3 Threats:

Environmental conditions of horseshoe crabs along the Indian coast still remain free from any kind of pollution. Also there is no known commercial exploitation for the production of amebocyte lysate or bait. But the degradation and destruction of breeding beaches by excess human activities have been posing a serious threat. This is in turn affecting the breeding migration of adult pairs (in amplexus) to come ashore for breeding.

9.3.6.4 Horseshoe Crab Sanctuaries

The future survival of the world's four remaining horseshoe crab species will ultimately depend upon the preservation of its spawning habitat - a challenging prospect in light of the ever-increasing human density along the same inland beaches horseshoe crabs have relied upon for thousands of years.

9.3.7 Conservation of Sharks

Sharks and their relatives, including skates, rays and chimaeras, collectively referred to as chondrichthyan fishes. Despite their evolutionary success, many species are increasingly threatened with extinction as a result of their low reproductive rates in the face of human activities, primarily overfishing. Whale sharks, the largest fish in the world, which arrive there seasonally to feed abundant plankton. Generally, chondrichthyans are characterised by slow growth, late maturity, and low fecundity. Because of

these characteristics, sharks and their relatives have very low rates of population increase and limited potential to recover from overfishing (direct or indirect) and other threats, such as pollution and habitat destruction.

	Scientific Name		Common Name
1.	*Carcharhinus limbatus*	-	Blacktip shark
2.	*Carcharhinus longimanus*	-	Oceanic whitetip shark
3.	*Carcharhinus obscurus*	-	Dusky shark
4.	*Carcharodon carcharias*	-	Great white shark
5.	*Galeocerdo cuvier*	-	Tiger shark
6.	*Hexanchus griseus*	-	Bluntnosesixgill shark
7.	*Isurusoxy rinchus*	-	ShortfinMako
8.	*Megachasma pelagios*	-	Megamouth
9.	*Prionaceglauca*	-	Blue shark
10.	*Rhincodon typus*	-	Whale shark
11.	*Sphyrna lewini*	-	Scalloped hammerhead
12.	*Sphyrna mokarran*	-	Great hammerhead
13.	*Squalusacanthias*	-	Spiny dogfish
14.	*Dalatiaslicha*	-	Kitefin shark
15.	*Alopiasvulpinus*	-	Thresher shark
16.	*Euprotomicrus bispinatus*	-	Pygmy shark

9.3.7.1 The IUCN Species Survival Commission's Shark Specialist Group

IUCN, the International Union for Conservation of Nature, is the world's largest global environmental network. It is a membership union with more than 1,000 government and non-governmental member organizations and almost 11,000 volunteer scientists in more than 160 countries.

The IUCN Species Survival Commission (SSC) is a science based network of some 7,500 volunteer experts from almost every country of the world, all working together towards achieving the vision of "a world that values and conserves present levels of biodiversity."

The SSG aims to promote the conservation of the world's chondrichthyan fishes, effective management of their fisheries and habitats and, where necessary, the recovery of their populations. It is now one of the largest and most active of the IUCN SSC Specialist Groups, with 180 members from 90 countries distributed among 12 ocean-region subgroups, all of whom are involved in chondrichthyan research, fisheries management, marine conservation, or policy development and implementation.

9.3.7.2 Laws Protecting Sharks

Currently, there are several conservation and management initiatives and plans that operate on many levels from international conventions to local laws.

9.3.7.3 Bans on Shark Fishing

In recent years, shark management, conservation and protection has taken the form of bans of finning, regulations of fishing (area and seasonal closures, catch quotas, gear restrictions, etc.) and shark fin trade bans

9.4 Ex-situ and in situ conservation of endangered species

9.4.1 Ex-situ conservation

Ex-situ conservation means literally, "**off-site conservation**". It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans.

The two main pillars of ex *situ* conservation programme are

(i) Live Gene Bank and

(ii) (ii) Gamete / Embryo Bank.

In **Live Gene Bank**, the endangered species are reared in captivity, bred therein and genetically managed avoiding in bleeding depression, domestication and unintended selection. In Gamete Embryo Bank, adequate samples representatives of the natural genetic variants of endangered species are kept in suspended state of animation under extra low temperature (-196C) in liquid nitrogen.

Establishment of Gene Bank by cryopreserved milt, eggs and embryos assures further availability of genetic materials of threatened categories and for intensive breeding programmes of economically important species.

9.4.2 In-situ conservation

In-situ conservation means "**on-site conservation**". It is the process of protecting an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. One benefit to in-situ conservation is that it maintains recovering populations in the surrounding where they have developed their distinctive properties.

Another is that this strategy helps ensure the ongoing processes of evolution and adaptation within their environments.

Stock enhancement through ranching is feasible only

(i) if there is in complete, colonization of available habitat by juveniles and

(ii) if the tropic capacity of the habitat is under-utilized by a stock and/or its competitors.

(iii) Conservation aquaculture is gaining importance in rehabilitation programmes of endangered/threatened fishes. It implies aquaculture for conservation and recovery of endangered fish populations by increasing the effective population size of the threatened species.

9.5 Captive breeding and management of endangered species

- Captive breeding is a process of breeding animals outside of their natural environment. It has become an important component of conservation planning for many endangered species and captive breeding programs now exist for a wide range of species.
- It is generally recognized that captive breeding is most effective when integrated into a comprehensive conservation program that addresses problems faced by the species in the wild (most frequently, these problems involve loss or degradation of habitat).

9.5.1 Three phases of a typical captive breeding program:

(1)**A founding phase**, during which managers attempt to balance the need to use an adequate number of founders against risks such collections would pose to the remaining wild population;

(2)**A growth phase**, during which captive abundance is increased as fast as reasonably possible; and

(3)**A capacity phase**, during which the captive population has approached carrying capacity and a portion can be used for reintroduction into the wild.

9.5.2 Goals

The goals of captive breeding programs are diverse and often include both short- and long-term objectives.

- **The short-term objective** is generally to maintain the gene pool, with minimal losses of diversity, while efforts are made to address the root causes for the species' decline.
- **The long-term goal** includes re-establishing a self-sustaining population in the wild.

9.5.3 Need for Captive Breeding and Reintroduction Programs

- **Captive breeding** is the only choice for species that are extinct or nearly extinct in the wild.
- Nearly one-fourth of **mammal** species, 11% of bird species, and 25% of reptiles are threatened with extinction, according to the 1996 IUCN (World Conservation Union) *list of Threatened Animals.*
- Because most at-risk species are threatened by habitat loss and degradation, the most common conservation need is **habitat protection and improvement.**
- Captive breeding and reintroduction programs play a minor conservation role in comparison to protecting and improving habitat

9.6 References

1. The Conservation Status of Pelagic Sharks and Rays, Report of the IUCN Shark Specialist Group. Pelagic Shark Red List Workshop Tubney House, University of Oxford, UK, 19–23 February 2007.

2. NYSDEC Environmental Education - New York State. Position Statement Shark Conservation & Management Measures 85th meeting of the INTER-AMERICAN TROPICAL TUNA COMMISSION Veracruz, Mexico June 10-14, 2013.

3. Mathew, A. N. P. 2008-2009. Marine Fisheries Conservation and Management in India. United Nations -The Nippon Foundation Fellowship Programme

4. A teaching manual on "Aquatic Environment and Biodiversity". 2007. A. Srinivasan,
Baskaran Manimaran, P.Padmavathi, and N.Jayakumar, Department of Fisheries
Environment, Fisheries College and Research Institute, Tamilnadu Veterinary and
Animal Sciences University, Thoothukudi

Course Name	Aquatic Ecology, Biodiversity and Disaster Management
Lesson 10	National and international conventions and regulations concerning Biodiversity and Use of selective gears and Exclusion devices
Content Creator Name	RANI.V
University/College Name	Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam
Course Reviewer Name	SAHAR MASUD
University/college Name	Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

10.1 Objectives

- Various National and international conventions and regulations concerning biodiversity
- Selective Fishing gears
- Different By catch Reduction devices

10.2 Glossary terms

- **Bycatch:** Discarded catch of marine species and unobserved mortality due to a direct encounter with fishing vessels and gear.
- **Non - target species: S**pecies for which the fishing gear is not specifically deployed or set, but may have immediate commercial value and be a desirable component of the catch.
- **Artisanal fishing:** Small scale, low-technology, low-capital, fishing practices undertaken by individual fishing households. Many of these households are of coastal or island ethnic groups.
- **Trammel net:** A three layered fishing net, the middle layer of which is fine-meshed, the others coarse-meshed, so that fish attempting to pass through the net will become entangled in one or more of the meshes.
- **Sessile**: Organism or biological structure attached directly by its base without a stalk (natural mobility absent or normally immobile).

10.3.0 Biodiversity: Definition

Biodiversity refers to all species and living things on earth or in a specific ecosystem.

10.3.1 Biodiversity related Conventions

1. Convention on Biological Diversity (CBD)

2. Convention on International Trade in Endangered Species of wild fauna and flora (CITES)
3. Convention on the Conservation of Migratory Species of wild animals (CMS)
4. The International Treaty on Plant Genetic Resources for food and agriculture (international seed treaty)
5. Convention on Wetlands (Ramsar Convention)
6. World Heritage Convention

10.3.2 (1) Convention on Biological Diversity

At the 1992 earth summit in **Rio de Janeiro** world leaders agreed on a comprehensive strategy for "sustainable development" meeting our needs while ensuring that we leave a healthy and viable world for future generations.196 countries signed and participated and the convention established with three main goals:

- The **conservation** of Biological Diversity
- The **sustainable** use of its components
- The **fair and equitable sharing** of the benefits from the use of genetic resources.

10.3.3(2) Convention on International Trade in Endangered Species (CITES)

The convention on international trade in endangered species of wild fauna and flora (CITES). Entered into force in 1975 and over 180 countries, or parties, have signed up, committing to protect over 35,000 animal and plant species from unsustainable or illegal

international trade. Aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

10.3.4(3) The Convention on the Conservation of Migratory Species of wild animals

(CMS)

The convention on the conservation of migratory species of wild animals (CMS; also known as the Bonn convention) aims to conserve terrestrial, marine and avian migratory species throughout their range and entered into force in 1983.

10.3.5(4) The International Treaty on Plant Genetic resources for Food and Agriculture

The objectives of the international treaty on plant genetic resources for food and agriculture for the conservation and sustainable use of all plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the convention on Biological Diversity, for sustainable agriculture and food security and signed in Rome in 2001, entered into force in 2004

10.3.5(5) Ramsar Convention

The convention on wetlands, called the Ramsar convention, is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources.

10.3.5 (6) World Heritage Convention

The primary mission of the convention is to identify and protect the world's natural and cultural heritage considered to be of outstanding universal value. It covers all aspects of wetland conservation and wise use, recognizing wetlands as ecosystem that are extremely important for biodiversity conservation in general and for the well being of human communities.

10.3.6 (7) International Whaling Commission (IWC)

To provide conservation of whale stocks that will help in developing of the whaling industry.(Fig.1)

Fig.1. Symbol of IWC

10.3.7 (8) International Union for Conservation of Nature (IUCN)

To conserve our vital biodiversity, that is one of the important wheels of life cycle.It helps the world to find pragmatic solutions to our most pressing environment and development challenges.

Fig.2. Symbol of IUCN

10.3.8 (9) A step towards Dolphin conservation

India's first dolphin research centre at Patna. The much awaited National Dolphin Research Centre (NDRC), India's and Asia's first, would be a reality soon.

After remaining in limbo for nearly six years, the NDRC is likely to be set up next month on the banks of the Ganga on the Patna university premises.It will play an important role in strengthening conservation efforts and research to save the endangered mammal.Bihar is home to around half of the country estimated 3000 dolphin population.

Fig.3 Morphological structure of Dolphins

10.4 Selective Fishing Gears

Most fishing gears, for example trawl gears, are selective for the larger sizes, while some gears (gill nets) are selective for a certain length range only, thus excluding the capture of very small and very large fish. This property of fishing gear is called **gear selectivity**

10.4.1 Fishing selectivity

- Fishing selectivity can be defined as the ability to target and capture fish by species, size or sex during harvesting operations, allowing all incidental by catch to be released unharmed.
- Selectivity play a major role in the development of a sustainable and economically viable fishery.
- The results of selectivity experiments can be befitted to the fishermen to allow them to capture only targeted fishes and ensures the essential return of juvenile fishes.

10.4.2 Gill net selectivity

Gill netting is a common fishing method used by commercial and artisanal fishermen of all the oceans and in some fresh water and estuary areas.Gill net are vertical panels of netting normally set in a straight line.Gill net have a high degree of size selectivity. Most salmon fisheries in particular have an extremely low incidence of catching non - target fish.

10.4.2.1 Problem with gill net fishing

Gill nets work by trapping the fish in the nets holes. This fish is able to fit its head through the holes in the net, but the wider body will not go through.When they try to go to back out, their gills become hung on the net and fishermen haul them in.Unintended consequences have made this method of fishing questionable in the eyes of many people.

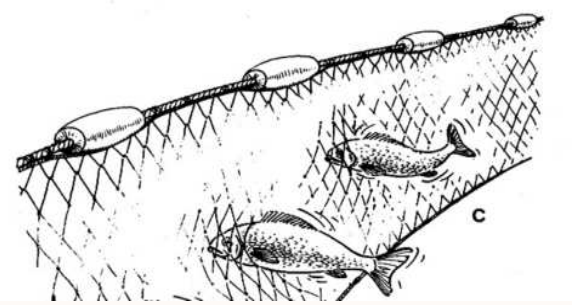


Fig.4. Fish trapped in gill net

10.4.3 Trawl net selectivity

- Trawling is a method a fishing that involves pulling a fishing net through the water behind one or more boats. The net used for trawling is called trawl. Trawls may be non-selective, sweeping both marketable and undesirable fish and fish of both legal and illegal size. Any part of the catch which cannot used is considered by catch, some of which is killed accidentally by the trawling process.
- Size selectivity is controlled by the mesh size of the “cod-end”- the part of the trawl

  where fish are retained.

`

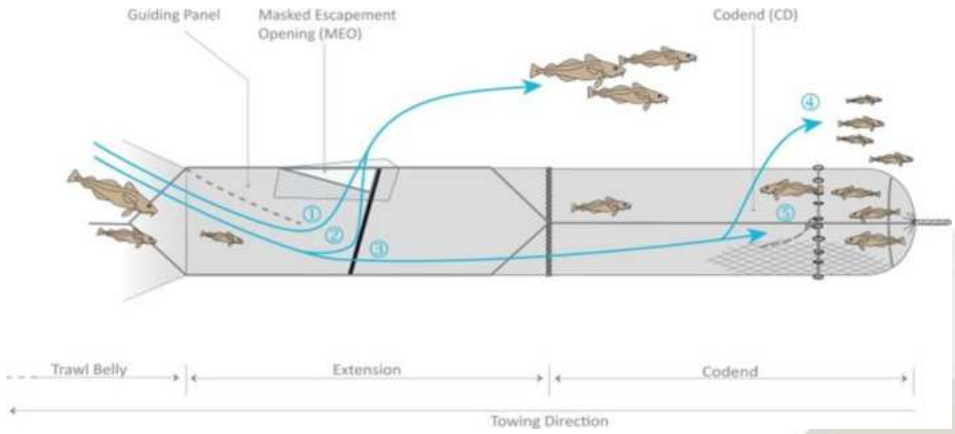


Fig.5. Structure and operation of trawl net

10.4.3.1 Environmental damage by bottom trawling

- Bottom trawling involves towing heavy fishing gear over the seabed, it can cause large scale destruction on the ocean bottom, including coral shattering, damage to habitats and removal of seaweed.
- Trawling disturb or damage sessile organisms or rework and re-suspend bottom sediments.
- These impacts result in decreases in species diversity and ecological changes towards more opportunistic organisms.
    - Trawling can kill coral reefs by breaking them up and burying them in sediments. In addition, trawling can kill corals indirectly by wounding coral tissue, leaving the reefs vulnerable to infection.

10.4.3.2 Disadvantages of trawling

- Disturbs and destroy the seabed including sea grasses, coral reefs, rock gardens where fishes hide from predators, spawning grounds.
- By catches and discarded valuable fish (turtles, sea birds, marine mammals), unwanted fish caught and thrown away.
- Compete directly with traditional nets.
- Over fishing gear is non-selective and discards a lot of sea fish
- Direct threat to local fishing communities, tourism and sport fishing
- Illegal fishing in deep sea.

10.6.3.6 Mitigating methods

- Using larger meshes in the cod ends

- Devices in the trawl that reduce the capture of small and unwanted organisms.
- TED - turtle excluder device
- Legislation and implementations.

10.7. Use of Exclusion Devices

Exclusion devices: Devices used for excluding non-target animals and non-living material which are caught while fishing

10.7.1 Turtle Excluder Devices

- TED or turtle excluder device is any modification to a trawl designed to reduce the capture of turtles.
- These devices are sometimes called a “trawl efficiency device” because they can also prevent the capture of other large animals including sharks, stingrays, jelly fish and some large fish.
- Soft TEDs use a non rigid inclined panel of netting to guide bycatch towards the escape opening in the top of the trawl.
- Hard TEDs typically uses a rigid grid made of aluminium, steel or plastic.
- crew (depend on location in cod end)

10.7.2 By Catch Reduction Devices

Any modifications to a trawl designed to reduce the capture of bycatch. Usually refers to devices that are specifically designed to reduce the capture of fish bycatch and other small animals and debris.Other modifications that may reduce bycatch include larger

meshes in the main body of the trawl, ground gear modifications or headline height adjustment.

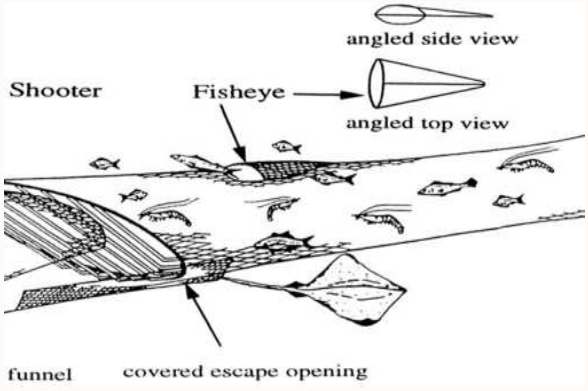


Fig.6. By catch reduction devices in fishing net

10.7.3Juvenile Trash Excluder Device (JTED)

This device is designed to exclude small fish, usually juvenile or trash fish from the trawl and maintain the catch of large fish.

10.7.4 Fish eye

Fish eyes are usually placed in the top or sides of the cod end so that strong swimming fish can escape, while shrimp passively enter the cod end.

10.7.5 RES and Jones- Davis BRD

RES stands for radical escape section, designed to allow fish to voluntarily swim from the trawl.The Jones- Davis BRD is similar to the RES but the escape openings are simply large holes cut into the cod-end netting.

10.7.6 Square mesh window

A square mesh window is usually a panel of square mesh netting located in the top panel of the cod end or trawl body to escape the fishes.

10.7.7 Fish box

A fish box is a box like device fitted to the top or bottom of the cod end with an opening through which fish can swim and escape. Its designed to alter the movement of water in the cod end.

10.8.References:

10.8. References

1. www.slideshare.net.2013. Conventions on biological diversity, Hasnahana chetia cited on 12.01.2021.
2. www.slideshare.net.2018 Biodiversity, conservation and conventions, environment, cited on 12.01.2021
3. m.jagranjosh.com list of International Organizations and Conventions related to Biodiversity(2018) cited on 12.01.2021
4. www.cms.int, cited on 12.01.2021
5. www.ramsar.org., cited on 12.01.2021
6. www.wikipedia.org., cited on 12.01.2021
7. www.cites.org., cited on 12.01.2021
8. www.slideshare.net. Fishing gears, Shobiya,Saruga, Kaleena environment (2017)., cited on 12.01.2021
9. www.slideshare.net. Gear selectivity, Aadil hussain, faculty of fisheries (2018), cited on 12.01.2021