Ministry of Higher Education and Scientific Research

University of Baghdad

College of Science

Department of Biology

Aquatic ecology (Freshwater Ecology)

For Postgraduate - Master Ecology

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Aquatic ecology

Ecology is the scientific study of how organisms interact with each other and with their environment. This includes relationships between individuals of the same species, between different species, and between organisms and their physical and chemical environments. Aquatic ecology includes the study of these relationships in all aquatic environments, including oceans, estuaries, lakes, ponds, wetlands, rivers, and streams.

A science that examines the relationship between aquatic organisms on one hand and between the hydrosphere components on the other. includes the study of these relationships in all aquatic environments, including oceans, estuaries, lakes, ponds, wetlands, rivers, and streams.

Aquatic ecosystems consist of communities of living organisms ranging from microorganisms to large fish and mammals and the environment they inhabit. Relationships between different types of living organisms, and their interactions with their environment, are often complex and interdependent. Understanding these relationships and how human actions can affect them allows for better management of aquatic resources.

Aquatic ecology is a branch of the science of ecology which is concerned with the study of aquatic ecosystems. This field can be broken into two divisions: **freshwater ecology** and **marine ecology.** Given that most of the Earth is covered in water, understanding aquatic ecosystems is very important, especially since water is critical to the survival of all life on Earth. Without water, Earth would be a very different place, and there probably wouldn't be any ecologists around to study it.

An ecosystem is a community of living organisms and their physical and chemical environment, linked by flows of energy and nutrients. Ecosystems function as a discrete ecological unit, and can be defined at a variety of scales. For example, the any River basin can be considered an ecosystem, as can a small pond, a log, or the entire planet. The boundaries of an aquatic ecosystem are somewhat arbitrary, but generally enclose a system in which inflows and outflows can be estimated. Ecosystem ecologists study how nutrients, energy, and water flow through an ecosystem.

The physical characteristics of aquatic habitats affect the types of organisms found there. Living organisms in a particular environment are directly affected by environmental characteristics such as nutrient concentrations, temperature, water flow, and shelter. Only the organisms that are able to survive in the conditions of a particular habitat and use the resources available there will thrive. Interactions between living organisms also affect the type of organisms found in an aquatic ecosystem, as competition for resources (e.g., food, habitat) and predation affects species abundance and diversity. In turn, the living organisms in an environment can influence some aspects of their environment (e.g., beaver dams can change water flows).

Understanding the basic components of aquatic ecosystems and the interaction among living organisms and their environment can lead to better management of human impacts on these systems.

The importance of the study of aquatic ecology

Increasing attention to everything related to the **aquatic ecology** and its wealth and includes two aspects:

1 - Cultural aspect and knowledge is the thirst for human knowledge of the hidden secrets of this unknown, which has been challenging human knowledge over history.

2. This includes the interest of countries in this food-rich source in order to meet the current or expected population growth, which is limited to traditional food sources.

The oceans contain more than 150,000 species, which are fish, 7% to 8%, 1% to whales, and only 1% to marine plants.

The importance of seafood is as follows:

1- Fish are a major source of protein.

2. Fish contains unsaturated oils that have a health benefit for the consumer.

3- Eating sea food reduces the intake of saturated fat.

4- Sea food is rich in vitamins and minerals.

5 - The proportion of grease in marine food is low if compared with other food sources of meat in addition to that it is a few prices.

6. About 35% of the total catch is used for the production of fishmeal used in poultry feed and others.

7. Skin sharks are used in different leather industries.

8 - Extract the material of amber from the liver of whales for the production of perfume as well as oil.

9. Pearls are extracted from some types of oysters.

10. Sponge is used for various industrial purposes.

11. Seaweeds and algae have many benefits, including:

A. Used as food for humans.

B - Animal feed.

C - Used as raw material in some industrial products.

D- Used in food preservation (canning industry).

E - Used in the types of soup, especially red algae, which contain protein by 25%, salts 27% and carbohydrates 44% of dry weight..

F- Some algae species are used in the manufacture of ice cream and confectionery, in the pharmaceutical industry, in dental molds, in cosmetics, in the manufacture of paper, dyeing and rubber.

G- Green algae also have a known nutritional significance such as Enteromorpha. In addition to the brown algae, such as the genus Undaria, which is of economic importance.

12 - Sea water contains more than 50 elements in addition to salt table, magnesium, potassium, bromine and others in addition to the presence of heavy metals such as gold, titanium, copper, chrome and nickel in addition to the fact that the seabed is rich in salt deposits in addition to crude oil.

Marine water

Marine ecosystems are among the largest of Earth's aquatic ecosystems. Examples include salt marshes, intertidal zones, estuaries, lagoons, mangroves, coral reefs, the deep sea, and the sea floor. They can be contrasted with freshwater ecosystems, which have a lower salt content. Marine waters cover two-thirds of the surface of the Earth. Such places are considered ecosystems because the plant life supports the animal life and vice versa. See food chains.

Marine ecosystems are essential for the overall health of both marine and terrestrial environments. According to the World Resource Center, coastal habitats account for about one-third of marine biological productivity. Estuarine ecosystems, such as salt marshes, seagrass meadows and mangrove forests, are among the most productive ecosystems on the planet. Coral reefs provide food and shelter to the highest levels of marine diversity in the world.

Marine ecosystems usually have a large biodiversity and are therefore thought to have a good resistance against invasive species. However, exceptions have been observed, and the mechanisms responsible in determining the success of an invasion are not yet clear.

The Earth's Water Budget

storage and fluxes

Water covers 70% of the earth's surface, but it is difficult to comprehend the total amount of water when we only see a small portion of it. The following diagram displays the volumes of water contained on land, in oceans, and in the atmosphere. Arrows indicate the annual exchange of water between these storages.

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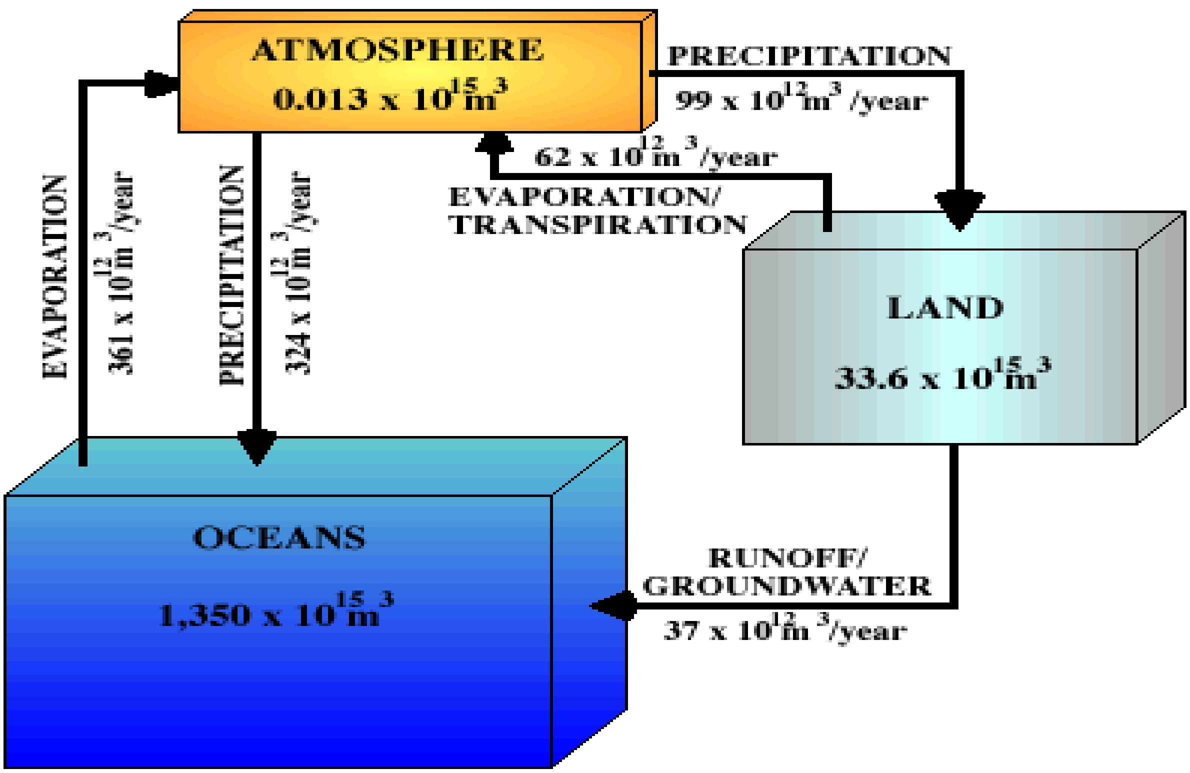


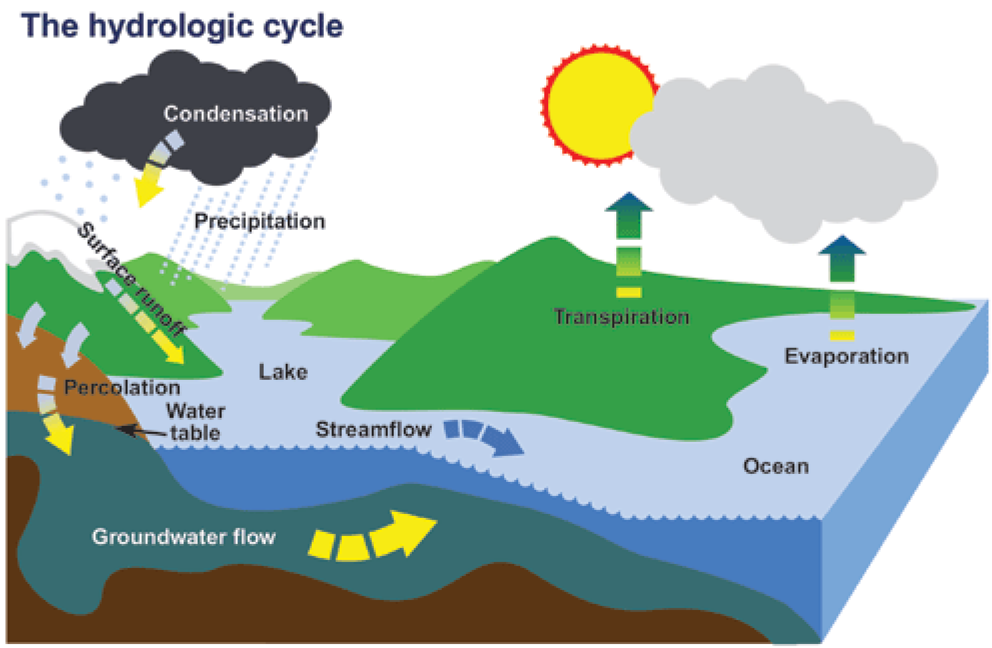
The oceans contain 97.5% of the earth's water, land 2.4%, and the atmosphere holds less than .001%, which may seem surprising because water plays such an important role in weather. The annual precipitation for the earth is more than 30 times the atmosphere's total capacity to hold water. This fact indicates the rapid recycling of water that must occur between the earth's surface and the atmosphere.

To visualize the amount of water contained in these storages, imagine that the entire amount of the earth's annual precipitation fell upon the state Texas. If this was to occur, every square inch of that state would be under 1,841 feet, or 0.3 miles of water! Also, there is enough water in the oceans to fill a five-mile deep container having a base of 7,600 miles on each side.

Freshwater is defined as having a low salt concentration usually less than 1%. Plants and animals in freshwater regions are adjusted to the low salt content and would not be able to survive in areas of high salt concentration (i.e., ocean). There are different types of freshwater regions:

Ponds and lakes , Streams and rivers , Wetlands.

Freshwater ecology involves rivers, lakes, streams, seasonal bodies of water, underground water deposits, and the surrounding areas, while marine ecology is concerned with the ocean. Estuaries, where freshwater meets saltwater, may be studied by ecologists from either field, and sometimes both, working cooperatively on projects which require the expertise of freshwater and marine ecologists. Because water systems are interconnected, there is a great deal of cooperation between professionals working in various aspects of aquatic ecology, and between aquatic ecologists and other members of the ecology profession.



Clearly all surface water (and much groundwater as well) is part of the Earth's hydrologic cycle. Beginning arbitrarily with the point at which water evaporates, the cycle works as follows: Water evaporates from the oceans, meaning that it goes from a liquid state to a gaseous state. Some of this evaporated water is ransported by wind currents in the form of clouds over land, where it may form into droplets (liquid) or crystals (solid) and precipitate onto the land. It may come down in the familiar forms of rain, snow, and sleet, as well as heavy fog, rime ice, or frost.

Precipitation lands on the ground surface, trees, rooftops, and roads. Once it lands (or, in the case of snow and ice, once it melts) it may run off, infiltrate into the ground, or evaporate and return to the atmosphere.

Infiltrated water percolates through the soil and subsoil but, like runoff, also moves downhill. Eventually it feeds into a stream or river system; a lake, pond, or wetland; or the sea. Depending on the distance involved, the nature of the subsurface environment (such as gravel deposit, clay layer, sand deposit, or rock), and surface topography (how steep), the journey may take minutes to years or even centuries.

All bodies of water, whether oceans, lakes, ponds, rivers, or wetlands, are connected through their mutual participation in the hydrologic cycle. Whether or not this connection is significant for the biota depends on the particular hydrologic process and on geography.

For example, floodplain wetlands are considered to be wetlands, but they are also properly considered to be part of the river system, even though there may be no direct connection after river levels fall and the river retreats from the floodplainwetland system. During the flood period when the river and the floodplain become

one, river organisms occupy the floodplain and its wetlands. This occupation may play an important part in a particular organism's reproductive cycle. At the same time, the river in flood adds sediment, organic material, and nutrients to the floodplain-

wetlands ecosystem. The two systems, which may be considered different biomes, are tightly coupled .

Lakes of any size are fed by surface flows, usually in the form of river systems.

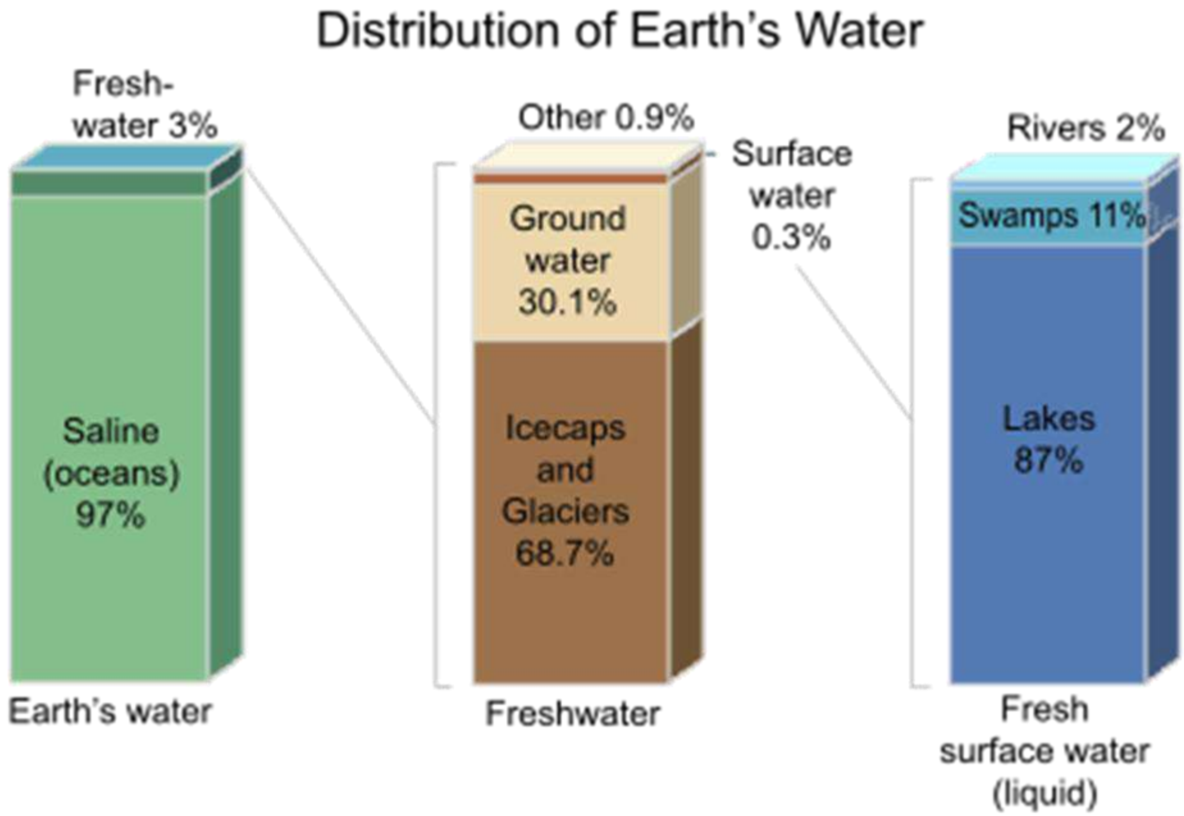
The hydrologic connection also provides an avenue for nutrient exchanges, sediment movement, and dispersal of living organisms.

Aquatic ecology (Freshwater Ecology) Lect.2

The importance of studying the freshwater environment .

1- Freshwater systems – including streams, rivers, ponds, lakes and wetlands – are important components of landscapes.
2- The organisms that make up food webs in freshwater systems are diverse and important both ecologically and economically.
3- Many aquatic species are well known, including a variety of important fish species, but at the bottom of a water body are organisms that are members of benthic communities.
4- The term benthos derives from the Greek word bathys, meaning deep. Benthic communities are composed of algae, bacteria, fungi, and invertebrates — organisms that transform matter and energy into LIFE — living biomass that eventually becomes food for other organisms like fish.
5- Insects that emerge from streams and lakes also provide important nutrients and energy to neighboring forests and sustain terrestrial organisms, such as birds, spiders and lizards1,2,3.
6- Benthic organisms have unique adaptations that allow their communities to perform valuable "ecosystem services", such as improving water quality for drinking, sustaining commercial fisheries, offering leisure and recreational opportunities, and providing inspiration for artistic expression and spiritual renewal.
7- When the world was relatively "empty" of humans, the bounty of these ecosystem services was so vast that it seemed limitless. However, in today's world of 7 billion people, our

footprint has grown so large that it is impairing the capacity of freshwater ecosystems to provide these valuable services.



Different Types of Freshwater

Essentially there are two main types, Static Water (called lentic) and Flowing Water (called lotic). However, this is still vague. For example, static water could be any size, a puddle left over from the last rain shower up to Lake Baikal (photo below) in Russia, the deepest freshwater lake in the world at 1620 metres deep. It also holds the greatest volume of water in the world with over 300 streams feeding it. Incidentally Lake Superior in North America has the greatest surface area.

Ecological Factors

In order to study the effect of the environment surrounding the organism, it is necessary to identify the natural environmental factors that have a direct impact on the growth and behavior of living organisms in the water bodies, the most important of which are:

1- Temperature.

2-Light.

3- Water movement.

4- Pressure

5 - Turbidity.

6. The nature of the bottom of the substratum.

7. Ionizing Radiation.

8. Factor combination .

The following factors will be discussed in detail in order to discuss each topic separately, noting that the factors listed above are not only the most important ones.

1-Temperature : -

The oceans show little change in temperature as their water undergoes geographic and vertical differences in absorption and thermal radiation. Temperature in the seas (except for shallow water) is generally lower than in freshwater. The relative stability of sea temperature is due to the rapid non-impact of changes in ambient temperature.

The highest temperature in the sea is located in the water surface of the areas near the equator and ranges from 26-30 ° C, and may be even more in shallow areas or semi-closed areas and may arrive in some ponds near the seas affected by the tidal movement to more than The temperature of the sea water is different depending on the amount of salinity, less than 0% of dissolved salts. The temperature remains constant throughout the year in the water of the areas close to the equator.

In the waters of rivers and streams, the small mass of water in its column relative to the oceans or seas is affected by seasonal changes, especially when air temperature is associated with seasonal and seasonal changes. River temperatures have the following characteristics:

1- Is homogeneous by mixing well by water movement.

2. Strongly affected by the heat of the surrounding atmosphere.

The absorption of heat at the surface waters of the sea near the equator line produces a warm surface layer that is above the deepest and most intense deep layer, thus forming the thermal stratification which consists of the following layers:

1 - Top layer Epilimnion: -

It is also known as the Thermosphere and its water is warm and low density.

2 - The middle layer Metalimnion: -

It is known as the Thermocline layer and has a rapid temperature change without thermal gradient.

3. Hypolymnion:

Known as the cold layer Psychrosphere where the water is cold and more intense than the previous two layers and continue this layer to the bottom.

These layers disappear in the winter when the surface water is cooled and the temperature conveys with the depth and the layers are not formed in the deep or shallow seas and formed, they do not last for more than a few days.

Water temperature has a major control over the distribution and activity of living organisms depending on the temperature tolerance of species. They are therefore divided into:

1- Stenothermic: -

Which are described as tolerant to a narrow range of heat where they exist in areas with very small variations in temperature and are present mainly in the oceans.

Eurythermic: -

Are the species that bear a wide range of temperatures, and are present mainly in shallow water.

Based on the effect of water temperature on the distribution of aquatic organisms, the latter was divided into three groups:

Warm water groups:

Are found mainly in the surface layers of the continental belt where the surface water temperature of most areas is 26-27 ° C.

Cold water groups:

Are present in the Arctic and Southern Ocean when the surface temperature is between 5 ° C and just below 0 ° C.

C) Communities that co-exist in medium-temperature water:

Are found in temperate zones where surface water temperatures range between 5-18 ° C.

Through all this, we can summarize the effects of heat by the following points:

1. Temperature is a key factor in controlling the distribution of living organisms through its effect on key biological processes such as photosynthesis of green plants, respiration, nutrition, growth, productivity, and ammuzic regulation.

2 - regulates the production heat in several ways, as it controls the maturity of the gonads and the formation of hives and eggs, that it controls the extent and frequency of reproduction and mortality rates during the first stages of development and the life of the larvae.

3 - Temperature indirectly affects the effect of some physical properties of water such as density and viscosity and melting of different gases affected by the characteristics of flotation and movement and breathing.

2- Light: -

That the light or visible light as we have previously known as part of the radiation energy, which includes wavelengths 380-780 nanometer, which can distinguish seven colors or different spectra. A number of vital biota are influenced by this environmental factor directly or indirectly.

Light is one of the essentials of life on Earth. It supplies the energy required to stabilize carbon dioxide by plants in the form of organic matter. This organic material is the source of energy and carbon for bacteria and fungi directly or after being transferred by animals.

Radiation in a wavelength less than 270 nanometers does not reach the ground because of its absorption by the ozone layer. This is particularly important because these lengths are a determinant or lethal factor or have a significant impact on the occurrence of genetic changes because they are considered the peak of absorption for DNA.

Large amounts of light also cause damage and may kill some small organisms.

The intensity of light falling in water varies by place, season and time during the day.

1 - absorption of water and suspended substances, including phytoplankton.

2 - Reflection of light by the elites and other suspended materials.

3 - some deviation of light by water molecules (dispersion of particles), and may also be dispersion by suspended materials.

Three vertical layers can be diagnosed depending on the presence of light in both freshwater seas and lakes:

A-photovoltaic layer Euphotic Zone:

A layer where there is sufficient light to cause photosynthesis of aquatic plants.

(B) Dysphotic Zone:

A layer in which light is of very limited quantity.

(C) The dark layer.

Is the layer where there are no plants because the area is permanently dark.

For the importance of light intensity and spectral composition in the process of photosynthesis and the growth of phytoplankton, the measurement of light for the water column can give some picture of the productivity of that site and is measured by different devices, including:

1 - Luxmeter device Luxmeter.

2- Secchi Disk.

Effect of light on plants: -

First- Tolerance: -

Algae vary greatly in relation to resistance to high intensity of light, and in general, the geometrists that gather near the surface more resistant to the intensity of light than the high ones in the depth.

The effects of the intensity of high-light on the clouds: -

1- Affects the speed of photosynthesis of phytoplankton.

2. The amount of chlorophyll dye of phytoplankton decreases in the surface waters of the sea when exposed to direct sunlight.

3 - The intensity of light harmful to seaweed attached also attached where algae growing in a shaded place better than those exposed to direct sunlight.

Experiments have shown that light factor damage is due to short wavelengths. In other experiments, wavelengths longer than 550 nm have killed parts of algae living in semi-coastal areas.

Second-Activities and biological interactions:

1 - Production of dye and chromatography: -

Most studied algae do not need light to form chlorophyll dye. However, some freshwater algae especially green need light to form and maintain chlorophyll. The light also activates the formation of carotenoids in plants, which increases the composition of carotenoids by increasing the intensity of light.

2 - photosynthesis: -

The intensity of the light with the ratio of photosynthesis is associated with a linear relationship to reach light saturation, which then does not affect the increase in the intensity of the light on the proportion of photosynthesis.

3 - The introduction and organization of ion: -

There are two ways in which light can be identified by the ionic motion:

A-The direct method: is done by photosynthesis and the production of high-energy vehicles ATP and also in the transfer of electrons, which affects the taking of ion transport effective.

B - indirect method: It is through the effectiveness of photosynthesis where the taking of ions such as phosphates and sulphates through their representation in organic compounds.

4. Growth:

A-Algae differ in their growth relative to light requirements, affecting their growth by:

Most algae live well under light.

B - Light is important in the formation and subtraction of reproductive cells for adherent algae. Sometimes the quality of light affects the formation of male and female gametes

Third- Effect of light on animals: -

1. Light encourages growth in corals while dark promotes growth in crustaceans.

2. Light affects the larvae of marine invertebrates in shallow waters.

3 - Light affects the activities of adult animals such as movement, nutrition, swimming and laying eggs.

4 - Light is important for short-term reproductive activities such as the formation of eggs or for a long time such as maturity of gonads and gametes and identification of sex.

5. Light is a determining factor in controlling vertical migration during the day for livestock and invertebrate invertebrates.

6. Studies confirm that light, especially ultraviolet light, may be the cause of fish death.

3-Water Movement:

Water movement is an important environmental factor in its effect on the distribution of living organisms through:

1- Effect of movement on bottom components, transport of nutrients and stability of plant complexes and affect the composition of aquatic organisms in water column.

2 - the effect of the movement on the concentration of oxygen in water where, as is known, the oxygen is increased by the movement of water with the consideration of the temperature of the adverse effect.

- The speed of water is very high, it is harmful through the physical accumulation of particles of sand, which affects the living sitting and inhibits its growth. The effect of the sand particles on the thin crust of larvae, where they break and damage the contents.

- Stream and rivers are described as moving bodies of water where they are equipped with rain water and pour water into the sea, ie it (open system).

- Lakes are defined as relatively stable (closed system).

- Specific factors for current speed: -

1 - slope in the gradient.

2 - roughness of the bottom.

3 - depth and width of the bottom.

4- Winds.

4- Pressure:

Called the science that is interested in studying the effects of pressure on living organisms Barbiology and divide the living organisms in microbiology by carrying pressure to:

1. Barophilic organisms that can live well when pressed between 400-500 air pressure ie they are (love-to-press).

Barophobic organisms are organisms that can not live or live poorly in 300-400 pressure air pressure.

That increased pressure may lead to the inhibition or acceleration of certain biological processes taking into account the differences in temperature, and found that there is a relationship between the responses of organisms to the increase in pressure and temperature at all levels of life regulation.

5- Turbidity: -

The Turbidity means the presence of insoluble substances in the water, which impedes permeability or light permeability. The concentration and size of granules of suspended substances affect the degree of brownness. The Turbidity is low in relatively stagnant water, as in the marshes, while the Turbidity of running water increases as a result of sediment movement with the current of water and this occurs in rivers. The effects of scarcity on aquatic life are:

1 - affect the growth of marine plants, which reduces the permeability of light that is used in photosynthesis, and the direct adhesion between the floating particles and plants or the absorption properties of suspended materials will change the amount of chemicals that are important to affect the impact of plant growth.

2 - Some studies show that Turbidity and suspended solids cause damage to fish or food, and high concentrations cause damage to fish gills and also inhibit their food activity.

6- Nature of the bottom Substratum: -

In determining the quality of the constituents of the seabed or any water level, several factors must be considered.

1 - speed of the current at the bottom.

2. Depth.

3. The geological and geological composition and characteristics of the coast, such as the presence of rocks or the sandy nature of the river or the sea.

4- Types of suspended materials in the water column including surface organissm.

5. Biodiversity communities.

The seabed provides several conditions suitable for animal life through:

1- The presence of ready-made food, which is mainly in the form of parts of organic substances submersible.

2. Soft sediments on the bottom shall be a hiding place for the protection of living organisms.

3. When the bottom is solid it will have a safe surface for adhesion to the living forms and protection of the organisms hiding in the rock cracks.

4. The bottom prepares large differences in the place of living due to the large differences in the bottom from one place to another

7- Onized radiation

onized radiation is one type of radiation to marine life that contains high-energy particles and photon radiation in both natural and artificial nuclear reactions.

A- Characteristics:

Ionized radiation contains electromagnetic waves from α rays and عة rays with fast-moving grains and charge, their susceptibility to influence and passage to living matter. The rays α and الأشعة are the most permeable and influential rays on the inner cell functions of the organism.

B - its biological impact: -

1. Ionized radiation changes the atomic structure or the charge of the living matter molecules, which change the bond of energy and encourage division and molecular breakdown.

2. Because the living material exposed to radiation mainly contains water, the direct effect is through changes in the bonds between the hydrogen and oxygen atoms and the production of highly active products such as HO2 and H2O2, which can feed protein molecules and thus affect enzymes, cell permeability, etc. .

3. Ionized radiation is concentrated along the food chain, so its concentration in animal tissues is greater than in sea water.

4 - Ionized radiation affects the bacteria, fungi and blue green algae through its effect on vital events such as breathing, enzymes and cell permeability.

-Note:-

Algae are more resistant to ionizing radiation than upper plants and animals, and a number of phylogenetic functions of algae are more resistant to radiation, such as cell division.

8-Factor Combination : -

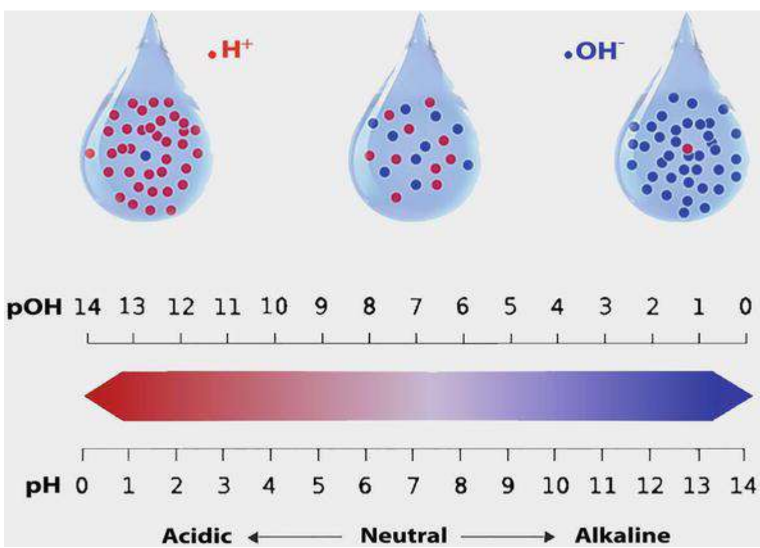
The response of the organism to all environmental factors is influenced by physiological, chemical and life factors that are closely related to each other. That is, environmental factors are interrelated and interrelated and affect the biological processes of the organism. For example, the light factor interferes with the temperature factor with the gas factor that provides inorganic carbon in water with the conditions of the brownness and the presence of different aquatic organisms and phytoplankton to perform this process photosynthesis in addition to other factors of the presence of nutrients to the degree of salinity and other factors that have an interrelated effect on the vital events and Must be taken into consideration for the purpose of studying these events.

Chemical parameters of water quality

1- pH

pH is one of the most important parameters of water quality. It is defined as the negative logarithm of the hydrogen ion concentration . It is a dimensionless number indicating the strength of an acidic or a basic solution . Actually, pH of water is a measure of how acidic/basic water is . Acidic water contains extra hydrogen ions (H^+) and basic water contains extra hydroxyl (OH^-) ions .

pH ranges from 0 to 14, with 7 being neutral. pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base solution . Pure water is neutral, with a pH close to 7.0 at 25°C. Normal rainfall has a pH of approximately 5.6 (slightly acidic) owing to atmospheric carbon dioxide gas . Safe ranges of pH for drinking water are from 6.5 to 8.5 for domestic use and living organisms need .



A change of 1 unit on a pH scale represents a 10-fold change in the pH , so that water with pH of 7 is 10 times more acidic than water with a pH of 8, and water with a pH of 5 is 100 times more acidic than water with a pH of 7.

There are two methods available for the determination of pH: electrometric and colorimetric methods .

Excessively high and low pHs can be detrimental for the use of water. A high pH makes the taste bitter and decreases the effectiveness of the chlorine disinfection, thereby causing the need for additional chlorine . The amount of oxygen in water increases as pH rises. Low-pH water will corrode or dissolve metals and other substances .

Pollution can modify the pH of water, which can damage animals and plants that live in the water .

The effects of pH on animals and plants can be summarized as follows:

- Most aquatic animals and plants have adapted to life in water with a specific pH and may suffer from even a slight change .
- Even moderately acidic water (low pH) can decrease the number of hatched fish eggs, irritate fish and aquatic insect gills, and damage membranes .
- Water with very low or high pH is fatal. A pH below 4 or above 10 will kill most fish, and very few animals can endure water with a pH below 3 or above 11 .
- Amphibians are extremely endangered by low pH because their skin is very sensitive to contaminants . Some scientists believe that the current decrease in amphibian population throughout the globe may be due to low pH levels induced by acid rain.

The effects of pH on other chemicals in water can be summarized as follows:

Heavy metals such as cadmium, lead, and chromium dissolve more easily in highly acidic water (lower pH). This is important because many heavy metals become much more toxic when dissolved in water .

A change in the pH can change the forms of some chemicals in the water. Therefore, it may affect aquatic plants and animals . For instance, ammonia is relatively harmless to fish in neutral or acidic water. However, as the water becomes more alkaline (the pH increases), ammonia becomes progressively more poisonous to these same organisms.

2-Salinity: -

Water bodies are divided into salts containing three salts:

1- The Sea Marine:

With salinity ranging from 30-40 parts per thousand, while the overall salinity rate is 34.5 parts per thousand.

2 - Brackish:

The salinity rate is less than 17 ppt.

3- Fresh Fresh:

With low salinity (less than 0.5 ppt).

Note:-

The amount of salts in fresh water is often expressed as a fraction of a millionth of a milligram per liter, rather than a fraction of a thousand in quantity.

Studies on plant phytoplankton have shown that it is difficult to separate the effect of salinity from the temperature in terms of the distribution of organisms, so it has been divided accordingly into:

1. Low-temperature species (-8.1-5.3 ° C) and salinity ranging from 6.32 to 5.34 parts per thousand These species are known as **Stenothermal** and **Stenohaline**, which are present in the Antarctic Ocean.

2. Species in variable temperature and salinity water called **Eurythermal** and **Stenohaline** are present in the arid zone seas.

3. Living organisms that are saturated with both species are known as **Eurythermal** and **Euryhaline**, which are found in estuaries.

3- Acidity

Acidity is the measure of acids in a solution. The acidity of water is its quantitative capacity to neutralize a strong base to a selected pH level . Acidity in water is usually due to carbon dioxide, mineral acids, and hydrolyzed salts such as ferric and aluminum sulfates . Acids can influence many processes such as corrosion, chemical reactions and biological activities .

Carbon dioxide from the atmosphere or from the respiration of aquatic organisms causes acidity when dissolved in water by forming carbonic acid (H_2CO_3). The level of acidity is determined by titration with standard sodium hydroxide (0.02 N) using phenolphthalein as an indicator .

4- **Alkalinity**

The alkalinity of water is its acid-neutralizing capacity comprised of the total of all titratable bases . The measurement of alkalinity of water is necessary to determine the amount of lime and soda needed for water softening (e.g., for corrosion control in conditioning the boiler feed water) . Alkalinity of water is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions (HCO^{3-}), and carbonate ions (CO_3^{2-}), or a mixture of two of these ions in water. As stated in the following equation, the possibility of OH^- and HCO_3^- ions together are not possible because they react together to produce CO_3^{2-} ions:

OH−+HCO3−→CO32−+H2OOH−+HCO3−→CO32−+H2OE8

Alkalinity is determined by titration with a standard acid solution (H_2SO_4 of 0.02 N) using selective indicators (methyl orange or phenolphthalein).

The high levels of either acidity or alkalinity in water may be an indication of industrial or chemical pollution. Alkalinity or acidity can also occur from natural sources such as volcanoes. The acidity and alkalinity in natural waters provide a buffering action that protects fish and other aquatic organisms from sudden changes in pH. For instance, if an acidic chemical has somehow contaminated a lake that had natural alkalinity, a neutralization reaction occurs between the acid and alkaline substances; the pH of the lake water remains unchanged. For the protection of aquatic life, the buffering capacity should be at least 20 mg/L as calcium carbonate.

5- Chloride

Chloride occurs naturally in groundwater, streams, and lakes, but the presence of relatively high chloride concentration in freshwater (about 250 mg/L or more) may indicate wastewater pollution . Chlorides may enter surface water from several sources including chloride-containing rock, agricultural runoff, and wastewater.

Chloride ions Cl^- in drinking water do not cause any harmful effects on public health, but high concentrations can cause an unpleasant salty taste for most people. Chlorides are not usually harmful to people; however, the sodium part of table salt has been connected to kidney and heart diseases . Small amounts of chlorides are essential for ordinary cell functions in animal and plant life.

Sodium chloride may impart a salty taste at 250 mg/L; however, magnesium or calcium chloride are generally not detected by taste until reaching levels of 1000 mg/L . Standards for public drinking water require chloride levels that do not exceed 250 mg/L. There are many methods to measure the chloride concentration in water, but the normal one is the titration method by silver nitrate .

6- Chlorine residual

Chlorine (Cl_2) does not occur naturally in water but is added to water and wastewater for disinfection . While chlorine itself is a toxic gas, in dilute aqueous solution, it is not harmful to human health. In drinking water, a residual of about 0.2 mg/L is optimal. The residual concentration which is maintained in the water distribution system ensures good sanitary quality of water .

Chlorine can react with organics in water forming toxic compounds called trihalomethanes or THMs, which are carcinogens such as chloroform $CHCl_3$. Chlorine residual is normally measured by a color comparator test kit or spectrophotometer .

7- Sulfate

Sulfate ions (SO_4^{2-}) occur in natural water and in wastewater. The high concentration of sulfate in natural water is usually caused by leaching of natural deposits of sodium sulfate (Glauber's salt) or magnesium sulfate (Epson salt) . If high concentrations are consumed in drinking water, there may be objectionable tastes or unwanted laxative effects , but there is no significant danger to public health.

8 - Nitrogen

There are four forms of nitrogen in water and wastewater: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen . If water is contaminated with sewage, most of the nitrogen is in the forms of organic and ammonia, which are transformed by microbes to form nitrites and nitrates . Nitrogen in the nitrate form is a basic nutrient to the growth of plants and can be a growth-limiting nutrient factor .

A high concentration of nitrate in surface water can stimulate the rapid growth of the algae which degrades the water quality . Nitrates can enter the groundwater from chemical fertilizers used in the agricultural areas . Excessive nitrate concentration (more than 10 mg/L) in drinking water causes an immediate and severe health threat to infants . The nitrate ions react with blood hemoglobin, thereby reducing the blood's ability to hold oxygen which leads to a disease called blue baby or methemoglobinemia .

9- Fluoride

A moderate amount of fluoride ions (F^{-}) in drinking water contributes to good dental health . About 1.0 mg/L is effective in preventing tooth decay, particularly in children .

Excessive amounts of fluoride cause discolored teeth, a condition known as dental fluorosis . The maximum allowable levels of fluoride in public water supplies depend on local climate . In the warmer regions of the country, the maximum allowable concentration of fluoride for potable water is 1.4 mg/L; in colder climates, up to 2.4 mg/L is allowed.

There are four methods to determine ion fluoride in

There are four methods to determine ion fluoride in water; the selection of the used method depends on the type of water sample .

10- Iron and manganese

Although iron (Fe) and manganese (Mn) do not cause health problems, they impart a noticeable bitter taste to drinking water even at very low concentration .

These metals usually occur in groundwater in solution as ferrous (Fe^{2+}) and manganous (Mn^{2+}) ions. When these ions are exposed to air, they form the insoluble ferric (Fe^{3+}) and manganic ($Mn^{3+)}$ forms making the water turbid and unacceptable to most people .

These ions can also cause black or brown stains on laundry and plumbing fixtures . They are measured by many instrumental methods such as atomic absorption spectrometry, flame atomic absorption spectrometry, cold vapor atomic absorption spectrometry, electrothermal atomic absorption spectrometry, and inductively coupled plasma (ICP) .

11- Copper and zinc

Copper (Cu) and zinc (Zn) are nontoxic if found in small concentrations . Actually, they are both essential and beneficial for human health and growth of plants and animals . They can cause undesirable tastes in drinking water.

At high concentrations, zinc imparts a milky appearance to the water . They are measured by the same methods used for iron and manganese measurements .

12- Hardness

Hardness is a term used to express the properties of highly mineralized waters . The dissolved minerals in water cause problems such as scale deposits in hot water pipes and difficulty in producing lather with soap .

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions cause the greatest portion of hardness in naturally occurring waters . They enter water mainly from contact with soil and rock, particularly limestone deposits .

These ions are present as bicarbonates, sulfates, and sometimes as chlorides and nitrates . Generally, groundwater is harder than surface water. There are two types of hardness:

- *Temporary hardness* which is due to carbonates and bicarbonates can be removed by boiling, and
- *Permanent hardness* which is remaining after boiling is caused mainly by sulfates and chlorides .

Water with more than 300 mg/L of hardness is generally considered to be hard, and more than 150 mg/L of hardness is noticed by most people, and water with less than 75 mg/L is considered to be soft.

From health viewpoint, hardness up to 500 mg/L is safe, but more than that may cause a laxative effect . Hardness is normally determined by titration with ethylene diamine tetra acidic acid or (EDTA) and Eriochrome Black and Blue indicators. It is usually expressed in terms of mg/L of $CaCO_3$.

No.	Parameters of water quality		
	Types of water quality parameters		
	Physical parameters	**Chemical parameters**	**Biological parameters**
1	Turbidity	pH	Bacteria
2	Temperature	Acidity	Algae
3	Color	Alkalinity	Viruses
4	Taste and odor	Chloride	Protozoa
5	Solids	Chlorine residual	
6	Electrical conductivity (EC)	Sulfate	
7		Nitrogen	
8		Fluoride	
9		Iron and manganese	
10		Copper and zinc	
11		Hardness	
12		Dissolved oxygen	
13		Biochemical oxygen demand (BOD)	
14		Chemical oxygen demand (COD)	
15		Toxic inorganic substances	
16		Toxic organic substances	
17		Radioactive substances	

An accepted water classification according to its hardness

Water classification	Total hardness concentration as mg/L as $CaCO_3$
Soft water	<50 mg/L as $CaCO_3$
Moderately hard	50–150 mg/L as $CaCO_3$
Hard water	150–300 mg/L as $CaCO_3$
Very hard	>300 mg/L as $CaCO_3$

13 - Dissolved oxygen

Dissolved oxygen (DO) is considered to be one of the most important parameters of water quality in streams, rivers, and lakes. It is a key test of water pollution . The higher the concentration of dissolved oxygen, the better the water quality.

Oxygen is slightly soluble in water and very sensitive to temperature. For example, the saturation concentration at 20°C is about 9 mg/L and at 0°C is 14.6 mg/L .

The actual amount of dissolved oxygen varies depending on pressure, temperature, and salinity of the water. Dissolved oxygen has no direct effect on public health, but drinking water with very little or no oxygen tastes unpalatable to some people.

There are three main methods used for measuring dissolved oxygen concentrations: the colorimetric method—quick and inexpensive, the Winkler titration method—traditional method, and the electrometric method .

14- Biochemical oxygen demand (BOD)

Bacteria and other microorganisms use organic substances for food. As they metabolize organic material, they consume oxygen . The organics are broken down into simpler compounds, such as CO_2 and H_2O, and the microbes use the energy released for growth and reproduction .

When this process occurs in water, the oxygen consumed is the DO in the water. If oxygen is not continuously replaced by natural or artificial means in the water, the DO concentration will reduce as the microbes decompose the organic materials. This need for oxygen is called the biochemical oxygen demand (BOD). The more organic material there is in the water, the higher the BOD used by the microbes will be. BOD is used as a measure of the power of sewage; strong sewage has a high BOD and weak sewage has low BOD .

The complete decomposition of organic material by microorganisms takes time, usually 20 d or more under ordinary circumstances . The quantity of oxygen used in a specified volume of water to fully decompose or stabilize all biodegradable organic substances is called the ultimate BOD or BOD_L.

BOD is a function of time. At time = 0, no oxygen will have been consumed and the BOD = 0. As each day goes by, oxygen is used by the microbes and the BOD increases. Ultimately, the BOD_L is reached and the organic materials are completely decomposed.

The value of the constant rate k depends on the temperature, the type of organic materials, and the type of microbes exerting the BOD .

15- Chemical oxygen demand (COD)

The chemical oxygen demand (COD) is a parameter that measures all organics: the biodegradable and the non-biodegradable substances . It is a chemical test using strong oxidizing chemicals (potassium dichromate), sulfuric acid, and heat, and the result can be available in just 2 h . COD values are always higher than BOD values for the same sample .

16- Toxic inorganic substances

A wide variety of inorganic toxic substances may be found in water in very small or trace amounts. Even in trace amounts, they can be a danger to public health . Some toxic substances occur from natural sources but many others occur due to industrial activities and/or improper management of hazardous waste . They can be divided into two groups:

- *Metallic compounds:* This group includes some heavy metals that are toxic, namely, cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), silver (Ag), arsenic (As), barium (Ba), thallium (Tl), and selenium (Se) . They have a wide range of dangerous effects that differ from one metal to another. They may be acute fatal poisons such as (As) and (Cr^{6+}) or may produce chronic diseases such as (Cd, Hg, Pb, and Tl) . The heavy metals concentration can be determined by atomic absorption photometers, spectrophotometer, or inductively coupled plasma (ICP) for very low concentration .

  - *Nonmetallic compounds:* This group includes nitrates (NO_3^-) and cyanides (CN^-), nitrate has been discussed with the nitrogen in the previous section. Regarding cyanide, as Mackenzie stated . it causes oxygen deprivation by binding the hemoglobin sites and prevents the red blood cell from carrying the oxygen . This causes a blue skin color syndrome, which is called cyanosis . It also causes chronic effects on the central nervous system and thyroid . Cyanide is normally measured by colorimetric, titrimetric, or electrometric methods .

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17- Toxic organic substances

There are more than 100 compounds in water that have been listed in the literature as toxic organic compounds . They will not be found naturally in water; they are usually man-made pollutants. These compounds include insecticides, pesticides, solvents, detergents, and disinfectants . They are measured by highly sophisticated instrumental methods, namely, gas chromatographic (GC), high-performance liquid chromatographic (HPLC), and mass spectrophotometric .

18- Radioactive substances

Potential sources of radioactive substances in water include wastes from nuclear power plants, industries, or medical research using radioactive chemicals and mining of uranium ores or other radioactive materials . When radioactive substances decay, they release beta, alpha, and gamma radiation . Exposure of humans and other living things to radiation can cause genetic and somatic damage to the living tissues .

Radon gas is of a great health concern because it occurs naturally in groundwater and is a highly volatile gas, which can be inhaled during the showering process . For drinking water, there are established standards commonly used for alpha particles, beta particles, photons emitters, radium-226 and -228, and uranium .

The unit of radioactivity used in water quality applications is the picocurie per liter (pCi/L); 1 pCi is equivalent to about two atoms disintegrating per minute. There are many sophisticated instrumental methods to measure it .

Aquatic ecology (Freshwater Ecology) Lect.4

Third- Biological parameters of water quality

One of the most helpful indicators of water quality may be the presence or lack of living organisms . Biologists can survey fish and insect life of natural waters and assess the water quality on the basis of a computed species diversity index (SDI) . hence, a water body with a large number of well-balanced species is regarded as a healthy system . Some organisms can be used as an indication for the existence of pollutants based on their known tolerance for a specified pollutant .

Microorganisms exist everywhere in nature . Human bodies maintain a normal population of microbes in the intestinal tract; a big portion of which is made up of coliform bacteria . Although there are millions of microbes per milliliter in wastewater, most of them are harmless . It is only harmful when wastewater contains wastes from people infected with diseases that the presence of harmful microorganisms in wastewater is likely to occur .

1- Bacteria

Bacteria are considered to be single-celled plants because of their cell structure and the way they ingest food [.. Bacteria occur in three basic cell shapes: rod-shaped or bacillus, sphere-shaped or coccus, and spiral-shaped or spirellus . In less than 30 min, a single bacterial cell can mature and divide into two new cells

Under favorable conditions of food supply, temperature, and pH, bacteria can reproduce so rapidly that a bacterial culture may contain 20 million cells per milliliter after just 1 day . This rapid growth of visible colonies of bacteria on a suitable nutrient medium makes it possible to detect and count the number of bacteria in water .

There are several distinctions among the various species of bacteria. One distinction depends on how they metabolize their food . Bacteria that require oxygen for their metabolism are called aerobic bacteria, while those live only in an oxygen-free environment are called anaerobic bacteria. Some species called facultative bacteria can live in either the absence or the presence of oxygen .

At low temperatures, bacteria grow and reproduce slowly. As the temperature increases, the rate of growth and reproduction doubles in every additional 10°C (up to the optimum temperature for the species) . The majority of the species of bacteria having an optimal temperature of about 35°C .

A lot of dangerous waterborne diseases are caused by bacteria, namely, typhoid and paratyphoid fever, leptospirosis, tularemia, shigellosis, and cholera . Sometimes, the absence of good sanitary practices results in gastroenteritis outbreaks of one or more of those diseases .

2- Algae

Algae are microscopic plants, which contain photosynthetic pigments, such as chlorophyll . They are autotrophic organisms and support themselves by converting inorganic materials into organic matter by using energy from the sun, during this process they take in carbon dioxide and give off oxygen . They are also important for wastewater treatment in stabilization ponds . Algae are primarily nuisance organisms in the water supply because of the taste and odor problems they create . Certain species of algae cause serious environmental and public health problems; for example, blue-green algae can kill cattle and other domestic animals if the animals drink water containing those species .

3- Viruses

Viruses are the smallest biological structures known to contain all genetic information necessary for their own reproduction . They can only be seen by a powerful electronic microscope . Viruses are parasites that need a host to live . They can pass through filters that do not permit the passage of bacteria . Waterborne viral pathogens are known to cause infectious hepatitis and poliomyelitis . Most of the waterborne viruses can be deactivated by the disinfection process conducted in the water treatment plant .

4- Protozoa

Protozoa are single-celled microscopic animal . consume solid organic particles, bacteria, and algae for food, and they are in turn ingested as food by higher level multicellular animals . Aquatic protozoa are floating freely in water and sometimes called zooplankton . They form cysts that are difficult to inactivate by disinfection .

Indicator organisms

A very important biological indicator of water and pollution is the group of bacteria called coliforms . Pathogenic coliforms always exist in the intestinal system of humans, and millions are excreted with body wastes . Consequently, water that has been recently contaminated with sewage will always contain coliforms .

A particular species of coliforms found in domestic sewage is *Escherichia coli* or *E. coli* . Even if the water is only slightly polluted, they are very likely to be found. There are roughly 3 million of *E. coli* bacteria in 100 mL volume of untreated sewage . Coliform bacteria are aggressive organisms and survive in the water longer than most pathogens. There are normally two methods to test the coliform bacteria—the membrane filter method and multiple-tube fermentation method . Since the test of coliform bacteria is very important for public health, the first method will be described in details in the coming section.

Testing for coliforms: membrane filter method

A measured volume of sample is filtered through a special membrane filter by applying a partial vacuum .

The filter, a flat paper-like disk, has uniform microscopic pores small enough to retain the bacteria on its surface while allowing the water to pass through. The filter paper is then placed in a sterile container called a petri dish, which contains a special culture medium that the bacteria use as a food source .

Then, the petri dish is usually placed in an incubator, which keeps the temperature at 35°C, for 24 h. After incubation, colonies of coliform bacteria each containing millions of organisms will be visible . The coliform concentration is obtained by counting the number of colonies on the filter; each colony counted represents only one coliform in the original sample .

Coliform concentrations are expressed in terms of the number of organisms per 100 mL of water as follows:

coliformsper100mL=number of colonies×100/mLof samplecoliformsper100mL=number of colonies×100/mLof sampleE11

Aquatic ecology (Freshwater Ecology) Lect.2

Water quality

Water quality is defined in terms of the chemical, physical, and biological content of water. The water quality of rivers changes with the seasons and geographic areas, even when there is no pollution present. There is no single measure that constitutes good water quality. For instance, water suitable for drinking can be used for irrigation, but water used for irrigation may not meet drinking water guidelines. Water quality guidelines provide basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses.

Many factors affect water quality

Substances present in the air affect rainfall. Dust, volcanic gases, and natural gases in the air, such as carbon dioxide, oxygen, and nitrogen, are all dissolved or entrapped in rain. When other substances such as sulfur dioxide, toxic chemicals, or lead are in the air, they are also collected in the rain as it falls to the ground. Rain reaches the earth's surface and, as runoff, flows over and through the soil and rocks, dissolving and picking up other substances. For instance, if the soils contain high amounts of soluble substances, such as limestone, the runoff will have high concentrations of calcium carbonate. Where the water flows over rocks high in metals, such as ore bodies, it will dissolve those metals.

Industrial, farming, mining, and forestry activities also significantly affect the quality of rivers, lakes, and groundwater. For example, farming can increase the concentration of nutrients, pesticides, and suspended sediments. Industrial activities can increase concentrations of metals and toxic chemicals, add suspended sediment, increase temperature, and lower dissolved oxygen in the water. Each of these effects can have a negative impact on the aquatic ecosystem and/or make water unsuitable for established or potential uses.

Aquatic ecosystem

An ecosystem is a community of organisms – plants, animals, fungi and bacteria – interacting with one another and the environment in which they live. Protecting aquatic ecosystems is in many ways as important as maintaining water quality, for the following reasons:

- Aquatic ecosystems are an integral part of our environment. They need to be maintained if the environment is to continue to support people. World conservation strategies stress the importance of maintaining healthy ecosystems and genetic diversity.

- Aquatic ecosystems play an important role in maintaining water quality and are a valuable indicator of water quality and the suitability of the water for other uses.

- Aquatic ecosystems are valuable resources. Aquatic life is a major source of protein for humans. In most countries, including iraq, commercial and sport fishing is economically important.

- Aquatic ecosystems are two types of lotic and lentic .

The lotic water varies from lentic water:

- Continuous water movement in one direction.
- Variability of water flow velocity.
- A large variation in the water level.
- Depth is less than lakes.
- Physical, biological and chemical factors vary along the waterway in one direction.
- The higher the running water, the greater length and width and depth.
- Current water transfers erosion materials.
- .Lotic water is open and lentic water is closed.
- The productivity of running water depends on the quality and quantity of nutrients found in the basin.
- The use of food in the lentic water have several times while in Lotic water temporarily.
- Oxygen concentration in lentic water is more similar to the water layers of static water.

What is Limnology?

The term "limnology" is derived from the ancient greek word (limne) meaning lake or pond; it is therefore literally the study of lakes and ponds. First coined by the swiss François-Alphonse Forel in his pioneering monograph Le Léman at the end of the 19th century (check exact date), the term limnology gained rapid acceptance both in Europe and North America.

Its scope also evolved to include not only lakes and ponds but also streams and rivers and is now widely understood to cover all types of inland waters. It is directly the equivalent of oceanography but confined to inland waters and, in many ways, the distinction between limnology and oceanography is largely related to the size of the water body.

Our inland waters are vital and important resources. They provide us with drinking water, recreation, bird and wildlife viewing, fishing, land protection, and so much more. Limnology is the study of inland waters and their many different aspects. The word comes from the Greek limne, which means marsh or pond. But limnology is so much more than that. Limnology covers all inland waters, which may be lakes, rivers, and streams, but also reservoirs, groundwater, and wetlands. These are often freshwater systems, but limnology also includes inland salt and brackish, or slightly salty, waters.

Life forms in the aquatic environment

Viruses

Viruses are extremely small (30–300 microns) and lack a cellular structure, but they are alive in the sense that they self-replicate and evolve. Without a cellular structure of their own, they can live only as parasites inside the cells of other organisms. They are ubiquitous, and many cause diseases in their host organisms.

Bacteria

Bacteria inhabit freshwater systems in large numbers, especially on organic detritus which they help to decompose—in sediments, and in a biofilm covering all submerged surfaces. These surfaces include rock and gravel particles on the river or lake bottom, the skin of fishes, fragments of large woody debris, and sides of boats. Their concentrations in the water column are lower. Most are consumers of dissolved organic material (DOM). The autotrophic cyanobacteria, or blue-green algae, are a major planktonic group, particularly in nutrient-rich waters.

Fungi

Numerous fungi occur in freshwater environments, but the **hyphomycete** fungi are the most important. These tiny organisms colonize dead leaves, wood, and other organic detritus in streams, softening the tougher components and rendering them more palatable and more valuable as food to invertebrates. Their astronomically numerous spores are also consumed by specialized detritivores.

Algae

Algae are single- or multicelled organisms, mostly microscopic plants. Along with the cyanobacteria, they are the primary autotrophs (organisms that roduce carbohydrates through photosynthesis) in freshwater systems.

The algae may be grouped according to where they occur. **Periphyton**, or **periphytic** algae, are attached to substrate (rocks, sediments, or the surfaces of aquatic macrophytes); phytoplankton, or planktonic algae, are suspended in the water column.

Macrophytes

Macrophytes are larger, multicellular plants that play a key role in many aquatic environments. In terms of growthform, macrophytes can be emergent, floatingleaved, free-floating, or submerged. Emergent plants are rooted in the underwater substrate, but they grow up out of the water. Floating-leaved plants are similarly rooted; their leaves float on the surface but do not extend further. Free-floating plants are not rooted but float freely on the surface and often form large floating mats upon which other forms of life become established (as in many tropical freshwater environments). Submerged plants are rooted but completely underwater.

Protozoans

The protozoans are a diverse group of unicellular animals such as **ciliates** (protozoans with hairlike structures). Most are microscopic, though some can be seen with the unaided eye. They tend to prefer slackwater areas, depositional areas (areas where suspended material is deposited), and interstitial spaces in the substrate (that is, the spaces between particles of sand or gravel). Some protozoans graze on bacteria and algae; others are predators; still others are parasites. Protozoans in turn are consumed by many small invertebrates, including midge larvae.

Rotifers

Barely visible to the unaided eye, these tiny animals are an important and abundant constituent of the zooplankton (along with protozoans) in most freshwater environments. They constitute a major food source for some fish. The rotifers are a large group that consumes algae, bacteria, and smaller ani

mals.

Flatworms

In streams and rivers, planaria (Order Tricladida) are the most important representatives of this group. Many prefer cold water and so are found mostly in headwater streams. Mostly flat or ribbon-like worms (0.2–1.2 in or 5–30 mm) long, planaria glide over the substrate, scavenging or hunting for prey.

Nematodes

Nematodes are unsegmented microscopic or near-microscopic roundworms. An extremely diverse and ubiquitous group, they inhabit marine, terrestrial, and freshwater aquatic environments. Many are parasitic, but some free-living species inhabit freshwater environments, where they are part of the microbial loop.

Annelid Worms

Of this large phylum, two main groups occur in freshwaters: oligochaetes and hirudinae (leeches). Most oligochetes are detritivores (scavengers in sediment deposits, for example, in the substrate of pools). Some leeches are scavengers; others are parasites. Annelids tend to tolerate low dissolved oxygen levels; if they are dominant,it is an indication of poor water quality.

Sponges

While the members of this phylum (Porifera) are usually associated with marine environments, about 150 sponges occur in freshwater environments throughout the world. Morphologically simple creatures, they range in size from less than 1 in (1–2 cm) to about 3 ft (1 m), and are typically brown, greenish, or yellow, according to the colors of the algae living on them. They attach to pieces of wood or other relatively stable pieces of substrate, and live by filtering algae, protozoans, and fine particles.

Molluscs

Two classes of molluscs are common in freshwaters: gastropods (snails and limpets) and pelecypods (the bivalve clams and mussels). Snails feed on periphyton and sometimes on detritus; they are herbivorous or omnivorous. Most freshwater bivalves are filter feeders, filtering fine particles of algae, bacteria, and organic detritus from the water. As such they play an important ecological role in reducing turbidity, particularly in lake environments. In turn molluscs are prey for fish, some bird species, and mammals such as raccoons .

Crustaceans

Of the approximately **40,000 known** species of crustaceans, only about **4,000 live in freshwater**. The larger freshwater inhabitants include **isopods, amphipods and decapods** ,. Freshwater aquatic isopods and amphipods inhabit clean, cold waters and are omnivorous scavengers. The decapods are detritivores, herbivores, and predators, some changing feeding habits with different life stages.. In turn these organisms are prey to a wide variety of predators, including fish, birds, snakes, and mammals.

Insects

The vast majority of species of this enormous taxon are terrestrial, but aquatic insects account for the majority of macroinvertebrates in most rivers and streams. Most do not spend their entire lives in water, only their larval stages. For some, however, the larval stage is long compared with a relatively brief adult period. The major insect taxa that play important roles in freshwater systems are introduced below.

- **Mayflies** (Ephemero ptera). The mayflies include more than 300 genera and more than 2,000 species and are found on every continent except Antarctica. Most species are obligate river-dwellers; only a few inhabit lakes and wetlands. Mayfly species can be found in all of the freshwater aquatic habitats and are an important food source for fish.

- **Caddisflies** (Trichoptera). The caddisflies are a large insect order with almost 10,000 species described, and estimates of several times this many existing globally. They are a major food source for fish and are widely distributed.
- **Stoneflies** (Plecoptera). The stoneflies, as the common name suggests, tend to inhabit rocky or gravelly substrate. This implies headwater streams, with their generallyhigh levels of oxygen and cool temperatures, and these are in fact the conditions that most stoneflies require. The nearly 2,000 species tend to be concentrated in the mid- and high-latitudes. The larvae, eggs, and adults are consumed by a variety of fish species, birds, amphibians, and larger invertebrates .
- **True flies** (Diptera). Although many flying insects are termed ‘‘fly’’ (for example, dragonfly, mayfly, caddisfly), only those belonging to the order Diptera are ‘‘true’’ flies. This order contains 10000 species, The larval black flies are almost all filter feeders, occur sometimes in high densities in the aquatic environment, and (especially in such high densities) are an important prey for a broad spectrum of fish, birds, and larger invertebrates.

- **Beetles** (Coleoptera). The Web site of the Coleopterists Society contains the following description of beetles:
  Beetles… are the dominant form of life on earth. One of every five living species of all animals or plants is a beetle! Various species live in nearly every habitat except the open sea, and for every possible kind of food, there’s probably at least one beetle species that eats it. More than 300,000 species have been described, and it is estimated that the total number is many times that.
- **True bugs (**Hemiptera). This large order has more than 3,300 species living in or on water. The most conspicuous is probably the giant water bug (family Belostomatidae) or ‘‘toe-biter,’’ which as its name suggests can inflict a painful bite. It has powerful pinchers because it is a predator, as are many of its fellow Hemipterans.

- **fishflies** (Megaloptera). This medium-size, mostly terrestrial order contains some of the freshwater environment's best-known aquatic insects, in particular the spectacularly large and voracious dobsonfly larva, also known as the hellgrammite.
- **Dragonflies** (Odonata). The adult members of this order are known even to the least observant frequenter of freshwater environments. Most people see them only in their winged adult forms, which include many large dragonflies and gorgeously colored damselflies.

Vertebrates

Fishes. The fishes are the dominant aquatic lifeform both in terms of their importance in the freshwater food web and their interest to humans. All fishes are obligate aquatics. Although other vertebrates live in and around freshwater environments and are part of the aquatic food web, relatively few spend their entire lives in the water.

The fishes are a vast group; about 25,000 species are scientifically described. Of these, about 41 percent or more than 10,000 are freshwater and 1 percent move between freshwater and the sea during their lives. The fishes have adapted to conditions in practically every aquatic environment on Earth. They range in size from the very small (less than 0.5 in or about 1 cm long) to the very large (the whale shark can reach 39 feet or 12 meters in length). They may be shaped like discs, pencils, boxes, doormats, and basketballs. Some fish have scales and others do not; some fish are brilliantly colorful, others are drab. Some eat plants (herbivores), some eat invertebrates, some eat detritus, some eat other fish, and some (in a pinch) will eat people.

Amphibians. All amphibians need some form of freshwater habitat for at least a part of their lives; many prefer lentic and lotic habitats example :- froge , salamanders and toads. Amphibians in aquatic systems, lentic or lotic, tend to be grazers in their larval stage and predators as adults.

Reptiles. A number of reptiles, in particular, members of the order Crocodylia, snakes (Squamata) of many families, and freshwater turtles

(Testudines, sometimes referred to as chelonians), play important roles in freshwater food webs. Crocodiles, alligators, and related species are voracious predators that may feed on invertebrates as well as fish, especially early in their lives. Some crocodiles and alligators grow to impressive sizes, and it is likely that their impact on the fish population is substantial. They mostly inhabit lowland, sluggish streams and rivers, lakes and ponds, and wetlands. Snakes are almost all predators, preying on fish primarily but also invertebrates. Terrapins tend to be omnivorous. The fearsome alligator snapping turtle is a good example, eating fish, invertebrates.

Birds. Many birds live along rivers, in wetlands, and on and around lakes, and are involved in the aquatic food web, in many cases as top carnivores . Ducks, geese, and other waterfowl forage in shallows of lakes and rivers. Eagles, ospreys, kingfishers, and various wading birds are fish-eaters (piscivores) but are not limited to aquatic habitats, nor do they spend much time actually in the water .

Some, like the otters, are predators, feeding on fish and invertebrates; others, like the hippos, graze aquatic plants.

The adult stages of aquatic insect larvae feed many birds that are not themselves in any sense aquatic.

Many species of birds, however, can be considered truly aquatic in the sense

that they spend a good deal of their lives either on the water or underwater. Cormorants and anhingas, for example, are quite as much at home underwater, where they pursue fish, as in the air. Some water birds prefer moving water, even rapidly moving water. The dippers wade or swim underwater in rapids, typically in loworder mountain streams, looking for insect larvae and the occasional fish or crustacean.

There are also several ducks that seek out invertebrates in fast-moving waters.

A list of bird orders with member species that are associated with freshwater environments follows.

Mammals. Many mammals use riparian environments and are connected to aquatic food webs, but few actually inhabit the water. For example, brown bears feast on salmon returning upstream to spawn, but no one would call them aquatic organisms. Mammals that do spend a significant part of their lives in freshwater include otters (family Mustelidae, subfamily Lutrinae) and a few other mustelids, beavers (family Castoridae), hippopotami (family Hippopotamidae), river dolphins (family Platanistoidae), and the Australian platypus (family Ornithorhinchidae).

Aquatic ecology (Freshwater Ecology) Lect.6

The Rivers

What is a river .

The first image that comes to mind when we think of a river is that of water running continuously from mountain to valley. This may sound obvious, but it is precisely this aspect that allows us to understand what a river is and how it functions.

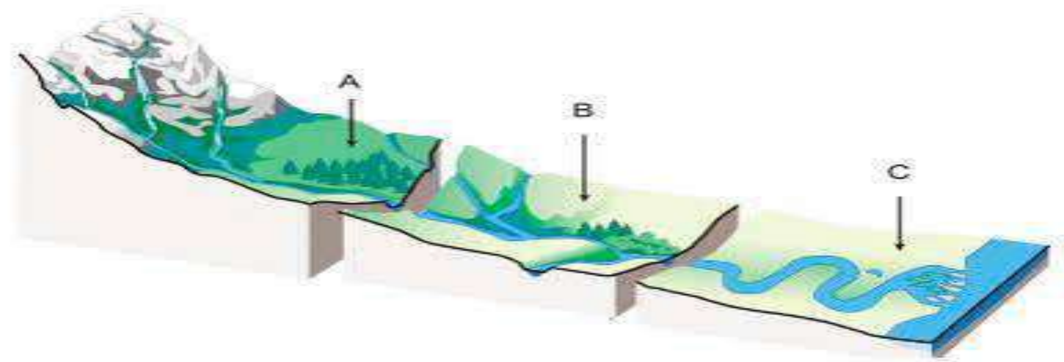
A river is a course of water that originates in the mountains and flows downwards until it reaches the sea. On its perpetual journey, river water crosses land, hills and plains. Starting in the mountains, the water is at first torrential because of rainfall and the melting of ice.

Rivers, blood of the earth

Along its entire route, a river is a fundamental resource not only for human life but for fauna and flora too. Each and every river is crucial to the equilibrium of the environment and biodiversity. That is why rivers must be considered a most precious good, to be guarded and protected from all forms of pollution or excessive exploitation.

The ages of a river

We can divide each river up into three ages, comparable to the life phases of human beings: youth, maturity and old age. These three phases roughly correspond to the regions the river runs through. The river's course is its life, its entire journey from source to mouth where it sheds its banks and merges with the water of the sea.



Figures 1 - The ages of a river: youth, maturity, old age

Youth

When it first starts out, a river is still small and narrow, a mountain spring whose waters run quickly downwards towards the valley. The land here is sloping, often steep, and does not allow the river to create an alternative

course. It is often torrential, that is to say its rate of flow depends on the amount of rainfall. Even if there isn't much water initially, the speed with which it flows downwards erodes the surrounding rock, and in this way the water absorbs many mineral salts and elements from stones, soils, vegetation and wood.

Maturity

Once out of the mountainous stretch, the river flows through hills and valleys – known as valley bottom, or piedmont regions, where the land is more gentle than in the mountains and where the water meets up and joins with other rivers and torrents. The land slopes less and the river flows more slowly. Material brought down by the current begins to deposit, first the large pieces of debris get left behind, then the smaller pieces, right down to mud and sand.

Old age

The river flows from the hills down into the plains. The flow speed slows down yet again, debris becomes finer, and the riverbed, the basin in which the water flows, gets wider. The flatness of the land allows the water to freely “explore” its surrounding territory and change its form as it moves around whatever it meets. Sometimes little islands form in this way along rivers, known as fluvial islets.

Longitudinal attributes.

The elevation profile of the ‘‘typical’’ river is concave; in the headwaters, slopes tend to be steeper, while near the mouth of the river, slopes diminish toward the horizontal. River scientists find it useful to divide a river, considered longitudinally, into the zone of erosion, the zone of transport, and the zone of deposition .

The zone of erosion is typically the headwaters of the stream or river and includes the upper part of the watershed and the small, first- and second-order streams that drain it. Headwater streams are typically steep, so flowing water has more energy to move sediment and larger sediment particles. These streams are actively cutting down, often through solid rock, and are likely to feature waterfalls and rapids. They are also likely to have water with relatively high dissolved oxygen levels and low temperatures, facts of great significance to the biota.
Headwater streams are typically characterized by channels whose bottom and sides are primarily bedrock. Because of the energy available in steep slopes for moving sediment, such streams often scour right down to the ‘‘living rock.’’ Such stream channels are relatively straight (lack sinuosity) and have only the beginnings of floodplains, or none at all.

In the transfer zone, rates of deposition and erosion are approximately equal.

This zone corresponds to mid-size (third- through sixth-order) streams. Sediment is moved through, with no net change in elevation or cross-sectional shape of the stream channel. Stream channels in the transfer zone have a mix of features characteristic of the headwater zone and the zone of deposition. Floating down such a river, one might pass over ledges and through rapids formed by relatively durable bedrock, into pools filled with sediment. On one side or the other, one might see well-developed floodplains, though not of great breadth.

In the zone of deposition, sediment is deposited and floodplains are built up.

Even though water velocity may be as great or greater than headwater streams, due to lack of channel roughness, the ability of the river to carry sediment is diminished

The mouth

At the end of its journey the river flows out into the sea.The place where fresh and salt water meet is known as the river mouth or outlet, and this can either take the form of an estuary, or a delta. An estuary is a simple outlet where the water from the river reaches the sea directly. There are no islets or amassments of debris which deviate the last lap of the river because the sea currents are so strong that they all get swept away. A delta outlet is the opposite of an estuary. Here the river can fork off into complex branches, and this is made possible because the sea currents are weak and unable to sweep away the debris that has been formed by the river. Islets may form which make the river fork off into intricate directions.

Following are the major determinants of river habitat type and quality:

- Size of watershed
- Terrain
- Underlying geology of watershed

- Soils of watershed
- Climate
- Terrestrial vegetation
- Discharge amount, timing, and rate of change (flow regime)
- Water quality parameters
- Temperature (average and range of variability)
- Dissolved solids levels
- Light
- Dissolved oxygen levels
- Nutrient availability, particularly of nitrogen (N) and phosphorus (P)
- Turbidity
- Presence and characteristics of pollutants including fine sediments
- Channel substrate, cover, and form
- Condition of the riparian corridor
- Disturbance regime and disturbance history
- Introduced species of plants and animals

Aquatic ecology (Freshwater Ecology) Lect.7

The many functions of a river

A river is an extremely complex environment which carries out fundamental processes in order to maintain environmental equilibrium, with benefits for both the natural world and the human world. Of these benefits, we should begin by stressing the crucial role that aquatic ecosystems play in the depuration of water.

But we should also point out that the capacity a river has for self-depuration is strictly linked to its integrity.

Only a healthily functioning river can effectively combat pollution without compromising its quality at the same time. So, for rivers to keep up their natural capacity for self-depuration, it is vital to protect and strengthen their natural conditions against excessive forms of exploitation and pollution. Now let’s take a look at some of the major tasks rivers perform in more detail.

The best water depurators in the world

Not many people know that rivers have a huge capacity for self -cleansing or depuration, and are actually the best water depurators in existence! A series of chemical and biological processes take place in rivers which can fight various forms of pollution, both of natural or human origin.

Water

Rivers carry water and nutrients to areas all around the earth. They play a very important part in the water cycle, acting as drainage channels for surface water. Rivers drain nearly 75% of the earth's land surface.

Habitats

Rivers provide excellent habitat and food for many of the earth's organisms.

Many rare plants and trees grow by rivers. Ducks, voles, otters and beavers make their homes on the river banks. Reeds and other plants like bulrushes grow along the river banks.
Other animals use the river for food and drink. Birds such as kingfishers eat small fish from the river. In Africa, animals such as antelopes, lions and elephants go to rivers for water to drink. Other animals such as bears catch fish from rivers.

River deltas have many different species of wildlife. Insects, mammals and birds use the delta for their homes and for food.

Transport

Rivers provide travel routes for exploration, commerce and recreation.

Farming

River valleys and plains provide fertile soils. Farmers in dry regions irrigate their cropland using water carried by irrigation ditches from nearby rivers.

Energy

Rivers are an important energy source. During the early industrial era, mills, shops, and factories were built near fast-flowing rivers where water could be used to power machines. Today steep rivers are still used to power hydroelectric plants and their water turbines.

Planform characteristics of rivers.

Looking down at a river reach from above, one of the most striking things is that rivers are not straight. This may be attributed,in part, to the fact that the land surface the river is cutting through is varied. Some parts are easily roded, and others less so; rivers will follow the path of least resistance, and it is unlikely that path will be straight. But even in the absence of such heterogeneity, rivers do not run straight. They are sinuous, and even if forced by engineers into a straight channel, they will work to reestablish heir natural curves.

The factors that make rivers tend toward sinuosity are complex. Slope is one of the channel attributes that rivers can adjust in response to changes in the flow regime or sediment load. For a given flow regime and sediment load, there is an equilibrium slope. Rivers adjust slope by adjusting sinuosity, much like what skiers, snowboarders, and skateboarders do when descending a hill. By weaving back and forth, taking a sinuous line, these athletes increase the length of their downhill run.

The ecology of the river refers to the relationships that living organisms have with each other and with their environment – the ecosystem. An ecosystem is the sum of interactions between plants, animals and microorganisms and between them and non-living physical and chemical components in a particular natural environment.

An ecosystem is the entire spectrum of plants and animals in any one area which depend on each other for their continued survival. The sum of all their interactions is known as an ecosystem. An aquatic ecosystem therefore refers to those interactions which develop among the living creatures of a given climatic, geological and morphological context along a course of water.
We find many different aquatic ecosystems along a river's course, and any interruption or alteration to their composition can cause serious problems indeed.
from fishing to medicines, from wood to a multitude of other natural resources).

River ecosystems have:

River Biota

The same general groups of plants, animals, and other organisms inhabit rivers as wetlands and lakes. Relatively few species are uniquely riverine compared with the large number that inhabit freshwater systems generally. This fact attests to the interconnectedness of freshwater aquatic habitats.

Autotrophs in river systems.

River autotrophs can be classified into three major groups according to their form and physical habitat: periphyton, phytoplankton, and macrophytes. The periphyton and phytoplankton together account for the majority of autotrophic production in most rivers. Where their oncentrations are high, for example, in the Pantanal of Brazil during certain seasons, they can exert significant influence on levels of dissolved oxygenand carbon dioxide through their photosynthesis, respiration, and eventual decomposition.

Sources of energy.

The autotrophic algae described above, along with some photosynthesizing bacteria, are the sources of food energy produced in the stream. Such energy is termed autochthonous energy. Other energy, allochthonous energy, comes from terrestrial plants, as well as from the terrestrial food webs that they support.

Like all green plants, terrestrial producers use solar energy to build carbohydrate molecules that store the sun's energy, which is transformed into proteins, fats, and other molecules in the plant tissues. Stored energy is extracted for use by the plants through the process of respiration.

Decomposers.

Decomposers, strictly speaking, are those organisms that consume dead organic material, breaking it down into an inorganic form. Decomposers in rivers include primarily fungi and bacteria. Together with the detritivores, they are an important link between allochthonous sources of energy and higher trophic levels in the aquatic food web. The detritivores include micro- and macroinvertebrates, as well as a few species of fish and other vertebrates.

Heterotrophs.

Heterotrophs account for all the other trophic levels in the aquatic food web. Heterotrophs that feed on autotrophs or producers are known as primary consumers; heterotrophs that prey on other heterotrophs are known as secondary, tertiary, or higher-level consumers. In aquatic systems, some organisms fit neatly into such a scheme, occupying only one trophic level, while others might feed at several levels. Some macroinvertebrates, amphibians, and fishes move from one trophic level to another at different life stages. Certain crayfish, for example, are herbivores while small and then move toward a more predatory style as they grow older and larger.

Macroinvertebrate Feeding Groups

Macroinvertebrates can be categorized by four feeding groups: grazers, shredders, collectors, and predators.

Grazers. Organisms that feed on a thin layer of organic life, primarily periphyton but including microscopic animals, bacteria, and detritus, that coats underwater surfaces. They typically have mouth parts that enable them to shear, grind, or rasp off attached organic material from submerged surfaces. Examples include water **pennies and snails**.

Shredders. Organisms that feed upon (“coarse particulate organic matter) **CPOM**, primarily leaves. They prefer leaves that have been in the water long enough to have been colonized by fungi and bacteria. Examples include crane flies (Diptera), some stonefly species (Plecoptera), and scuds (order Amphipoda, family Gammaridae).

Some species of true flies (Diptera), beetles (Coleoptera), and caddisflies (Trichoptera) are known as shredder-gougers; these organisms feed on woody CPOM.+

Collectors. Organisms that feed upon (filters particulate organic matter) **FPOM**. Collectors can be further distinguished on the basis of whether they collect FPOM that is suspended in the water (filterer-collector) or that is in sediments that have settled to the bottom. The hydropsychid caddisflies .

Predators. Organisms that feed upon animal prey, primarily other invertebrates but occasionally small amphibians or fishes. Predators typically have mouthparts designed for piercing and biting.Examples include many dragonfly (Odonata) larvae as well as numerous species of dobsonflies (Megaloptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and beetles (Coleoptera).

Fishes, like the invertebrates, have evolved feeding specializations that are reflected in both behavioral repertoires and body parts, for example, jaws, teeth, and digestive system. Indeed, body shape itself has evolved according to feeding preferences in many species. Predators whose specialty is lying in wait and darting out to seize their prey—pike and gar, for example—have highly streamlined, torpedo- like bodies. Some bottom feeders—suckers, for example—have mouths that are oriented downward like vacuum cleaner hoses. Fish that feed on insects floating on the surface have upward-tilting mouths.

Birds

A large number of birds also inhabit river ecosystems, but they are not tied to the water as fish are and spend some of their time in terrestrial habitats. Fish and water invertebrates are an important food source for water birds.

limiting factors in the river environment

Some limiting factors of rivers are the turbidity, temperature, pH level, and dissolved oxygen. All these factor change depending on where you are, while on the river.–

- An example is the water of a river at the end of the river, so there would be less oxygen (one of the limiting factors.) Another example is the
- pH level (acidic level) being too high in some places in the river, that causes some animals to not be able to live there, such as having a low

pH level can be harmful to every organism in the river, excluding bacteria.

- Temperature is a limiting factor by if the temperature is too low, there is less plant life and more fish diseases, making it an inhabitable place for fish.
- Turbidity is how much clay, silt, waste, and sewage is in the water. These materials can absorb sunlight causing the sunlight to hit the lower plants, this causing for a lack of photosynthesis, thus less oxygen. These are four of many limiting factors in rivers.
- The Current

  The speed of water flow will determine the substrate at the bottom of the stream or river. Fast flow will remove all but the heaviest material and send this down stream. If the velocity is extreme then only bedrock will exist. A river in spate occurs at the time of high rainfall. The amount of water will have increased but the channel remains the same: hence it flows faster. As the channel widens there may be sections that have a slower speed and here deposition of material will occur. By the time a river reaches the lowland areas the velocity will have slackened so much that it can become pond-like and here silt and sand are deposited on the bottom allowing rooted plants to become established.

Water flow

Water flow is the main factor that makes river ecology different from other water ecosystems. This is known as a lotic (flowing water) system. The strength of water flow varies from torrential rapids to slow backwaters. The speed of water also varies and is subject to chaotic turbulence. Flow can be affected by sudden water input from snowmelt, rain and groundwater. Water flow can alter the shape of riverbeds through erosion and sedimentation, creating a variety of changing habitats

Substrate

The substrate is the surface on which the river organisms live. It may be inorganic, consisting of geological material from the catchment area such as boulders, pebbles, gravel, sand or silt, or it may be organic, including fine particles, leaves, wood, moss and plants. Substrate is generally not permanent and is subject to large changes during flooding events.

Light

Light provides energy for photosynthesis, which produces the primary food source for the river. It also provides refuges for prey species in the shadows it casts. The amount of light received in a flowing waterway is variable, for example, depending on whether it’s a stream within a forest shaded by overhanging trees or a wide exposed river where the Sun has open access to its surface. Deep rivers tend to be more turbulent, and particles in the water increasingly weaken light penetration as depth increases.

Temperature

Water temperature in rivers varies with the environment. Water can be heated or cooled through radiation at the surface and conduction to or from the air and surrounding substrate. Temperature differences can be significant between the surface and the bottom of deep, slow-moving rivers. Climate, shading and elevation all affect water temperature. Species living in these environments are called poikilotherms – their internal temperature varies to suit their environmental conditions.

Water chemistry

The chemistry of the water varies from one river ecosystem to another. It is often determined by inputs from the surrounding environment or catchment area but can also be influenced by rain and the addition of pollution from human sources.

Oxygen

Oxygen is the most important chemical constituent of river systems – most organisms need it for survival. It enters the water mostly at the surface, but its solubility decreases as the water temperature increases. Fast, turbulent waters expose a wider water surface to the air and tend to have lower temperatures – achieving more oxygen input than slow backwaters. Oxygen is limited if water circulation is poor, animal activity is high or if there is a large amount of organic decay in the waterway.

Bacteria

Bacteria are present in large numbers in river waters. They play a significant role in energy recycling. Bacteria decompose organic material into inorganic compounds that can be used by plants and by other microbes.

Plants

A variety of plants can be found growing within a river system. Some plants are free-floating while others are rooted in areas of reduced current.

Plants photosynthesise – converting light energy from the Sun into chemical energy that can be used to fuel organisms' activities.

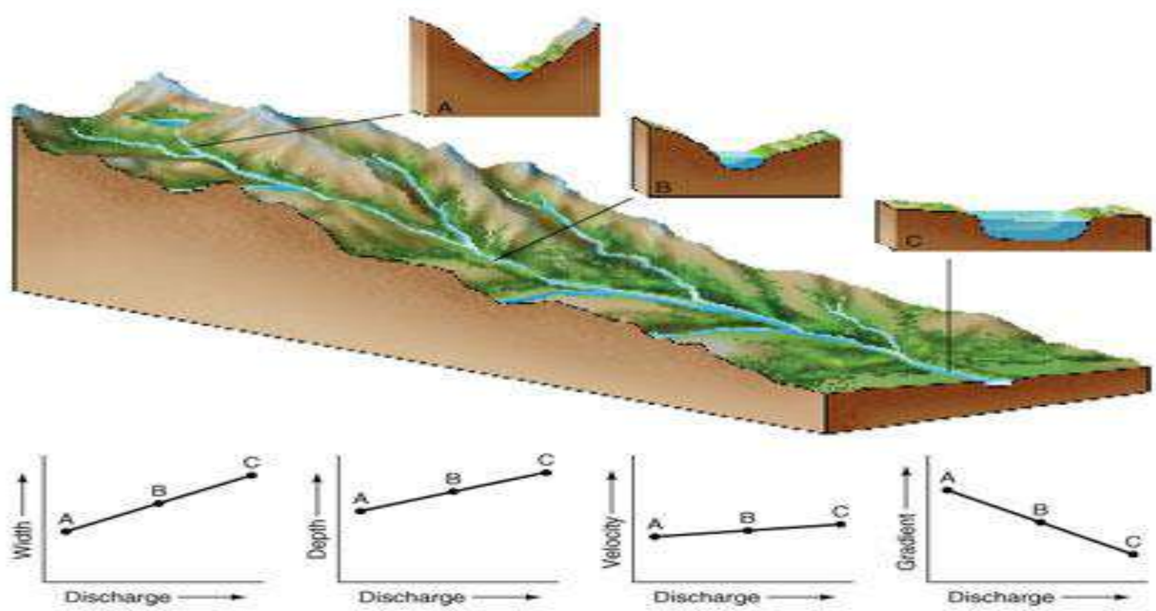
Algae are the most significant source of primary food in most rivers or streams. Most float freely and are therefore unable to maintain large populations in fast-flowing water. They build up large numbers in slow-moving rivers or backwaters. Some algae species attach themselves to objects to avoid being washed away.

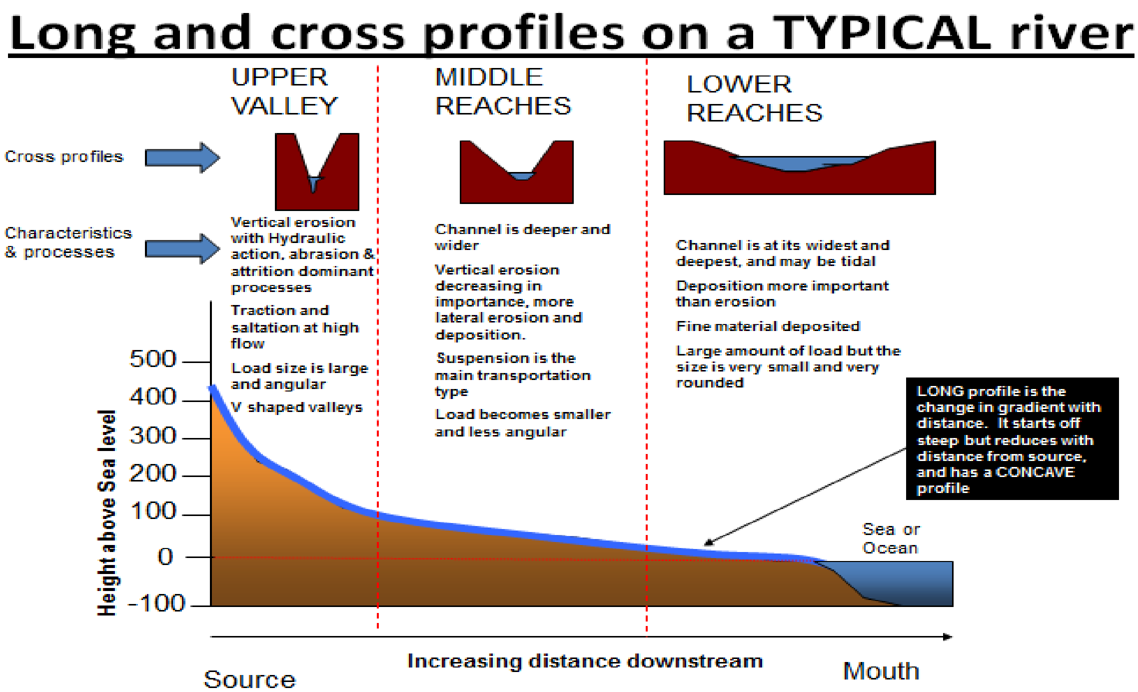
Plants are most successful in slower currents. Some plants such as mosses attach themselves to solid objects. Some plants are free-floating such as duckweed or water hyacinth. Others are rooted in areas of reduced current where sediment is found. Water currents provide oxygen and nutrients for plants. Plants protect animals from the current and predators and provide a food source.

Invertebrates

Invertebrates have no backbone or spinal column and include crayfish, snails, limpets, clams and mussels found in rivers. A large number of the invertebrates in river systems are insects. They can be found in almost every available habitat – on the water surface, on and under stones, in or below the substrate or adrift in the current. Some avoid high currents by living in the substrate area, while others have adapted by living on the sheltered downstream side of rocks. Invertebrates rely on the current to bring them food and oxygen. They are both consumers and prey in river systems.

Longitudinal Profile and Profile Development





Types of rivers

Permanent Rivers

Permanent Rivers have water all year round.

Periodic Rivers

Rivers that run dry on occasion, usually located in arid climates where evaporation is greater than precipitation.

Episodic Rivers

Rarely occurring rivers formed from run-off channels in very dry regions.

Exotic Rivers

These are rivers that flow through arid (desert) regions.

A long narrow channel of water that flows as a function of gravity and elevation across the Earth's surface. Many rivers empty into lakes, seas, or oceans.

Iraq map showing the most important internal water sources

Lakes and Reservoirs

Introduction

Lakes, ponds, and reservoirs are bodies of water characterized by relatively deep, open water that is without, or nearly without, current. There is no universally accepted, scientifically based distinction between lakes and ponds, but ponds are small and lakes are large. Since they are ecologically similar to small lakes, ponds will be subsumed under the discussion of lakes.

Reservoirs, or impoundments, are manmade lakes. In many regions of the world, they outnumber natural lakes. Reservoirs are, with some exceptions, lentic (nonflowing) bodies of water created by the building of a dam on a river. Ecologically they are quite similar to natural lakes of like proportions, except that their hydrology is subject to considerable human manipulation. They will be discussed separately from lakes.

A lake (from Latin lacus) is a large body of water (larger and deeper than a pond) within a body of land. As a lake is separated from the ocean, it is not a sea. Some lakes are very big, and people in the past sometimes called them seas. Lakes do not flow, like rivers, but many have rivers flowing into and out of them.

Composition of the lake:

There are several ways in which lakes can be formed and these methods depend on how the lake basin is formed:

- Some basins formed as a result of the movement of crust or volcanic activity or activity refrigerators.
- Others are caused by landslides or by living organisms or the dense growth of high-end aquatic plants that obscure water in a given area of the valley.

The form of the lake depends on the way in which the basins is.

1- Circular ponds are lakes of volcanic origin,
2- Semi-circular basins are lakes of origin dating back to the Ice Age,
3- Lakes with semi-slanted basins formed due to the movement of the earth's crust
4- The crescent basins formed by streams and rivers.
5- Sometimes there are external factors that affect the shape of the lake such as dams and canals

Ways to Classify Lakes

There are a number of ways to classify lakes. They can be classified according to their **origins**, their **nutrient status**, their **mixing system**, **their ecoregional setting**,**their size and shape** (whether they are on balance autotrophic or heterotrophic),**and their degree of human impact.**

Classification of lakes

The lakes are divided according to the quantity of organic matter:

`1- Low organic matter lakes(**Oligotrophic Lake): -**

- This type of lake lacks living organisms relative to the body of the lake.
- Excess of oxygen in the lower layers due to lack of living.
- Be deep and the beach area is small.
- Food resources are low (Ca, N, P).
- In the summer the lower layer is cool layer (Hyplimnion) and the upper part warm layer (Epilimnion)and separated these two layers are a third layer called Metalimnion

2 - Lakes rich in organic substances(**Eutrophic Lake**): -

- Contains a large amount of biomass.
- Shall be shallow and have large beaches.
- The lower area of the lake is deeper than the upper region, the concentration of oxygen in the summer decreases in the lower layer where oxidation process is used for organic matter at the bottom.

3- Mesotrophic lakes: -

- This type of lake has intermediate characteristics between the two previous lakes.
-

4- Dystrophic lakes: -

- They are found in mountain areas and marshy areas.
- Rich in organic matter.

- Contains high concentrations of Humic Acid.
- The amount of humus is great.
- Water is brown.
- PH concentration is low.
- The process of organic analysis is low because of the lack of concentration of Ca, which causes the accumulation of organic matter and the lack of dissolved food.

Classification by Sources of Nutrient

Autotrophic and Heterotrophic Lakes

Lakes are called autotrophic if their food webs are based primarily on plant production in the lake, and heterotrophic if the greater part of energy available to their food webs is from organicmaterial supplied to the lake from terrestrial sources. The terrestrial

organic material may take the form of leaves and pine needles; excreta from terrestrial animals; seeds, fruits, and pollen; and dissolved organic compounds from organic material in the soils. In autotrophic lakes, the amount of carbon stored through photosynthesis is greater than that used by the lake biotic community in respiration.

In heterotrophic lakes, the greater part of food energy that moves through the lake food web comes from the decomposers, which make organic material of terrestrial origin available to the lake food web. In the net-heterotrophic lake, more energy is used in respiration than is produced in photosynthesis in the lake. Taken together, the world’s lakes are heterotrophic, putting more carbon dioxide into the atmosphere via respiration than they remove via photosynthesis.

Classification Based on Mixing

Lakes are sometimes classified according to how often their waters Mixing often takes place as a result of wind, and therefore is often seasonal. In the temperate regions, windy conditions are usually associated with spring and fall, while summer is a time when wind is lacking. Mixing is also a function of seasonality in that the warming (in spring and summer) and the cooling (in fall and winter) of the top layer of water make it the same density as the bottom layer on more thanare mixed.

one occasion during the course of the year, and mixing can then occur. Finally, the size and shape of the lake also contribute to its mixing regime: large, shallow lakes are more subject to the influence of the wind than small, deep lakes .

Different lakes have different mixing regimes, since the variables that influence mixing—climate, size, and shape—are different for different lakes.

The categories of lakes according to their mixing regime are as follows:

- **Monomictic**: lakes that mix from top to bottom once a year, usually for a relatively brief period
- **Dimictic**: lakes that mix from top to bottom twice a year (common in temperate-zone lakes), once in the spring, once in the fall
- **Polymictic**: lakes that stratify and then mix a number of times each year
- **Oligomictic**: lakes that rarely if ever mix; such lakes are common in the tropics

- **Meromictic**: lakes that may mix in the upper layers but have a bottom layer that rarely if ever mixes, partly because of its low temperature and therefore high density and partly because of its higher concentrations of dissolved solids (which also increase density).

Static water(lentic water)

Water is static both lakes and ponds

Different lakes for ponds:

- Lakes largest area of ponds.
- Lakes more capacity.
- The offshore area is larger than the shore area and vice versa for the ponds. The offshore area is more important in terms of productivity for the lakes and the coastal area, more important in terms of productivity for the ponds.
- There is a temperature regulation in some seasons of the year in the lakes, but in ponds the movement of water prevents this synthesis.

Aquatic ecology (Freshwater Ecology) Lect.9

Al-Tharthar lake

The Al-Tharthar lake is located in Iraq north-west of Tikrit and northern Anbar province; one of the largest natural depressions in Iraq.

Since 1956, it has been used to store surplus water of the Tigris during the flood days by means of a diversion channel that begins at the Samarra dam at the city of Samarra, which was established in 1955, and later linked to the Tigris and Euphrates Rivers, so that sufficient amounts of irrigation water can be returned to the rivers this was needed in summer.

Sawa lake

Sawa is a closed salt lake located in the Iraqi province of Muthanna near the river Euphrates, 23 km west of the city of Samawah. The lake belongs to the Sea of Sawa rivers flowed or graduated from them but are supplied with groundwater from under the lake, which filtered from the Euphrates through cracks and cracks.

Habbaniya Lake

The site is located south of Ramadi and it can be accessed via from south of Ramadi via the road toward Al-Angoor village.

Plants & Habitats: No botanical survey was conducted at the site but species of Phragmites sp., Typha sp, Achillea sp, Artemeisia sp, Acacia sp and Alhagi sp were the most widely distributed plants.

Conservation Issues: It appeared that water shortages are causing an increase in salinity. Water stagnation and quality appears also to be an issue in some parts of the lake, so increasing water flow may be important.

The Habbaniya tourism village is considered to be the main human factor that highly impacts the

environment especially as the survey team witnessed new efforts at rehabilitation of the area by the Anbar authorities during 2011. Summer sees the highest number of visitors and the most serious impact to the site, with large quantities of solid waste such as cans, plastic containers and bags left behind, which spread rapidly throughout the site and are carried by water currents to the lake edges. Several small villages on the southern and eastern edges of the lake deposit sewage and other waste into the lake. Hunting and trapping of wildlife especially for the large mammals, game birds, and raptors such as Saker Falcon and Peregrine Falcon during winter is another high threat (Al-Sheikhly, 2012).

Land near Habbaniya is also used as an air force base. The frequent training flights result in widespread noise pollution and other environmental impacts sufficient to disturb and harm both resident and migrant species.

Agricultural expansion represented by small annual crop farms is limited and restricted to the northern and northwestern edge of the site, but was evaluated as a medium threat. A few villages and urban areas at the western edge of the site near Al-Angoor were also considered a medium threat. Other impacts such as energy production, mining, transportation and service corridors were rated as low threats.

Recommendations: Water quality studies are essential to determine the lake’s viability for supporting human and animal life. Surveys with a focus on non-avian species are highly recommended. More strict and modern methods for the control and management of solid waste and sewage are urgently needed. Enforcing Iraq's current hunting laws and raising the scientific awareness among local hunters and fishermen in cooperation with local hunting groups or association in Anbar should reduce the potential for declines in the wintering

raptors and other wildlife. Additional fisheries surveys are also needed.

Razzaza Lake

Site Description: In Evans (1994), this area is listed as "Bahr Al Milh" (IBA021) but it is more commonly referred to as Razzaza Lake.

Evans states that the lake was formed in the 1970s as a storage reservoir to control floods on the Euphrates. It is connected to Habbaniya Lake in the north by a narrow canal running through semi-desert, called Sin Al-Thibban Canal. Razzaza used to be a large, deep lake, but it has shrunk in size and is now characterized by very high salinity levels, which has increased during the past ten years due to the shortage of water and evaporation during Iraq's very dry, hot summers. Locals report that the lake is likely now only 5–10 m deep. The extensive shrinkage of the lake is graphically seen in the two satellite images taken in 2000 and 2013 (see below). These are not seasonal changes but are based on management and water allocation to Razazza via the Sin AlThibban Canal from Habbaniya Lake. The delineated map above

is based on the recent historical extent of the lake, which the lake would likely return to if more water is dedicated to the area.

Islands in the lake provide breeding areas for gulls and potential breeding ground for Greater Flamingo. By the last KBA Survey in 2010, the lake still seriously lacked water and most of the birds were found concentrated in the area of the sole source of water that brings sewage from Karbala. The Sin Al-Thibban Canal (that brings water from Habbaniya) was still closed by the Anbar government. The geology of the area is marls, siltstone, gypsum/

anhydrite, and limestone bands, mainly silts. Though there is little to no plant life on the lake itself and most plants are near the seasonal drainages and canals that bring sewage water to the lake, the main plants found include beds of Phragmites australis, Juncus acutus, Aeluropus lagapoides, Salicornia herbacea, andSchoenoplectus littoralis and there are desert shrublands with plants such as Tamarix aucherana, T. macrocarpa, Prosopis farcta, Zygophyllum fabago, Nitraria retusa, and Haloxylon salicornicum.

Two main towns lie close to the lake: Ain Al-Tamr (to the southwest) and Al-Rahaliya (west). The area west of Ain Al-Tamr was part of the survey area. There are many date farms on the west edge of the site (all depending on well and rainwater) but the area to the south and east is shrublands. A paved road passes through the site. Al-Rahaliya, a small town situated near

the western bank of the lake, is near a saline shallow-water area. The semi-desert areas around this features xerophytes and halophytes but also contains recently planted date palm trees and orchards near the town. Al-Taar area is a depression in the desert to the west of Karbala and south of the lake that collects rainwater from the relatively higher lands to the south and west. Four sub-sites were surveyed at Razzaza Lake.

In Iraq, there are many tanks like

1- Al-Qadisiyah Dam Reservoir (Haditha Dam)

2- Hamrin Dam Reservoir

3- Dukan Dam Reservoir

4- Derbandikhan Dam Reservoir

5- Dibs Dam Reservoir

6- Mosul Dam Reservoir and others

Aquatic ecology (Freshwater Ecology) Lect.10

Introduction to the Wetland

What is wetlands

Defines wetlands as ‘‘lands transitional between terrestrial and aquatic systems where the ground water is usually at or near the surface or the land is covered by shallow water.

In 1971, at a meeting in Ramsar, Iran, most of the world’s industrial countries and a large number of developing countries agreed that wetlands were valuable environmental assets that should be protected. By 2006, 153 countries had agreed to the principles of the Ramsar Convention, as it is now known; and many countries,including the United States

This international consensus that wetlands are worthy of protection represents a complete turnaround from the attitude toward wetlands most people held for hundreds of years:

- Where people had a long-held belief that that **wetlands** were, at best, wild places, uninhabited obstacles to human progress; at worst, they were waste places harboring disease. Before it was discovered that microorganisms caused infectious diseases, many scientists believed that ‘‘miasmas’’—poisonous airs arising in swamps—caused the terrible diseases (typhoid and cholera among others) that killed millions of people every year.

- Therefore, in the absence of government regulation, many property owners choose to destroy wetlands and use the land for agriculture or urban development. As a result, the loss of wetlands continues, perhaps at a slower pace than before the 1970s.

-

Extent and Geographic Distribution of Wetlands

Wetlands are found in every geographic setting, on every continent except Antarctica.There are wetlands in the desert, wetlands in the Arctic, wetlands in the rainforest,and wetlands in the most densely populated regions. Estimates of the global extent of wetlands vary greatly, from 3.3 to about 8 million mi2 (5.3 to 12.8 million km2), which equates to between 3.5 and 8.5 percent of a total land surface area of about 93 million mi2 (150 million km2). At first glance, one might think that the global extent of wetlands was a well-known fact, but this is not the case. While it is true that the entire surface of the Earth can be and is viewed, photographed, and analyzed via Earth-orbiting satellites, it is not easy to distinguish precisely wetlands from other lands based on remotely sensed data. National and regional geospatial data sets and wetlands inventories are of inconsistent quality and definitions vary.

Wetland Characteristics

1- Water

The movement, distribution, and quality of water is the primary factor influencing wetland structure and function. To be classified as a wetland, the presence of water must contribute to the formation of hydric soils, which are formed under flooded or saturated conditions persisting long enough for the development of anaerobic conditions during the growing season . Water conditions in wetlands can vary tremendously with respect to the timing and duration of surface water inundation as well as seasonal patterns of inundation.

1- The health or condition of wetlands and associated vegetation communities can be negatively impacted by increasing salinity, sedimentation, pollution, removal and destruction of wetland habitat, and altered wetting regimes. These threatening processes can impact on the fauna directly, through toxic effects, or indirectly, including by the loss of suitable breeding, sheltering and feeding sites and isolation of populations due to loss of water connectivity, particularly between floodplain wetlands and their adjacent river system. These impacts and threats can result in a loss of aquatic biodiversity from these systems. Restoration of aquatic habitats aims to return these systems back to a natural state and minimise threats. By measuring the condition of aquatic systems we can establish the severity of detrimental impacts and threats and develop strategies for restoration efforts.

2- Flooding can affect the physiochemistry of wetlands in various ways. Water can introduce or remove sediment, salt, nutrients or other materials from wetlands, thereby influencing its soil and water chemistry. Hydrology also influences the structure and function of wetland ecosystems through its influence on species richness, productivity, rates of organic matter accumulation, and nutrient cycling. Hydrology may restrict species richness in areas subject to long-term flooding while enhancing it in areas with variable or pulsing hydroperiods.

3- Oxygen Availability

The inundation or saturation of wetland soils by water leads to the formation of anaerobic conditions as oxygen is depleted faster than it can be replaced by diffusion. The rate of oxygen loss in flooded soils can vary depending on other soil conditions, such as temperature and rates of microbial respiration. In most wetlands, small, oxidized layers of soils may persist on the surface or around the roots of vascular plants, but generally, anaerobic, or reduced, conditions prevail.

2- Soils

Wetlands are characterized by soils known as hydric soils. The U.S. Department of Agriculture, Natural Resources Conservation Service, defines hydric soils as soils ‘‘that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part.’’These ‘‘anaerobic conditions’’ refer to a lack of oxygen caused by saturation with water.

Wetland soils are classified as either organic or mineral. Organic soils have a high proportion (greater than a third) of organic material. Compared with mineral soils, their ability to hold water.

Organic wetland soils are divided by soil scientists into three groups, the

fibrists (peat), the hemists (peaty muck), and the saprists (muck) (see Table 1). Mineral soils have less than one-third organic content. They hold less waterthan organic soils and also have relatively low permeability. Because water cannotmove through them readily, anoxic conditions develop fairly rapidly upon saturation and persist.,

Table 1 : - Hydric Organic Soil Characteristics

No.	ORGANIC SOIL TYPE	COLOR	CHARACTERISTICS
	Fibrists (peat soils); Soil Order Histosol	Brown to black	Wet histosols in which organic materials are only slightly decomposed. Plant material recognizable; low bulk density; greatest ability to hold water like a sponge porosity)
2	Saprists (muck soils); Soil Order Histosol	Black	Wet histosols in which organic materials are well decomposed. Will stain fingers when moist; runny when wet; may have ‘‘rotten’’ odor; few if any plant fibers recognizable; higher bulk density; lower porosity
3	Hemists (mucky peats); Soil Order Histosol	Brown to black	Wet histosols in which organic materials are moderately decomposed; all characteristics are intermediate between those of the Fibrists and Saprists, the Hemists representing a state of decomposition greater than Fibrists but less complete than Saprists

3-Vegetation

Plants that are found in wetlands are either obligate (plants that only grow in a wetland environment) or facultative (plants that can grow in wetlands but can also thrive in other environments). Obligate wetland plants occur in wetlands 99 percent of the time and only 1 percent are found outside wetlands, whereas facultative wetland plants are found in wetlands 67–99 percent of the time. Obligate wetland plantsare used as wetlands indicators—plants whose presence indicates the existence of wetland conditions with a high degree of confidence.Wetland plants have a number

of adaptations that enable them to live in wetlands; these adaptations are discussedin the section ''Life in aWetland,'' below. It is not possible to present a general list of ''typical'' wetland plants, as the plant communities differ considerably depending on the type of wetland and other factors. For example, marshes are dominated by herbaceous emergent vegetation adapted to conditions of frequent or continuous inundation.

Life in a Wetland

Wetlands as living environments present many challenges to organisms, necessitating various adaptations. The main challenges are conditions of low or no oxygen (anaerobic conditions); fluctuating water levels so that, in the extreme, plants, animals,and microorganisms must be able to survive extended inundation and extended periods of dry conditions; the presence of phytotoxic concentrations of substances resulting from biochemical transformations caused by anaerobic conditions; and the presence of salt in marine or estuarine wetlands.

Microorganisms

The adaptations of bacteria and protists to freshwater wetland conditions are complex and various. They primarily involve adaptations of cellular biochemistry that allow the organisms to respire and engage in cellular metabolism without using oxygen.

Anaerobic bacteria have developed mechanisms at the subcellular level that allow them to deal with the toxic end products—such as lactic acid—of anaerobic metabolism, either by detoxifying these substances or expelling them. They are able to use reduced organic compounds in wetlands soils as a source of energy and also can use inorganic soil elements in place of oxygen as electron receptors. Facultative anaerobic bacteria are able to switch from using oxygen as an electron receptor to using these other elements. Obligate anaerobic bacteria use sulfate and are responsible for the production of hydrogen sulfide, the gas whose odor is sometimes associated with wetlands (the ‘‘rotten egg’’ smell).

and metabolic changes are similar to those seen in one-celled organisms.

plants are also able to grow special structures and change their morphology (growthform) in ways that allow them to survive in low-oxygen environments. For emergent wetland plants—plants that are rooted in saturated substrates but have most of their growth above water—the problem is confined to their roots, which must have oxygen to function. If the roots do not function, they cannot pull water or nutrients up into the leaves, and the plants die.

The development of aerenchyma, spongy or cork-like tissue that consists of relatively large intercellular voids or spaces, allows oxygenated air to diffuse to the roots from above-water parts of the plant. Some plants, such as some alders (for example, the speckled alder and European alder), develop aerenchyma only in response to anaerobic conditions; if they are growing in an upland environment,they will not do so. Often special structures (for example, pneumatophores or ‘‘air roots’’) contain the aerenchyma.

The transfer of oxygen to the roots of wetland plants results in excess oxygen being given off by the roots and creating an aerobic soil microenvironment around the roots. This well-oxygenated film permits the development of mycorrhizae,symbiotic associations between plant root hairs and certain fungi, that allow for more effective root functioning on the part of the plant and are an adaptation allowing plants to live in wetlands environments. The oxygenated zone is responsible for the reddish-colored deposits of iron oxide that characterize hydric soils and allows for the oxidization of sulfides and reduced metal ions that renders them nontoxic to plants.

Wetland plants have developed what might be termed behavioral adaptations.

Wetland Animals

The enormous variety—geomorphic, hydrologic, ecoregional—of habitats included in the term ‘‘wetlands’’ precludes the easy listing of wetland species.

Invertebrates. In wetlands, insects are common and include many of the taxa that live in other freshwater environments. Their aquatic larvae are important links in detrital food chains in marshes and swamps, feeding fish, amphibians,and birds. Mosquitoes (members of order **Diptera**) and dragonflies and damselflies (order **Odonata**) are well-known wetland insects. Species of both taxa have adapted to all kinds of wetlands and are widely distributed.

Vertebrates. Amphibians are, perhaps more than any other group of animals, associated in the popular mind with wetlands. Wetland examples include frogs, toads salamanders, and newts.

Reptiles are rightly associated with wetlands in the popular imagination. While relatively few reptiles are obliged to live in water, many spend much or most of their lives in freshwater environments. Members of the order **Crocodilia** inhabit wetlands, lakes, and rivers in Africa, the Americas, southern and east Asia, and Australasia. Today’s crocodilians—crocodiles, alligators, and caimans—are not much changed since their ancestors in the Cretaceous period (about 84 million years ago). Turtles and snakes are often found in wetlands, particularly in temperate and tropical regions.

Snakes are the most common reptiles in wetlands

Fishes are present in most freshwater wetlands. Fringe and riverine wetlandsshare many species with the lakes and rivers to which they are connected, and often serve as ''nursery habitat'' for fish species that live in open water as adults. Isolated wetlands, such as prairie potholes, may not have any fish or only introduced fish.

Wetlands are home to many **birds**; their invertebrate populations provide afood source of great importance even to terrestrial birds. The association of waterfowl with wetlands is well founded; ducks, geese, and coots all prefer to inhabit wetlands. Certain birds are emblematic of particular wetlands. For example, the Jabiru Stork has come to symbolize the Pantanal, while the Caribbean Flamingo is associated with the Florida Everglades.

The abundance of food in wetlands, ranging from grasses to insects, **amphibians**, and nesting birds, attracts many terrestrial **mammals**. Most **mammals** are frequent visitors to wetlands, but relatively few are lifelong inhabitants. Typical residents include otters, muskrat, nutria, beaver, mink, raccoon, swamp rabbit,marsh rice rat, hippopotamus, and water buffalo. Many wetland mammals are herbivores or omnivores.

Common Human Impacts on Wetlands

Common human impacts on wetlands include hydrologic alteration, pollution, disturbance, and fragmentation.

Hydrologic Alteration

- Stabilization of water levels can reduce or eliminate disturbance (flood pulse) required to maintain the system; often a consequence of dam operations, particularly those aimed at flood control.

- Increased water levels or lengthened hydroperiod; may be caused by impoundments or land subsidence resulting from oil and gas extraction.

- Decreased water levels or shortened hydroperiod; typically caused by drainage, often by ditching for agriculture, or by increased water extraction.

- Decreased water levels caused by elevating ground surface, that is, filling in wetlands.

Pollution

- Increased siltation from land-disturbing activities in the watershed.

- Nutrient enrichment from point or nonpoint sources, or from atmospheric deposition.

- Increased levels of toxic substances, such as metals or pesticides.

Disturbance

- Setting fires, or suppressing fires in systems requiring periodic fires.

- Off-road vehicle use.

- Introduction of invasive exotic species, such as common reed or nutria.

- Removal of species through hunting or poaching, leading to cascading alterations of trophic relationships, species composition, and even physical habitat as in the case of beavers.

Fragmentation

- Construction of roads, canals, drainage ditches, and levees that interrupt hydrologic processes and block species movement and dispersal.

Main Marshes

Central Marshes

The Central Marshes receive water from influxes of the Tigris's distributaries, namely the Shatt al-Muminah and Majar-al-Kabir south of Amarah. The Tigris serves as the marshes' eastern boundary while the Euphrates serves as its southern boundary.

Covering an area of 3,000 km2 (1,200 sq mi), the marshes consist of reed beds and several permanent lakes including Umm al Binni lake. The Al-Zikri and Hawr Umm Al-Binni lakes are two of the notable lakes and are 3 m (9.8 ft) deep.

Hammar Marshes

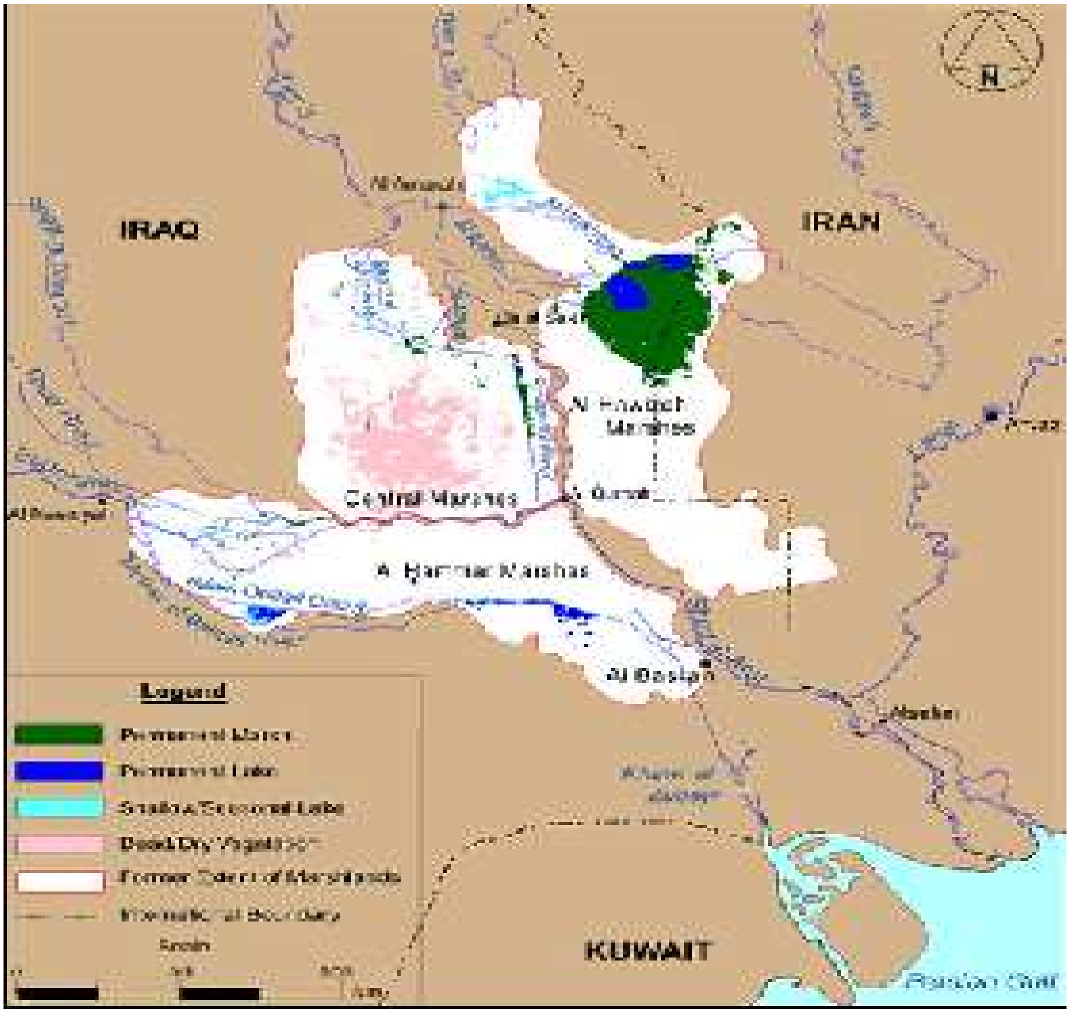
The Hammar Marshes is primarily fed by the Euphrates and lies south of it with a western extent to Nasiriyah, eastern border of the Shatt al-Arab and southern extent of Basrah. Normally, the marshes are a 2,800 km2 (1,100 sq mi) area of permanent marsh and lake but during period of flooding can extend to 4,500 km2 (1,700 sq mi). In periods of flooding, water from the Central Marsh, fed by the Tigris can overflow and supply the marshes with water. Hammar Lake is the largest water body within the marsh and has an area of 120 km (75 mi) by 250 km (160 mi), with depths ranging between1.8 m (5.9 ft)-3 m (9.8 ft). In the summer, large portion of the marshes' and lake's shore are exposed, revealing islands that are used for agriculture.[7]

Hawizeh Marshes

The Hawizeh Marshes lie east of the Tigris and a portion lie in Iran. The Iranian side of the marshes, known as Hawr Al-Azim, is fed by the Karkheh River, while the Tigris distributaries Al-Musharrah and Al-Kahla supply the Iraqi side, only with much less water than the Karkheh. During spring flooding, the Tigris may directly flow into the marshes. The marshes are drained by the Al-

Kassarah. This river plays a critical role in maintaining the Al-Hawizeh marshes as a flow-through system and preventing it from becoming a closed saline basin.

The marshes are 80 km (50 mi) from north to south and about 30 km (19 mi) from east to west, covering a total area of 3,000 km2 (1,200 sq mi). Permanent portions of the marshes include the northern and central portion while the southern part is generally seasonal. Moderately dense vegetation can be found in the permanent areas along with large 6 m (20 ft)-deep lakes in the northern portions.[7] As the Hawizeh Marshes fared the best during the draining, they can facilitate the reproduction of flora, fauna and other species in Central and Hammar marshes.[8]



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