**CHAPTER ONE**

1. **INTRODUCTION TO AQUATIC AND WETLAND MANAGEMENT**

**WHAT IS AQUATIC ENVIRONMENT?**

These are ecosystems that occupy the largest part of the biosphere and are covered with water. Water is the essential substance of life and the dominant component of all living organisms. About 75–95 percent of the weight of all living cells is water, and there is hardly a physiological process in which water is not fundamentally important.

The largest proportion, about 75 %, of the Earth’s surface is covered by water. Marine ecosystems cover approximately 71 % of the Earth's surface and constitute about 97 % of the planet's water. The inland aquatic ecosystems, in contrast, account only for smaller proportion covering about 0.8 % of the Earth’s surface and constituting 3 % of its total water. About 68.7 % of this is either frozen in glaciers and ice and 30.1 % is buried in aquifers as groundwater. The remainder is found as surface waters (in lakes, ponds, rivers, and streams) and as moisture. Lakes constitute the largest proportion (87%) of the surface waters.



Figure: Distribution of Earth’s Water

Aquatic ecosystems are composed of biotic communities (also called biota) and a biotic environmental factor, which form a self-regulating and self-sustaining unit.

* The biotic components of aquatic ecosystems are **either autotrophic or heterotrophic**.
* Abiotic environmental factors of aquatic ecosystems include: -
	+ Amount of dissolved oxygen (DO),
	+ Temperature,
	+ Amount of light,
	+ Salinity and pH,
	+ Nutrients such as nitrogen (in the form of mainly nitrates) and
	+ Phosphorus (in the form of phosphates).
* The amount of dissolved oxygen in a water body is frequently the key substance in determining the extent and kinds of organic life in the waterbody. Fish need dissolved oxygen to survive. Conversely, oxygen is fatal to many kinds of anaerobic bacteria.
* The salinity of the water body is also a determining factor in the kinds of species found in the water body. Organisms in marine ecosystems tolerate salinity, while many freshwater organisms are intolerant of salt. Freshwater used for irrigation purposes often absorb levels of salt that are harmful to freshwater organisms. A major feature influencing the adaptations of organisms that inhabit aquatic environments is **water salinity**.
* For this reason, aquatic ecosystems are divided into **two major categories**: saltwater (or marine) and freshwater.

**1.1. INLAND AQUATIC ECOSYSTEMS (LENTIC, LOTIC WATERS, WETLANDS)**

They are an aquatic environment with salt concentration of < 3 gm/l or 3 parts per thousand (ppt.),

* These inland water bodies are closely linked to soils and biotic components of terrestrial biomes through which they pass and are influenced by patterns and speed of water flow and climate of area in which its located. The freshwater ecosystems generate nearly 3 % of net primary production and contain 41% of the world's known fish species.
* There are two categories of freshwater biomes
1. **Standing (lentic) bodies** of water which include lakes, ponds and inland wetlands; and
2. **Moving (lotic) bodies** of water which include rivers and streams. Lotic ecosystems move continuously in one direction. The structure of lotic ecosystems changes from their point of origin (headwaters) to where they empty into a larger body of water (mouth).

**At the head waters, the water:**

* Is cold and clear
* Carries little sediment
* Has few mineral nutrients
* The channel is narrow with a rocky substrate
* The water flows turbulently
* Near the mouth, the water:
* Moves slowly and is more turbid due to sediment entering from other streams and erosion
* The nutrient content is also higher
* The channel is usually wider with a silty substrate that has resulted from deposition of silt.
1. **Lakes**

They are large, natural bodies of standing water which could be fresh or saline. They are formed when precipitation, runoff, groundwater seepage fills depressions in earth’s surface. These depressions can be formed by

* glaciation (E.g. Great Lakes, NA)
* tectonic or crustal displacement (E.g. Lake Victoria, East Africa; Lake Baikal, Russia; Rift valley lakes)
* volcanic activity (E.g. Bishoftu crater lakes)
* Lakes could have different shapes (morphometry) depending on how they were formed and how geological processes have modified them. Large lakes may have many characteristics similar to oceans, such as a large pelagial (open water) region, deep depth, an extensive bottom area (benthic region), etc.
* This is a water ecosystem that provides many vital environmental functions both to human being and other organisms. For example:
	+ They are important in nutrient recycling, flood attenuation and habitat provision to wildlife (biodiversity).
	+ The largest proportion of rainfall comes from evaporation of waterbodies.
	+ They are also used for human recreation, and are very important to tourism industry, especially in coastal regions.
* **LAKES ARE OFTEN CLASSIFIED AS:**

Oligotrophic, Mesotrophic and Eutrophic classes based on the level of productivity or amount of organic matter produced. Trophic status of a lake thus, reflects the productivity level of a lake.

* **OLIGOTROPHIC LAKES**: are often deep, nutrient-poor lakes in which the Phytoplankton is not very productive. In oligotrophic lakes the water is usually clear and the profundal (bottom) zone has high oxygen concentration since little detritus is produced in the limnetic (upper) zone to be decomposed.
* **MESOTROPHIC LAKES**: lakes having moderate productivity level
* **EUTROPHIC LAKES**: are shallow, nutrient-rich lakes with very productive phytoplankton. The eutrophic waters are usually murky due to large phytoplankton populations and the large amounts of detritus being decomposed may result in oxygen depletion in the profundal zone.

Human activities increase the nutrient content of runoff through:

* Lawn and agricultural fertilizers
* Municipal wastes

These activities enrich lakes with the nitrogen and phosphorus concentrations which in turn increases phytoplankton and plant growth. Algal blooms and increased plant growth results in more detritus and can lead to oxygen depletion due to increased decomposition.

1. **Rivers and streams**

These are bodies of water moving continuously in one direction (have current). The flow can originate from two sources:

* downward flow of surface water and
* groundwater flow from mountain highland to lower elevations.
* Rivers with rough and shallow bottoms produce turbulent flow known as **riffles**. In contrast, rivers with smooth and deep bottoms result in a slower, smooth flow called **pools**.
* Nutrient content of the water is higher in streams and rivers flowing through densely vegetated regions due to leaves and other vegetation entering the water adding organic matter and where erosion takes place which increases inorganic nutrient content.

Oxygen content of the water is affected by the flow rate;

* Turbulent flow constantly oxygenates the water giving rise to greater biodiversity
* While slow pool water contains relatively little oxygen and poor biodiversity.
* Turbidity reflects the amount of material suspended in the water. Large amounts of suspended organic matter also increase turbidity.
	+ streams and rivers flowing through areas of high erosion will have more suspended materials than those surrounded by hard substrates.
* The biological communities found in rivers and streams also differ from headwaters to mouth; they also differ from those found in ponds and lakes. In upstream areas where water is cool, clear and has high oxygen content, many insects and fish are found.
* Due to the relatively high-water current, large plankton communities are not common in rivers and streams. Thus, photosynthesis which supports the food chains are a function of attached algae and rooted plants.
1. **Wetlands**

A wetland can be defined as an area covered with water at some point in year that supports aquatic plants. It ranges from periodically flooded regions to soil that is permanently saturated. Some wetlands may even dry up during the dry season when water sources from precipitation and percolation become very low, and re-establish during the wet season.

* Several of Ethiopian wetlands such as in Gambela, Illubabor region, North-western highlands fall into this category of seasonal wetlands.
* Wetland conditions favour specially adapted plants called hydrophytes and characteristic bird and mammal fauna live in wetlands.

Wetlands can be freshwater or saltwater. Some of the wetland types include:

* **Marshes** which are usually covered with water year-round and the dominant plants are emergent (stems and leaves extending above surface)
* **Swamps** are dominated by woody plants
* **Bogs** are dominated by sphagnum mosses and are acidic.

The soils of the wetlands are water logged creating anaerobic conditions. They, thus, contain characteristic fauna and flora specially adapted to waterlogged soil condition. Wetlands are, therefore, considered transition ecosystems between the aquatic and terrestrial ecosystems as they are neither fully terrestrial nor are fully aquatic. Globally the total proportion of wetlands is not exactly known mainly due to their seasonal and spatial variability.

Estimates are that wetlands occupy nearly about 6 % of the world’s land area which is three times the area of lakes.

Wetlands are among the world’s most productive environments important for maintaining key ecological processes and socio-economic benefits to local communities.

Wetlands generally develop in three topographic situations

1. **Basin wetlands**: develop in shallow basins and range from upland depressions to filled-in lakes and ponds
2. **Riverine wetlands**: develop along shallow, periodically flooded banks of rivers and streams
3. **Fringe wetlands**: occur along coasts of large lakes and seas and the water flows back and forth due to changing lake levels or tidal action

Classification of the wetlands into certain categories also varies according to specified characteristics such as vegetation, hydrology, soils, animal species present, function, value, etc and the purpose of classification. According to Ramsar convention, five major wetland types are generally recognized:

* Marine wetlands: coastal wetlands including coastal lagoons, rocky shores, and coral reefs
* Estuarine wetlands: including deltas, tidal marshes, and mangrove swamps
* Lacustrine wetlands: wetlands associated with lakes
* Riverine wetlands: wetlands along rivers and streams
* Palustrine wetlands: wetlands such as marshes, swamps and bogs

**1.2. MARINE ECOSYSTEMS (OCEANS, SEAS AND ESTUARIES)**

A. **Marine biomes**

Here salt concentration exceeds 35 ppt or gm/l. This biome includes oceans and seas which cover ~ 75% of the earth’s surface and have enormous impact on planet’s climate. Evaporation of seawater provides most rainfall, ocean temperatures affect wind patterns, distribution of energy to land via currents, supply substantial portion of world’s oxygen due to photosynthesis by marine algae & photosynthetic bacteria. Marine plants consume huge amounts of atmospheric carbon dioxide as a result of photosynthesis by marine algae and photosynthetic bacteria.

**The following some examples of abiotic factors important in marine ecology:**

* **Temperature** affects biological processes and the ability of most organisms to regulate their body temperature. Temperature affects metabolism: few organisms have active metabolisms at temperatures close to 0º C and temperatures above 45º C denature most essential enzymes. The actual body temperature of ectotherms is affected by heat exchange with the environment; most animals maintain a body temperature only a few degrees above or below ambient temperature. Even endotherms function best within the temperature range to which they are adapted.
* **Salinity**: marine organisms can be euryhaline (i.e. wide range of tolerance) or stenohaline (narrow range of tolerance) according to their salt tolerance.
* **Sunlight:** provides the energy that drives nearly all ecosystems although only photosynthetic organisms use it directly as an energy source. In aquatic environments, water selectivity reflects and absorbs certain wavelengths; therefore, most photosynthesis occurs near the water surface. The physiology, development, and behaviour of many animals and plants are often sensitive to photoperiod.
* **Rocks and soil**: The physical structure, pH, and mineral composition of soil limit distribution of plants and hence animals that feed on those plants. The composition of the substrate in a stream or river greatly influences the water chemistry, which in turn influences the plants and animals. The type of substrate influences what animals can attach or burrow in intertidal zones.
* **Wind amplifies** the effects of temperature by increasing heat loss by evaporation and convection; wind also increase the evaporation rate of animals and transpiration rate of plants, resulting in more rapid water loss. Mechanical pressure of wind can affect plant morphology (for example, inhibiting growth of limbs on windward side of trees).
* **Periodic disturbances** such as fire, hurricanes, typhoons, and volcanic eruptions can devastate biological communities, after which the area is recolonized by organisms or repopulated by survivors. May go through a succession of changes. Those disturbances that are infrequent (volcanic eruptions) do not illicit adaptations. Adaptations do evolve to periodically recurring disturbances such as fires.

**B. Estuaries**

They are areas where freshwater (stream or river) merges with ocean. Salinity varies from that of fresh water to that of ocean water varies daily in areas due to rise and fall of tides. Thus, the estuarine waters are often known as brackish. Estuaries are very productive due to nutrients brought in by rivers and have a diverse flora and fauna. Salt marsh grasses, algae, and phytoplankton are the major producers. Many species of annelids, oysters, crabs and fish are also present. Many marine invertebrates and fish breed in estuaries. A large number of waterfowl and other semiaquatic vertebrates use estuaries as feeding areas.

**CHAPTER TWO**

**MAJOR FRESHWATER BODIES AND WETLANDS OF ETHIOPIA**

**2.1. Drainage Basins of Ethiopia**

Drainage basin is any area of land where precipitation collects and drains off into a common outlet, such as into a river, bay, or other body of water. The drainage basin includes all the surface water from rain runoff, snowmelt, and nearby streams that run downslope towards the shared outlet, as well as the groundwater underneath the earth's surface.

Ethiopia, often called the water tower of northeast Africa, is endowed with some 7000 km length of flowing water and some 7000 km2 of standing water. The drainage patterns are the result of the topographic features formed by the recent geologic activity of the Cenozoic Era during the Tertiary Period. Ethiopia, with its various geologic formations and climatic conditions, is endowed with considerable freshwater resources and wetlands.



The drainage systems of Ethiopia can be broadly divided into three topographic regions which in turn are further subdivided in to drainage basins. These are: the western drainage system, the south eastern drainage system and the Rift Valley drainage system.

* **WESTERN DRAINAGE SYSTEM**: includes the Tekeze drainage basin, Abay (Blue Nile) drainage basin, Baro-Akobo drainage basin and Gibe-Omo drainage basin. The major lakes, such as **Tana Lake**, are located within this drainage system. This is the largest drainage system that drains nearly 40 % of the total area and 60 % of the annual water flow. This is an exorheic system in which the rivers in the system ultimately drain into the **Mediterranean Ocean**.
* **SOUTH-EASTERN DRAINAGE SYSTEM**: includes Wabishebele and Ghenale drainage basins. This is also an exorheic system in which the rivers in this system ultimately drain into the **Indian Ocean**.
* **RIFT VALLEY DRAINAGE SYSTEM**: includes Awash drainage basin and major lakes such as Ziway, Shala, Abijata, Awassa, Abaya and Chamo are located in the Rift Valley. This is generally an **endorheic or closed system with no external flow**.

**2.2. LAKES**

The Ethiopian lakes roughly occupy some 7000 km2 area. The formation of most of the natural lakes is associated with **tectonic and volcanic activities** and thus most are **crater lakes**.

* **HIGH LAND LAKES** include Lake Tana, Lake Hayq (near Dessie), Ashengie, Lake Wonchi (near Ambo), and Bishoftu (Debrezeit) Lake groups (such as Lake Hora, Lake Bishoftu, Lake Kuriftu and Lake Arenguade, etc).
* **RIFT VALLEY LAKES** include lakes in:
* Northern rift valley lakes: Awassa, Langano, Abijata, Shalla and Ziway
* Southern rift valley lakes: Abaya, and Chamo and Chew Bahir

The man-made lakes known as reservoirs include Koka Reservoir, Fincha Reservoir, MelkaWakena Reservoir, Gilgel Gibe Reservoir, Tekeze Reservoir, etc.

Table 2.1. Some of the Major Ethiopian Lakes

|  |  |  |
| --- | --- | --- |
| **Lake** | **Area (Km2)** | **Max. Depth (m)** |
| Tana  |  3600 | 9  |
| Abaya  | 1150  | 13  |
| Chamo | 551  | 10  |
| Ziway | 434  | 4 (shallowest)  |
| Shala  | 409  | 266 (deepest)  |
| Abijata | 205  | 14  |
| Koka | 205  | 9  |
| Awassa |  129 | 46 |

Though fishery activities are not well developed in Ethiopia, some practices are seen in most of the lakes mentioned above. However, most of the fishery activities are common in Rift valley lakes and Lake Tana.

**2.3. RIVERS**

The Ethiopian rivers are more than 7000 km long. The major rivers located among the various drainage basins are summarized in Table 2.2. Ethiopian rivers are characterized by:

* Extreme seasonal fluctuation due to the marked seasonality of the rainfall:
* They carry only small amount of water and some even dry up along part of their courses during dry season.
* High volume and run off during wet seasons
* Steep flow and profiles:
* Flowing from highlands of over 2,000-3,000 meters to a low land of an elevation less than 500 meters.
* The rivers have high erosive power due to their steep flow

Table 2.2. The Major Rivers of Ethiopia

|  |  |  |
| --- | --- | --- |
| River  | Length (km) | Major tributaries |
| Total | inside | outside |
| Abay (Blue Nile)  | 1360  | 800 | 560 | Dabus, Didesa, Fincha, Guder, Muger |
| Wabishebele | 2000 | 1340 | 660 | Ramis, Erer, Daketa, Fafen |
| Ghenale | 1050 | 480 | 570 | Dawa, Weyb, Welmel, Mena |
| Awash  | 1200 | 1200 | - | Akaki, Kesem, Borena, Mile |
| Tekeze | 1168 | 608 | 560 | Atbara, Angreb |
| Omo/Ghibe | 760 | 760 | - | Gojeb |
| Baro | 507 | 227 | 280 | Akobo |

**Many Ethiopian rivers including Abay are difficult for fisher activities primarily due to:**

* The steep gorge of the rivers that extends for a large portion of the basin. The presence of crocodiles in many segments of the rivers.
* Moreover, many of the tributaries dry or their volumes are highly reduced during the dry seasons

**The Ethiopian rivers generally flow into:**

* Mediterranean Ocean: Wester drainage system,
* Indian Ocean: South-Eastern drainage system
* Close (inland) flow i.e. with no external flow: Rift valley drainage system

**The general flow pattern of Ethiopian rivers is determined by the topography of the country:**

* Western and South eastern highlands have an outward slopping topography resulting in the out-ward flow of the rivers. Consequently, most major rivers of Ethiopian high lands cross the border and become internationally significant.
* Baro-Akobo, Abay (Blue Nile) and Tekeze rivers drain west ward into the Mediterranean Ocean.
* Ghenale and WabiShebele Rivers drain east ward into the Indian Ocean.
* Rift Valley has an inward slopping resulting mainly in an inland drainage System

**2.4. WETLANDS**

Wetlands are dynamic; they change seasonally with changes in annual precipitation. Wetlands with static water levels tend to become more pond like and lose some of their Wetlands with static water levels tend to become more pond-like and lose some of their ecological value. Many wetland plants and animals are adapted to the periodic saturation and drying that occurs and small changes in flood/dry patterns can drastically change plant and animal species composition.

In Ethiopia wetlands are distributed all across the topographic unit of the country ranging from the lowlands of salt lakes in the Afar depression to the freshwater shallow lakes at Bale and Semen Mountains. They are estimated to constitute 2% of the total area of the country.

Swamps and marshes are the predominant forms often identified by reference to a vegetation locally known as “cheffe”, which is the typical vegetation in most wetlands. Marshes are periodically saturated, flooded, or opened with water and characterized by herbaceous vegetation adapted to wet soil conditions. Swamps are, however, fed primarily by surface water inputs and are dominated by trees and shrubs. They are characterized by very wet soils during the growing season and standing water during certain times of the year.

**Wetlands are most productive environments important in:**

* Maintaining key ecological processes (reduce siltation, purifies water, ground water recharge and discharge, etc.)
* Supporting high biodiversity (such as waterfowl, mammals, reptiles, amphibians, fish and invertebrate species, medicinal plan species)
* Providing socio-economic benefits to local communities

**In Ethiopia, the socio-economic benefits of wetlands include:**

* Provision of clean water supplies throughout the year
* The wetland vegetation, such as “cheffe”, reeds, palms, bamboos and papyrus, etc. are harvested by the local people for roofing and making of various crafts including boats.
* The other wetland plants, such as *Hygrophila auriculata* (locally known as balanworanti) are used for medicinal purpose
* Most wetlands are used for cattle grazing and watering
* Wetlands are also used to cultivate maize and other edible plants during dry season.