**Addis Ababa University**

**College of Natural Sciences**

**Department of Zoological Sciences**

**(General Biology Program Unit)**

# Fisheries and Aquaculture (Biol. 4062)

**(Distance Module In-Service Program)**

**Prepared by**

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## Preface

In a country where a good portion of its population is suffering from lack of food and malnutrition, at times recurrently, looking for additional food resources should be inevitable. The aquatic resources provide alternative means of the most needed protein in several countries in the world. However, unfortunately, the aquatic resources of Ethiopia are underexplored and/or underutilized. It has been the case for years now that the fisheries and aquaculture sector in Ethiopia is, at best, marginalized and, at worst, ignored and its contribution to the GDP is minimal. This is despite the favorable natural conditions the country has to develop the sector. The average per capita consumption of fish in the world (consumption per person per year), at present, is 18 kg while it is, on the average, 8 kg in Africa while the per capita production (not consumption) in Ethiopia is only 260 grams, one of the lowest in the world. While the world is generating about US$ 187 Billion annually from the sector, Ethiopia is getting only about US$20 Million. With this situation at hand, I don't think that the status quo will continue amidst the need for more food resources and income for this country. One of the ways to get out of this quagmire is to train able and skilled manpower in the field. It is with this intention and out of the need to commence distance education in the In-service Program at Addis Ababa University that this module is compiled.

The different sections of the module were organized as a result of review of several literatures over many years of teaching the subject matter at undergraduate and post graduate levels as well as from results of own research in Ethiopia. Although primarily intended to serve undergraduate students that follow distance education; however, the material will certainly, serve our regular undergraduate and post graduate students as a valid reference and /or textbook. Other individual, groups, or institutions could also make use of this material with due acknowledgements and following the legal procedures of using literature prepared by Addis Ababa University.

There are 7 chapters in this module. The first chapter deals with general introductions about fishes, their characteristics and historical backgrounds on the study of fishes. The second chapter is about fish diversity and distribution in the global waters. It mentions all the groups of fishes in their phylogenetic placements with some details. It also discusses the ecological and geographical distributions of the fishes in the global waters. Mention is also made about commercially important fish and other aquatic organisms.

The third chapter is about the feeding, nutrition, growth and reproduction of fishes. These are parameters important in the production systems of capture and culture fisheries and that is why they need to be discussed as important and selected behavioral and physiological functions of life in fishes, as may also be true in other organisms.

The fourth chapter is dealing with the capture fisheries from the wild, starting from gears used to catch fishes, through methods of estimating growth and mortality to productivity and yield. The fifth chapter, as a continuation and counterpart of the wild catch, discusses culturing of fish in ponds, cages, pens, as well as in integrated and re-circulating systems. The chapter also includes the potential effects of aquaculture on the environment and the essential precautions that need to be made before venturing into aquaculture practices.

The sixth chapter is about preserving, packing and labeling of fish and other products of aquatic organisms. The last and seventh chapter deals with the Ethiopian aquatic resources. It discusses on diversity and distribution of fishes including economically important species. It also includes the status of the fisheries and aquaculture sector in Ethiopia with a copy of the Fisheries Development and Utilization Proclamation (Proclamation Number 315/2003) set by the Federal Democratic Republic of Ethiopia. The module, at the end of it, contains pertinent references for the subject. Moreover, there are summary and review questions for each chapter, besides the in-text questions set at various places within many of the chapters.

I believe that this module will serve the purpose it was intended for and will be improved in future editions based on comments that will be received from its end users.

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**Professor in Aquatic Biology**

## Module Learning Outcomes

**Upon completion of this module you students will be able to:**

- discuss the diversity and distribution of fishes,
- discuss methods of determining food habits and reproduction in fishes,
- demonstrate ways of catching fish and other aquatic organisms from their natural habitats,
- discuss methods of determining yield of fishery resources,
- implement, in small scales, aquaculture practices and fish tanks in their household yards or school compounds and
- contribute to the sustainable development of Ethiopian fisheries and aquaculture

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# Chapter 1-Introduction

Fishes make up more than half of the 48,000 species of living vertebrates. Fishes occupy nearly all-major aquatic habitats, from lakes and polar oceans to tropical swamps, temporary ponds, intertidal pools, ocean depths.

To colonize and thrive in such a variety of environments, fishes have evolved obvious and striking anatomical, physiological, behavioural and ecological adaptations. Fishes are excellent showcases of the evolutionary process, exemplifying the intimate relationship between form and function, between habitat and adaptation.

Fish could be defined as a poikilothermic, aquatic chordate with appendages (when present) developed as fins, whose chief respiratory organs are gills and whose body is usually covered with scales, although definitions are dangerous, since exceptions are often viewed as falsifications of the statement. **Fish** is singular and plural for a single species; **fishes** refers to more than one species.

Numerically, valid scientific descriptions exist for approximately 25000 living species of fishes in 482 families and 57 orders (Nelson, 1994) where as FishBase (data base on the internet) records about 31000 fish species. Of these, 85 are jawless fishes (hagfishes and lampreys); 850 are cartilaginous sharks, skates, rays, and chimaeras; and the remaining 23,000 or more species are bony fishes. 41% of the species live in freshwater, 58% live in sea water, and 1% move between freshwater and the sea during their life cycles.

Geographically, the highest diversities are found in the tropics. The Indo-West Pacific area that includes the western Pacific and Indian Oceans and the Red Sea have the highest diversity for a marine area, whereas Southeast Asia, South America, and Africa have the most freshwater fishes. The altitudinal record is set by some river loaches that inhabit Tibetan hot springs at elevations of 5200 m. The record for unheated waters is Lake Titicaca in northern South America, where pupfishes live at an altitude of 3812 m. The deepest living fishes are cusk eels, which occur 8000m down in the deep sea.

Diversity in body size ranges from *Trimmatuom nanus*, an Indian Ocean goby that matures at 8 mm long, to the world's largest fish, the 12 m long (or longer) whale shark.

Fishes are of great economic value for food, recreation, and aquarium use and are also important to the ecology of water systems. Fisheries production has reached about 145 Million tons in 2010 contributing about 174 Billion Dollars to the world economy.

***In-text question:*** *How is it possible to find proportionally high diversity of fishes (41%) in freshwater, which is a very small proportion of global water (less than 0.01%)?*

## History of the study of fishes

Aristotle (383-322B.C.) observed and recorded facts on 118 species of Greek fishes, and a few other Greeks and Romans added to the knowledge of Mediterranean fishes somewhat later.

Although natural historians in most cultures have studied fishes for millennia, modern science generally places its roots in the works of Carl Linne (Linnaeus). Linnaeus produced the first real attempt at an organized system of classification. Zoologists have agreed to use the tenth edition of his Systema Naturae (1758) as the starting point for our formal nomenclature. The genius of Linnaeus's system is what we refer to as binomial nomenclature, naming every organism with a two part name based on genus and species. Linnaeus did not care much for fishes, so his ichthyological classification is actually based largely on the efforts of Peter Artedi, the acknowledged "father of ichthyology". Artedi reportedly drowned one night after falling into a canal in Amsterdam while drunk.

In the mid-1800s, the great French anatomist Georges Cuvier joined forces with Achille Valenciennes to produce the first complete list of fishes of the world. During those times French explorers were active throughout much of the world, and many of their expeditions included naturalists who collected and saved material. Thus Cuvier and Valenciennes's Histoire Naturelle de Poissons includes descriptions of many previously undescribed species of fishes in its 24 volumes. Many of the specimens collected are housed in the Museum national d'Histoire Naturelle in Paris. A few years later, Albert Gunther produced a multivolume Catalogue of Fishes in the British Museum.

The major force in American ichthyology was David Starr Jordan. In 192, Jordan and Evermann published a list of all the genera of fishes that had ever been described, which served as the standard reference until recently, when it was updated and replaced by Eschmeyer (1990). Overlapping with Jordan was the distinguished British ichthyologist, C. Tate Regan, based at the British Museum of Natural History. A Russian ichthyologist, Leo Berg, first integrated paleoichthyology into the study of living fishes in his 1947 monograph Classification of Fishes, Recent and Fossil published originally in Russian and English. He was also the first ichthyologist to apply the "*iformes*" uniform endings to orders of fishes, replacing the classic and often confusing group names.

In 1966, three young ichthyologists- P. Humphry Greenwood at the British Museum of Natural History, Donn Eric Rosen at the American Museum of Natural History, and Stanley H. Weitzman at the U.S. National Museum of Natural History- joined with an old-school ichthyologist, George S. Myers of Stanford University, to produce the first modern classification of the majority of present day fishes, the Teleostei.

The 20$^{th}$ century has shown the diversification of fish and fishery studies from fish anatomy and physiology to genetics, ecology, fisheries and aquaculture.

Some wonders of the fish world

- Coelacanths, an offshoot of the lineage that gave rise to the Amphibians, were thought to have died out with the dinosaurs at the end of the Cretaceous, 65 million years ago. However, in 1938, fishermen in South Africa trawled up a very live coelacanth. This fortuitous capture of a living fossil not only rekindled debates about the evolution of higher vertebrates but also underscored the international and political nature of conservation efforts.
- Lungfishes can live in a state of dry "suspended animation" for up to 4 years, becoming dormant when their ponds dry up and reviving quickly when immersed in water.
- Antarctic fishes live in water that is colder than the freezing point of their blood. The fishes keep from freezing by avoiding free ice and because their blood contains antifreeze proteins that depress their blood's freezing point to $-2^{o}$C. Some Antarctic fishes have no hemoglobin.

- Deep sea fishes include many forms that can swallow prey larger than themselves. Some deep sea angler fishes are characterized by females that are 10 times larger than males, the males existing as small parasites permanently fused to the side of the female, living off her blood stream.
- Fishes grow throughout their lives, changing their ecological role several times. In some fishes, differences between larvae and adults are so pronounced that many larvae were originally described as entirely different taxa.
- Fishes have maximum life spans of less than one year to as long as 150 years. Some short-lived species are annuals, surviving drought as eggs that hatch with the advent of rains. Longer-lived species may not begin reproducing until they are 20 years old, and then only at 5-year (or longer) intervals.
- Gender change is common among fishes. Some species are simultaneously male and female, where as others change from male to female or from female to male.
- Fishes engage in parental care that ranges from simple nest guarding to mouth brooding to the production of external or internal body substances upon which young feed. Many sharks have a placental structure as complex as any found in mammals. Egg laying fishes may construct nests by themselves, whereas some species deposit eggs in the siphon of living clams, on the undersides of leaves of terrestrial plants, or in the nests of other fishes.
- Fishes are unique among organisms with respect to the use of bioelectricity. Many fishes can detect biologically meaningful, minute quantities of electricity, which they use to find prey, competitors, or predators and for navigation. Some groups have converged on the ability to produce an electrical field and obtain information about their surroundings from disturbances to the field, where as others produce large amounts of high-voltage electricity to deter predators or stun prey.
- Fishes are unique among vertebrates in their ability to produce light; this ability has evolved independently in different lineages and can be either autogenic (produced by the fish itself) or symbiotic (produced by bacteria living on or in the fish).
- Although classically thought of as cold-blooded, some pelagic sharks, billfishes, and tunas maintain body temperatures warmer than their surroundings and have circulatory systems specifically designed for such temperature maintenance.

- Predatory tactics include attracting prey with modified body parts disguised as lures or by feigning death. Fishes include specialists that feed on ectoparasites, feces, blood, fins, scales, young, and eyes of other fishes.
- Fishes can significantly change the depth of their bodies by erecting their fins or by filling themselves with water, an effective technique for deterring many predators. In turn, the ligamentous and levering arrangement of mouth volume when open by as much as 40-fold.

## Summary

Fish could be defined as a poikilothermic, aquatic chordate with appendages (when present) developed as fins, whose chief respiratory organs are gills and whose body is usually covered with scales. Fishes make up more than half of the 48,000 species of living vertebrates. Numerically, valid scientific descriptions exist for approximately 25000 living species of fishes while FishBase (data base on the internet) records about 31000 fish species. 41% of the species live in freshwater, 58% live in sea water, and 1% move between freshwater and the sea during their life cycles. Fishes live wherever there is water from altitude of some 5000 meters above sea level to about 8000 meters depths of seas and oceans. Diversity in body size ranges from *Trimmatuom nanus*, an Indian Ocean goby that matures at 8 mm long, to the world's largest fish, the 12 m long (or longer) whale shark. Fishes are of great economic value for food, recreation, and aquarium use and are also important to the ecology of water systems.

The beginning of the study of fishes goes back to the times of Aristotle (383-322B.C.). It has gone through phases from natural history studies to the study of genetics, ecology, behavior, fisheries and aquaculture.

## Review Questions

1. Define and characterize fishes.
2. When did the study of fishes start?
3. Which groups of fishes do you think could respire atmospheric oxygen?

# Chapter 2 - Diversity and Distribution of Fishes

## The Agnatha (Jawless fishes)

The very first fishes arose from invertebrate protochordates, perhaps a urochordate or cephalochordate. The jawless fishes are known from fossils and living fishes. The first known fishlike vertebrates occur in the fossil record of the Ordovician period, nearly 500 million years ago. These were jawless Ostracoderms, because of their armored skin. There are two living representatives of the group.

The first groups are the living hagfishes (Order Myxiniformes) that have nonfunctional eyes and are elongate, marine predators and scavengers that lack paired fins and vertebrae. They have cartilaginous skeletons. There are about 25 species, found mainly in temperate seas, and some are subjected to a fishery because of the use of their skins for small leather items. They are characterized by barbells around the mouth and the nasal opening.

The second groups are lampreys that are the living representatives of the Class Cephalaspidomorphi, so named because most of the known fossil members had armored heads. The lampreys comprise about 35 species that range in length from 75 mm to more than a meter. All undergo a long larval period buried in bottom materials and so are seldom seen except during migrations. Larger species are parasitic and feed on fishes and, at times, on marine mammals. The smaller kinds are usually nonparasitic and filter feed only during the larval stage. Although all spawn in freshwaters, some of the parasitic forms grow to maturity in the sea. Lampreys are eel shaped and have a cartilaginous skeleton. They lack paired fins, and the adults have an oral suctorial disc set with keratinous teeth. They are found in cold and temperate waters.

## Gnathostomes: Early jawed fishes

Although debate is common concerning relationships among jawless fishes, few authors have suggested that a known agnathous group was ancestral to the first jawed fishes that arose during the early Silurian. The evolutionary importance of true jaws cannot be overemphasized. As Romer, 1962 put it "Perhaps the greatest of all advances in vertebrate history was the development of jaws and the consequent revolution in the mode of life of early fishes".

Placoderms (plate-skinned) were known to be the first gnathostomes. Their name refers to the peculiar bony, often ornamented, plates that covered the anterior 30% to 50% of the body. Many placoderm groups show an evolutionary trend toward reduction in external armor leading to a mobile existence in the water column. Eight or nine orders, 30 families, and about 50 genera of placoderms are recognized; all are known from fossils.

***In-text question:*** *How do you easily distinguish Agnathans from Gnathostomes?*

## Cartilaginous Fishes (Class Chondrichthyes)

### *Elasmobranchi (Sharks, Skates and Rays)*

Definitive shark like fossils first appear in the mid-Devonian, with fragmentary remains suggesting perhaps a late Silurian or even an Ordovician origin. An early elasmobranch radiation, characterized by cladoselachid sharks, had five gill slits and a terminal mouth. Their dentition, referred to as cladodont, consisted of multicuspid teeth in which the central cusp was usually larger. The teeth were made of enamel-covered dentine and were homologous with scales.

Sharks and rays are widely distributed in marine waters and are of interest for many reasons. Many species are the objects of fisheries, not only for the harvest of their flesh but also for other materials such as their hides for leather and their jaws and teeth for souvenirs. A few sharks and rays are dangerous to humans. Stingrays and others with stinging spines can injure swimmers or fishermen. Sharks are generally large animals; the various species average about 2 m long, but the whale shark is the largest fish known. It reaches 12 m or more. There are at least 376 and perhaps as many as 480 species of sharks. These are all marine, although a few species, including the bull shark, which has been implicated in many shark attacks, enter freshwater.

There are 500 or more species of skates and rays, and, like the sharks, there are many species in tropical areas. There are true freshwater species in two families of stingrays, representatives of which live in tropical rivers.

### *Holocephali (Chimaeras)*

The name of the subclass emphasizes the fusion of elements of the skulll in many of the group. Their bizarre appearance has earned them such names as rabbit fish, ratfish, and ghost sharks, among others. There are fewer than 40 species; except for the few that live on the continental shelf, most live in deep marine habitat and are seldom seen or caught.

## Bony Fishes (Osteichthyes)—Teleostomi

Nelson uses Teleostomi as the grade embracing vertebrates other than Chondrichthyes, including the ray finned fishes (Sarcopterygii--including the tetrapods), and the ray-finned fishes (Actinopterygii).

### *Class Sarcoptrygii (Lobe-finned fishes)*

The lobe-finned fishes, which presumably gave rise to the tetrapods, comprise the coelacanths, lungfishes and the extinct rhipidistians. These fishes are characterized by fleshy lobate fins, usually with a characteristic flexible skeleton. They have also an epichordal lobe in the caudal fin, which is variously shaped to be heterocercal, heterodiphycercal, or diphycercal. Many ancestral lobe-fins had two dorsal fins, as does Latimeria, but the living lungfishes do not.

#### ***Order Coelacanthiformes***

The larger cartilaginous fin supports, or "spines" are hollow, as in the fossil relatives (hence the name coelacanth, hollow spine).

This order includes four extinct families that existed from the Upper Devonian to the Upper Cretaceous as well as the family Coelacanthidae, with several extinct genera and the only living member of the sub-class, which is *Latimeria chalumnae ("the Living Fossil")*. Until a specimen was captured off southeast Africa in 1938, the order was thought to have become extinct in the Cretaceous.

*Latimeria* is large, typically about 2 m long, with reported lengths of more than 2.5 m. Weights of around 80 kg have been reported. The smallest free-living specimen captured was 42 cm long. The pectoral, pelvic, second dorsal, and anal fins are all lobate and flexible.

*Infraclass Dipnoi (Lung fishes)*

These fishes have received various placement in different systems of classification. They differ from other bony fishes in having autostylic suspension of the upper jaw. In addition the teeth are fused into crushing plates. Maxillae, premaxillae and coronoids are lacking. Internal nares are present, as is a cloaca.

Fossil lungfishes are found on all continents, some from marine deposits. Nearly 60 nominal genera of extinct lungfishes are known, and as many as five extinct orders are recognized by some authorities. About half of the genera date back to the Devonian.

The living lungfishes are grouped into three genera and these are:

*Neoceratodus (Australian lung fish)*

The species differs structurally from other living lungfishes by having an unpaired lung and a cartilaginous endocranium as well as four pairs of gills. The species frequents permanent bodies of water and is incapable of estivation, but it can survive several weeks to a few months if kept moist in mud or vegetation.

*Protopterus (African lung fish) and Lepidosiren (South American lung fish)*

They show similar features. Both have paired lungs, filamentous-paired fins, and a membranous endocranium. Both families contain elongate fishes with fairly small scales. The habitat of these species is generally swampy and often contains low concentrations of dissolved oxygen, so the species have evolved the ability to utilize atmospheric oxygen. The gills are reduced and relatively ineffective as compared to those of *Neoceratodus*. If the swamps dry up, both the African and South American species can burrow into the muddy bottom and remain for several months in an inactive state, waiting for the next rainy season.

The genus *Protopterus* contains at least four species, the biggest being *P. aethiopicus* reaching a length of 1.8 m.

> ***In-text question:*** *Do you think that lung fishes respire using gills? How do you relate the scientific name of the group with their mode of respiration?*

*Class Actinopterygii (Ray-finned fishes)*

Actinopterygii is divided into three groups:

***Chondrostei***

The chondrosteans share some ancestral characteristics, such as spiracles, heterocercal tails, and more fin rays than ray supports in the dorsal and anal fins.

Two living orders are recognized: Polypteriformes and Acipenseriformes.

Polypteriformes includes two groups of fishes: *Polypterus* (the African bichir) and reedfishes. *Polypterus* contains about 10 species, all of African freshwaters. Order Acipenseriformes includes the sturgeons and paddlefishes plus extinct formes. The sturgeons are superficially distinguishable from paddle fishes by having bony scutes along the sides and back and four barbells on the underside of the rostrum, which is shorter than in the paddlefishes. The family contains four genera and over 20 species, which are distributed around the northern hemisphere (holarctic distribution) and have marine, freshwater, and anadromous members. The sturgeons are sought by fishermen for their flesh and their roe (eggs), from which caviar (a very expensive soup) is made. The largest sturgeon is the beluga (*Huso*) of the Caspian and Black seas. It is reported to reach a length of about 9 m and a weight of 1500 kg. Large specimens may be 100 years old and carry over 7 million eggs.

Some North American sturgeons are listed as rare and threatened. The requirements for clean water, their slow growth and later maturity, and the fact that the eggs are the most valuable product from these animals pose problems for fishery managers.

***Holostei***

There are two groups included here: the **gars** and **bowfins**. Gars are found in eastern North America from the Great Lakes region to Costa Rica, and one species reaches Cuba. These are elongate fishes with the body covered by heavy ganoid scales and the head covered by equally hard bone. Gars live in quiet, often weedy, waters and usually can be observed lyi ng almost motionless near the surface. They can utilize atmospheric oxygen in addition to that obtained through the gills. The eggs are reported to be poisonous.

The bowfins are represented by one living species, the North American *Amia calva*. The bowfin is found in only freshwaters.

***Teleostei***

The Teleostei is a large assemblage of many diverse groups and includes 38 orders, about 425 families, and nearly 4070 genera of living fishes.

The four major monophyletic lines of living teleosts are as follows:

1. The Osteoglossomorphs, including bonytongues, elephantfishes (mormyrids) featherbacks, mooneyes, and allies. This group is the Osteoglossomorpha. There is a single living order, Osteoglossiformis. Examples from Ethiopia include *Heterotis* from Osteoglossidae; *Mormyrus* and *Gymanarchus* from Mormyridae and Gymanarchidae respectively.
2. The tarpons, tenpounders, eels, and relatives. These are the Elopomorpha and comprise four extant orders: Elopiformes, Notacanthiformes, Anguilliformes, and Saccopharyngiformes. Eels are found in Ethiopia.
3. The herrings and allies. There is a single order, Clupeiformes. These are marine fishes. The family Clupeidae includes the herrings, pilchards, shads, sardines and similar fishes. Many species occur in dense schools, so they are subject to mass capture, and their oily flesh makes them the object of fisheries all over the world.
4. The subdivision Euteleostei, consisting of all the reminder teleostei, which comprises, 32 orders, 391 families, 3795 genera and 22,262 species.

***Euteleostei***

There are about nine superorders and two of the very important ones (as far as the freshwaters systems of Ethiopia are concerned ) will be discussed hereunder:

*Superorder Ostariophysi (Carps, Catfishes and Gymnotoids)*

These are the dominant freshwater fishes of the world and include a few marine representatives as well. According to Nelson (1994), the more than 6500 species of this suborder make up about 27 % of the known species of fishes in the world.

Ostariophysan fishes have modified anterior vertebrae and ribs, and most have a bony connection between the swimbladder and the ear-the Weberian apparatus-that aids in the reception of sound. Many of the Ostariophysan fishes have structures called unculi or "horny projections arising from single cells" No other fishes are known to bear the structures, which are concentrated in areas of contact, such as lips, ventral surfaces, and sucking discs. They differ from the multicelled contact organs and breeding tubercles seen in these and other fishes.

***Order Cypriniformes***

Cypriniformes contains the minnows, carps, loaches, suckers, and allied forms, all of which have toothless mouths and sickle shaped, lower pharyngeal teeth that usually bite upward against a cartilaginous pad borne on a posterior extension of the bassioccipital bone. The cypriniformes were naturally distributed in Africa, Asia, Europe, and North America, but there awere none in South America or Australia before they were introduced by humans. They are fishes of great importance, both ecologically and economically.

The Cyprinidae (carps and minnows) seems to have originated in southeast Asia but now is distributed in the freshwaters of Europe, Asia, Africa, and North America, with about 2000 species. Many important ornamental and aquarium species belong to this family, ranging from barbs, danios, and rasboras to the gold fish, Carassius quratus, and the carp, Cyprinus carpio, which has ornamental varieties.

***Order Characiformes***

Species of this order usually have opposing pharyngeal teeth, an adipose fin, and separation of the first hypural from the compound ural centrum. Jaw teeth are present, and barbells are absent. The characins (Characidae) and their relatives are found in freshwater in both Africa and South America north through Central America and Mexico to the Rio Grande in Texas. Their continental distribution is no doubt due to dispersal prior to the separation of Africa and South America, but no genera are common to the two continents. About 25 genera and 200 species occur in Africa and over 200 genera and over 1300 species in the Americas. The family Citharinidae of Africa is thought to be the most primitive of the characins. The family Characidae contains numerous genera of diverse habits in both Africa and the Americas.

## *Order Siluriformes*

This is the order of the catfishes. They have no true scales, and the skin is bare or covered with bony plates, which may bear dermal denticles. The premaxillary bears teeth, but the maxillary does not and is modified or is the basal skeleton unit of the maxillary barbell. Intermuscular bones are absent. Catfish spines are provided with a locking mechanism that holds them erect. Many species have venom glands associated with the spines, and wounds caused by the spines of certain species can be extremely painful or even fatal.

Various authorities recognize from 20 to 30 families of catfishes and estimate that the total number of species is nearly 2500, of which over half are found in South America. Catfishes are known from all continents except Antarctica, where they occur as fossils.

The Malapteruridae of Africa contains electrogenic species, one of which, *Malapterurus electricus*, can deliver a severe shock. Another African family, Mochokidae, contains some species that habitually swim upside down. The upside down swimming may aid in feeding on plankton in the surface layer and may help in obtaining oxygen from well-oxygenated water near the air-water interface. Amphiliidae, the loach catfishes, is an African family. The members are usually inhabitants of swift mountain streams.

## ***Order Gymnotiformes***

This order has some characteristics in common with the catfishes and is placed into the Siluriformes. It includes electric eel, which is a large, elongate, but heavy-bodied fish with about 250 vertebrae. The electric eel has about 80 percent of the body in the caudal region, which is largely made up of the electric organs. This species, *Electrophorus electricus*, is one of the strongest electrical fishes and is capable of producing 650 volts, although the average is about 350 volts.

## *Order Cyprinodontiformes*

This is the order of killifishes. They are soft-rayed physoclists with abdominal pelvic fins. Cyprinodontiformes are widely distributed and occur naturally in all continents except Australia and Antarctica.

Examples: Aplocheilichthys and Cyprinodontids (*Lebias*).

Superorder Acanthoptergii

***Order Perciformes***

This is the largest order of fishes with nearly 9300 species in 148 families. It is the largest order among the vertebrates. This order contains most of the spiny-rayed fishes. In addition to fin spines, these fishes have thoracic or jugular pelvic fins, with the pelvic girdle usually connected to the cleithra.

Centropomidae is a family in suborder Percoidei that includes the famous *Lates niloticus* (Nile Perch).

Cichlidae is also another family included in suborder Labroidei. The Cichlidae is an important freshwater family that ranges through warm freshwaters from India, Africa, South America, and Central America north to Rio Grande. In some of the great rift lakes of Africa, there are "species flocks" of cichlids, usually of the genus Haplochromis and close relatives.

***In-text question:*** *What differences can you mention between catfishes and cyprinids?*

## Distribution of Fishes

Fishes occur almost everywhere there is water. The question of interest then becomes one of discerning patterns in the present distribution of different species, genera, families, and higher taxa, and then trying to understand how these patterns are related to the evolution of the different groups. Basically, we are asking how and why fish fauna differ and how different fishes got where they are today. These questions form the basis of the science of zoogeography, distribution of animals.

Fish distributions are largely associated with **continental drift and tectonic plates**. Continents and ocean basins have changed dramatically in location and size during the earth's history. Continents are blocks of largely granitic and sedimentary rocks. Continents "drift" because they literally float on top of the earth's denser basaltic crust. The notion of continental drift was first seriously proposed by Alfred Wegener in 1915 to explain the fit that the west coast of Africa makes with the east coast of South America. Wegener's concept was ridiculed by most scientists for many years but has gained acceptance as geophysical and paleontologic evidence accumulated. So it is believed that the present continents were at one time all part of a single landmass, Pangea, that had coalesced by the Silurian (430 million years ago). About 180 million years ago, during the Mesozoic, Pangea split into a northern portion, Laurasia (Eurasia and North America), and a southern portion, Gondwana. Gondwana later split into South America, Africa, Australia, and Antarctica about 90 million years ago. Present distributions of several fish taxa, such as lungfishes, Osteoglossomorphs, and Ostariophysans may well have taken place when the southern continents were still connected, before the breakup of Gondwana.

Historically, the study of fish distribution has been divided into marine and freshwater components.

***Marine fishes***

Although terrestrial humans refer to our planet as Earth, it is really Planet Ocean. Not only is 71% of the planet's surface covered with water, but because water is dense enough to support life from the surface down to 11,000m, the total oceanic living volume is 300 times greater than in the terrestrial part. At the level of phyletic diversity (numbers of different phyla present), the seas support a greater biodiversity than does land. Of 33 animal phyla, 32 occur in the sea, and 15 of these are exclusively marine.

Four main ecological divisions of marine fishes can be recognized:

1. ***Epipelagic*** fishes, which dwell from the surface down to 200 m, make up 1.3% of the total, or about 325 species.
2. ***Deep pelagic*** fishes include about 1250 species, or about 5% of the total. These water-column-dwelling fishes can be further subdivided into mesopelagic fishes, which live between 200 and 1000 m, and deeper-dwelling bathypelagic fishes.
3. ***Deep benthic*** fishes comprise about 1500 species, or 6.4% of the total.
4. ***Littoral or continental shelf*** species, shallow-dwelling fishes that inhabit the shore and shelf above 200 m, are the largest group, constituting 45% of the total, or about 11,250 species.

Distributions of inshore marine fishes indicate four major marine regions, in order of decreasing biodiversity:

1. Indo-West Pacific
2. Western Atlantic
3. Eastern Pacific
4. Eastern Atlantic

The Indo-West Pacific Region- from South Africa and the Red Sea east through Indonesia and Australia to Hawaii and the South Pacific Islands all the way to Easter Island- contains about one-third of the species of shallow marine fishes, which amounts to about 3000 species, compared to no more than 1200 in any other region. Biodiversity is also high in other marine taxa in this region.

### *Freshwater fishes*

Freshwater fishes make a much larger contribution to biodiversity than might be expected based on area alone. About 41% of the world's fish species live in freshwaters. Freshwaters comprise only 0.0093% of the water on the planet, which means that nearly half of all fish species live in less than 1% of the world's water supply. It means that the average marine species has 113,000 $km^3$ available to it, whereas the average freshwater species has only 15 $km^3$. This is about 7500-fold disparity and the cause is very complex involving ecological as well as historical (phylogenetic and geologic) factors. Two likely influences are **productivity** and **isolation**.

Shallow waters receive significant sunlight, allowing photosynthesis, which forms the base of food webs. Most freshwaters are shallow and relatively productive, whereas most water in the world's oceans lies well below the euphotic zone where primary productivity occurs.

The potential for isolation is a historical factor that differs greatly between marine and freshwater habitats. Marine habitats are broadly continuous; significant faunal breaks occur primarily where continental landmasses, large rivers or sills, and major oceanic currents act as geographic boundaries. Freshwaters, in contrast, are frequently and readily broken up into isolated water bodies. Drought, volcanoes, landslides, tectonic up lifting, and beavers are some of the agents that can lead to a body of water losing its connection with other bodies, which in turn isolates the fishes in that body from gene flow with other areas. Genetic isolation is a driving force of evolution, leading to such dramatic events as explosive speciation and formation of species flocks.

There are **primary** freshwater fishes, whose members are very strictly confined to freshwater, and **secondary** freshwater fishes, whose members are generally restricted to freshwater but may occasionally enter salt water. The term **peripheral** has been used for a number of species and genera of marine families that have taken up more or less permanent residence in freshwater or that spend part of their life cycle in freshwater and another part in marine habitats (**Diadromous**).

## Freshwater zoogeographic regions

An effective way to understand the distribution of freshwater fishes is to recognize six regions or realms, as Walfred Wallace first proposed in 1876:

1. ***Nearctic*** (North America except tropical Mexico)
2. ***Neotropical*** (Middle and South America, including tropical Mexico)
3. ***Palearctic*** (Europe and Asia north of Himalaya Mountains)
4. ***African*** (or Ethiopian)
5. ***Oriental*** (Indian subcontinent, southeast Asia, the Philippines, and most of Indonesia)
6. ***Australian*** (Australia, New Guinea, and New Zealand)

The African region has a diverse freshwater fish fauna that includes about 2000 species of primary and secondary fishes belonging to about 280 genera and 47 families. Roberts (1976) recognized 10 ichthyofaunal provinces (from north to south): Maghreb, Abyssinian highlands, Upper Guinea, Nilo Sudan, Lower Guinea, Zaire, East Coast, Quanza, Zambezi, and Cape of Good Hope.

There are some two hundred or more natural lakes in Africa inhabited by fishes, the number of species ranging from one to around 250.

The names of the ichthyofaunal provinces are based on terms for geographical regions with which they correspond closely, although not perfectly in every instance. Thus "Guinea" is a term formerly applied to the entire coast of central West Africa from Senegal to Angola. Guinea is divided by the Niger Delta into Upper Guinea and Lower Guinea. The Upper Guinean ichthyofaunal province includes all of Upper Guinea except Dahomey, Togoland, and that part of Ghana occupied by the Volta basin. The Lower Guinean ichthyofaunal province includes all of Lower Guinea east to the Zaire River, plus the forested part of the Lower Niger Basin.

**"Maghreb",** from an Arabic word meaning "the West" designates the inhabited portion of Africa, which extends along the Mediterranean coast from Egypt to the Atlantic Ocean and includes Libya, Tunisia, Algeria, and Morocco. The outstanding physiographic feature of this region is the Atlas Mts. extending 1500 miles W.S.W.-E.N.E. from Cape Noun (W.) to the Gulf of Gabes, traversing Morocco, Algeria, and Tunisia. Still further south lies the Saharan Atlas in which the only permanent standing water is in oases. The large rivers in the Atlas are perrenial and subject to terrific spates. The freshwater fish fauna of the Maghreb is extremely poor. Primary division fishes are represented exclusively by six to ten species of Cyprinidae and a single species of Cobitidae.

***Abyssinian highlands***

The hydrography of N.E. Africa is dominated by the drainage of the Nile, which covers 1,100,000 square miles or roughly a tenth of the African surface. The only river longer than it is the Amazon. The Nile has three major tributaries, the most important being the Blue Nile, arising in the central highlands of Ethiopia. Next is the White Nile, draining lakes Albert and Victoria. The Atbara, arising in the N.W. highlands of Ethiopia and the last to join the Nile, is of much less importance than the other two. The lower 1670 miles of its course the Nile flows through arid country where the only tributaries it receives are wadis, which are usually, dry and supply water only during brief periods due to run-off caused by storms. The headwaters of the Blue Nile (or Abay) flow into L. Tana. The outlet of Lake Tana is the Blue Nile. The only falls of any height on the Blue Nile are at Tisisat, 20 miles below L. Tana. It is estimated that half the water of the White Nile is lost by evapotranspiration in the Sudd.

The mountainous Ethiopian plateau rises steeply from the Nile lowland. Its highlands are divided into two sections by the East Rift Valley. The N.W. section, culminating in Ras dashan (15,158 ft. high) is the larger and higher of the two; most of it, including Lake Tana, drains west or North into the Nile. In the south, however, it is drained by the Omo River into Lake Turkana (Rudolf). The narrow S.W. section descends gradually to the semiarid Ogaden plateau, which slopes towards the Indian Ocean. It is drained mainly to the East by the Webi Shebeli (1200 miles long) and the Juba, into the Indian Ocean. Cyprinidae dominates the impoverished fish fauna of the Ethiopian highlands.

**The Nilo-Sudanic** fish fauna ranges more or less continuously throughout the Nilo-Sudanic province. The northern limit of distribution of Nilo-Sudanic fishes is obviously controlled by climate. The majority of Nilo-Sudanic fishes in the Senegal, Niger, and Chad basins probably extend North as far as there are flowing rivers. In Ivory Coast, the entire Comoe system and the upper courses of the Bandama and Sassandra rivers are inhabited almost exclusively by Nilo-Sudanic fishes, while the lower courses of the Sassandra and Bandama and the entire Tano River of Ghana, covered by the rain-forest, are inhabited by a mixture of Nilo-Sudanic and Upper Guinean species.

In the Senegal system, the lower, middle, and probably some of the upper courses are largely populated by Nilo-Sudanic fishes. There is no evidence that the Nilo-Sudanic fish fauna formerly extended into the Eastern Rift valley south of Lake Rudolf. The Juba and Webi Shebeli are the only rivers on the East coast of Africa having Nilo-Sudanic fishes in any numbers.

The main coastal rivers of **Upper Guinea** are from Senegal to Ghana.

The main river systems in **Lower Guinea** are from Nigeria to Zaire. The fishes of these rivers are poorly known.

The **Zaire** drainage, including L. Tanganyika, is by far the largest in Africa and has the densest hydrographic network. It extends from $8^{o}$N to $13^{o}$S. The Zairean ichthyofaunal province has nearly twice the total number of riverine species as the next richest African ichthyofaunal province, and nearly three times the number of endemic riverine species.

Geographical or ecological factors that presumably favored this richness include:

1. The sheer size of the Zaire basin;
2. The density of its hydrographic network (related in large part to the high rainfall);
3. Climatic stability of the Zaire basin due to its equatorial position and forest cover;
4. Extent of both rain forest and savannah or steplands areas within the Zaire basin, and the large number of low and high gradient, blackwater, whitewater, and Clearwater streams;

5. Hydrographic barriers of varying effectiveness on virtually all major tributaries in the Zaire basin, as well as on the mainstream of the Zaire River, often marking the transition from low gradient to high gradient stream conditions or from forest to savannah areas and tending to prevent species from dispersing throughout the basin;
6. expansion of the catchment area of the Zaire at the expense of adjacent basins by river capture, often incorporating large parts of their fish fauna with its own

**The East Coast** fish fauna is very poor. There are less than 100 primary and secondary division species, and although more than half of them are endemic, there is only one endemic genus.

**The Zambesi** ichthyofaunal province includes the entire hydrographic basins of the Cunene, Ovambo, Okavango-Ngami, Zambesi, and Limpopo, plus the coastal rivers in between the lower Zambesi and the Limpopo, and south of the Limpopo up to and including the Pongola or Malputo.

**The Quanza** constitutes evidently a separate ichthyofaunal province. The principal drainages are from North to South, the M'bridge, Loje, Dande, Bengo, Quanza and Catumbela. The Quanza River over 600 miles long, with its tributaries the Lucala and the Luando, drains the largest area.

**The Cape of Good Hope**, as defined by geographers, coincides with an ichthyofauna province. It includes the entire hydrographic basin of the Orange-Vaal River and all of the drainage systems South of the Orange-Vaal and West of the Pongolo River. The freshwater fish fauna of the Cape, consisting of 54 species including peripheral division forms is notable for the high proportion of localized endemics, the predominance of Cyprinidae, and the very small number of Zambesian species.

## Commercially Important Fishes and Other Organisms

**Commercial fishing** is the activity of catching fish and other aquatic organisms for commercial profit, mostly from wild fisheries. It provides a large quantity of food to many countries around the world, but those who practice it as an industry must often pursue fish far into the ocean under adverse conditions. Large-scale commercial fishing is also known as **industrial fishing**. The major fishing industries are not only owned by major corporations but by small families as well. The industry has had to adapt through the years in order to keep earning a profit. Commercial fishermen harvest a wide variety of animals, ranging from **tuna, cod, carp, and salmon to shrimp, krill, lobster, clams, squid, and crab,** in various fisheries for these species.

There are large and important fisheries worldwide for various species of fish, mollusks, crustaceans, and echinoderms. However, a very small number of species support the majority of the world's fisheries. Some of these species are **herring, cod, anchovy, tuna, flounder, mullet, squid, shrimp, salmon, crab, lobster, oyster and scallops**. All except these last four provided a worldwide catch of well over a million tons in 1999, with herring and sardines together providing a catch of over 22 million metric tons in 1999. Many other species are fished in smaller numbers.

The industry also managed to generate over 185 billion dollars in sales and also provide over two million jobs, according to an economic report released by NOAA's Fisheries Service in 2006. Commercial fishing may offer an abundance of jobs for the unemployed.

More is known about finfish than most other species groups because of their generally larger size, and because they are subject to intense commercial fishing. Statistics on fish catches are reported regularly to the Fisheries and Agriculture Organization (FAO) of the United Nations.

Sixty-two large marine ecosystems (LME's) have been defined around the world. They are relatively large (>200,000 $km^2$) regions characterized by distinct bathymetry, hydrography, productivity, and interacting marine animal populations.

Japanese anchovy is widely distributed in the northwestern Pacific Ocean, and is the most abundant pelagic species in the Yellow and East China seas. Research surveys during the winters of 1986-1995 indicated that anchovy biomass fluctuated from 2.5 to 4.3 million t in the Yellow and East China seas. However, recent overexploitation seems to have depleted anchovy stocks in the Yellow Sea. Changes in the pelagic community are also obvious. In 1959, demersal fish species were dominant in Chinese waters. However, they have mostly been replaced by small pelagic fish and invertebrates over the past two to three decades.

Major fisheries in these areas are large trawls, large pair trawls, large purse seines and offshore stow nets. Major target species of this fishery are hairtail, filefish and common squid. Both catch and CPUE of the large trawl fishery increased continuously from the mid-1970s with the sudden increase in the catch of filefish. The catch showed a peak in 1990 at 170 thousand t, but thereafter decreased with the decreased catch of filefish in the early 1990s. However, the catch started increasing from 1995 with the increase in the catch of common squid. Major target species of the large pair trawl fishery are hairtail, small yellow croaker, corvenia and blue crab. Annual catches were pretty stable at about 110 thousand t in recent years.

Major species of the large purse seine fishery are chub mackerel, horse mackerel and sardine. Annual catch of the fishery showed some fluctuations ranging from 70 thousand t in 1975 to 460 thousand t in 1986, while annual CPUE was fairly constant, compared to catches. After 1986 catches started declining with the decrease in the catches of sardine and filefish. Catches increased again with the rising of chub mackerel catch in the late 1990s.

Major target species of the offshore stow net fishery are hairtail, small yellow croaker, corvenia, pomfret and blue crab. Annual catches of the fishery declined after 1987, and the catch was about 120 thousand t in 1997.

## Summary

The first known fishlike vertebrates occur in the fossil record of the Ordovician period, nearly 500 million years ago. These were jawless Ostracoderms, because of their armored skin. There are two living representatives of the group; hagfishes and lampreys.

Placoderms (plate-skinned) were known to be the first jawed vertebrates (gnathostomes). They were known only from fossil evidences and were pioneers for jaws and paired appendages (locomotory structures). The cartilaginous fishes are represented by the living sharks, rays, and ratfishes.

Bony fishes are the largest and dominant group with two major divisions; the Sarcopterygii (Lobe-finned fishes) and the Actinopterygii (Ray-finned fishes). The lobe-finned fishes include *Latimeria chalumnae* (Living Fossil), and the lung fishes (Dipnoi). The ray-finned fishes include three groups (Chondrostei, Holostei and Teleostei). The Chondostei are represented by Sturgeons and Polypterus (African Bichir), while Holostei is represented by Bowfins and Garpike.

The Teleostei is a large assemblage of many diverse groups and includes 38 orders, about 425 families, and nearly 4070 genera of living fishes. It consists of four monophyletic lines

(Osteoglossomorpha represented by elephant fishes; Elopomorpha represented by Eels; Clupeiformes represented by herrings and allies and Euteleostei encompassing about 22 000 species. Euteleosts consist of 9 Superorders, of which two are very important as far as the fish fauna of Ethiopia is concerned (Ostariophysii and Acanthopterygii). The former consists of orders like Cypriniformes, Characiformes and Siluriformes which consists of species that are common in freshwater systems of Ethiopia.

The distribution of fishes was influenced by the movement of the continents, as was the distribution of other organisms. The distribution can be conveniently expressed as Marine, Freshwater and Brackish water. The Marine habitat is a continuous system that can be divided into ecological zones based on depth (**Epipelagic** (up to 200 m. depth; **Deep pelagic** (200-1000 m), **Deep benthic** (1000-4000 m) and **Littoral (Continental shelf)** –above 200 meters and at shores).

The freshwater system is divided into realms, as are the terrestrial habitats. Six realms are recognized consisting of **Nearctic** (North America except tropical Mexico); **Neotropical** (Middle and South America, including tropical Mexico); **Palearctic** (Europe and Asia north of Himalaya Mountains); **African** (or Ethiopian); **Oriental** (Indian subcontinent, southeast Asia, the Philippines, and most of Indonesia); and **Australian** (Australia, New Guinea, and New Zealand).

The African region is divided into ten ichthyological provinces of which the Zaire basin consists of the most diverse species of fishes. Of the ten ichthyological provinces, Ethiopia consists (partly or wholly) three provinces (Nilo-sudan, East Africa and Abyssinian highlands).

**Commercial fishing** is the activity of catching fish and other aquatic organisms for commercial profit, mostly from wild fisheries. The world fisheries is largely from **herring, cod, anchovy, tuna, flounder, mullet, squid, shrimp, salmon, crab, lobster, oyster and scallops**.

The major commercially important fish species in Ethiopia include Nile tilapia (*Oreochromis niloticus)*, Barbs (*Labeobarbus* spp.), Nile perch (*Lates niloticus)*, Catfish (*Clarias gariepinus)* and Common carp (*Cyprinus carpio)* (introduced).

## Review Questions

1. Define fishes and characterize them.
2. How are lampreys different from other groups of fishes?
3. What are the four monophyletic lines within teleostei? Give examples for each.
4. Which three freshwater realms are rich in fish diversity? Why?
5. In which of the African Ichthyofaunal provinces is fish diversity highest? Why is that so?
6. Mention five commercially important groups of aquatic organisms, considering fish as one of these groups?

# Chapter 3 - Fish feeding, Growth and Reproduction

## Introduction

Food habits and feeding ecology research is a fundamental tool to understand fish roles within their ecosystems since they indicate relationships based on feeding resources and indirectly indicate community energy flux which allows inferring competition and predation effects on community structure.

Good nutrition in animal production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs. Fish nutrition has advanced dramatically in recent years with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of new species- specific diet formulations supports the aquaculture (fish farming) industry as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and seafood products.

From its food a fish must obtain macro-and micronutrients. The macronutrients are proteins, lipids and to a lesser extent carbohydrates. These macronutrients supply the basic building blocks-amino acids from proteins, fatty acids from lipids and sugars from carbohydrates, which are used to repair damage to the body tissues and to synthesize new flesh. The macronutrients are also the fuel that is oxidized during respiration, yielding energy. This energy is used to do the work of maintaining a functioning body, swimming and synthesizing new tissue in the form of body growth or reproductive products (eggs or sperm). The micronutrients are the essential vitamins and minerals that are required, in small quantities, for effective metabolism.

## Feeding

Feeding is carried out daily by most of fish. Other activities like flight from enemies, reproduction, and migration might be occasional or periodic but feeding is part of a day to day activity in some species it may need extended period of time. Competition can be reduced or avoided by switching to other foods even though the new foods are not customary.

The locomotion power and structures of fish are used in greater measure for finding and gathering of food. Detection of possible food item at a distance can be through chemical senses, the eye, auditory organs, lateral line system or electro-sensory system. Many species are visual feeders; the position of the eye in the head serving the particular feeding habit.

Olfaction and taste both play major roles in feeding. Fishes like lung-fish, eels, and spiny eels have well developed olfactory system as do sharks, rays, and many deep sea fishes. Many species get the first signal of food and follow the chemical gradient due to general alert of olfaction.

Taste along with the tentacle sense is significant in final selection of food and its retention for preparation and swallowing. Although taste buds are in the mouth, external taste buds over the skin are also observed in fishes like catfish and cyprinids. Fishes separate unwanted detritus from food at the level of pharynx. Taste buds are abundant on the gill arches, gill rakers, epi-branchial organs and tissues covering pharyngeal teeth. In many instances, materials are ejected through gill opening after subjected to taste sensory facilities. Large particles are ejected through the mouth with a ‘coughing’ action.

The amount of food ingested per day and the amount of time spent feeding depends on many factors. Active predators with high metabolic rate require more food energy than do sluggish fishes. If the predator feed on small organism, great amount of time is needed. However, if the predator can catch and swallow large organism, it may satisfy with one or two capture per day. Daily and seasonal temperature fluctuation affects food intake in most species. The predator, feeding on the body of other animal like crustaceans, squids and other fishes, is ingesting high protein that provides nutritional requirements. On the other hand, herbivore or detritivore must ingest large quantities of less concentrated foodstuff, so feeding activity in this kind of fish require greater period.

Some species feed by sight and active by day time, although peaks of feeding activity occur in morning and evening. Fishes that depend on chemical sense can feed in twilight. They may be more active in early morning and late evening. Other difference in feeding is due to season, cycles of migratory and reproductive activity or age and size. Small individuals consume more per day in relation to their body weight than large individuals.

## Feeding Structures and their Function

***The Mouth***

The structure of a fish's mouth can reveal its feeding habits; some fishes have protrusible mouth which can scroll in and out. Fishes can be divided into three feeding groups based on the position of feeding related to their mouth structure, Surface feeders (Superior), mid-water (Terminal), and bottom-feeders (inferior).

**Superior:** This kind of fish has an upturned, scoop-like mouth which is designed to feed on prey that swims above the fish, or perhaps on the surface of the ocean or lake, such as insects or plankton. Surface feeding fish usually have an undershot or upturned (superior) mouth for feeding on insects or floating prey. However a superior mouth does not automatically signify a surface swimming fish; fish with this mouth position feed on food that is above them and are either a predator or a strainer (Fig. 3.1.)


**Figure. 3.1 Mouth structure of surface feeders (Superior) fishes**

**Terminal:** Fish with a terminal mouth position have a mouth in the middle, or center of their head. These fish either chase their food or feed on what is ahead of them. The terminal mouth position is considered the "normal" position, and most fish inhabiting the middle levels of the oceans or lakes possess terminal mouths (Fig. 3.2)


**Figure. 3.2 Mouth structure of mid-water (Terminal) fishes**

**Inferior:** Bottom feeding fish generally have underslung or inferior mouths. Ventrally-oriented mouths or mouths located under the fishes head that are adapted for scavenging or grazing on algae, invertebrates or mollusks, and are usually seen in fish such as the catfish or flatfish like halibut or plaice (Fig. 3.3)


**Fig. 3.3 Mouth structure of bottom-feeders (inferior) fishes**

> ***In-text question***: *How does the shape of the mouth give clue to the feeding habits of fishes?*

## Variety of Foods and Foraging Activity

Most species of fishes are predatory, feeding on living animals. But in some tropical habitat 10 to 20 species primarily depend on plant material for food. Fishes are often categorized by their foods and feeding strategy into the following:

***Carnivores***

The benthic invertebrate fauna provides a significant portion of the food of carnivorous fishes. Organisms such as aquatic insect (larvae & pupa), small crustaceans, mollusks and worms constitute the main food source of most fishes. Some benthic predators live in the bottom and hunt individual organisms. Predaceous fishes may seek prey individually, in schools or in company of other species. Some pelagic predators such as sharks, salmons, tunas, jacks and dolphin fishes hunt by sight. In some case group of predators have herded prey against the shore into tightly packed schools thus preventing effective escape like the blackfin reef shark. Many predators such as sculpins, stonefishes, groupers, morays and flatfishes lie and wait in a hiding place then ambush prey that comes near. Benthic lophiiforms, such as goodefishes, batfishes and frogfishes employ lures to draw prey close to their mouths.

The ceratioid angler fishes and viperfishes have elaborate lures with luminescent developed from the dorsal fin for the attraction of prey. The squarehead or angler catfishes use wormlike barbells at the corner of their mouths as lures. Some predators like electric rays, electric catfishes and stargazers are aided in food capturing by strong electric organs that immobilize the prey. A special kind of dependence on other fishes as a source of food is seen in cleaning symbiosis. In this relationship the host fish is cleaned of parasites, in some cases the cleaner may bit the host fin like the ichthyoborids of Africa are known as fin biters due to parasitic existence by feeding on the fin of other fishes.

Some characoid of South America and several cichlids of the African lakes are scale eating fishes. The slender piranha can eat scales, parts of fins as well as flesh. Lampreys are generally termed parasitic feeders but they are predatoparasitic because they are close to the host body, rasp out and ingest viscera then kill the victim. Hagfishes are mostly saprophagous feeding as scavengers. Many species feed on zooplanktons, some by straining the water through the gill rakers others by selecting individual organisms. They capture individual organisms in two ways: - sucking in rather passive prey in simple particulate feeding and darting after more vigorous organisms.

***Herbivores***

There are no fishes that are lifelong herbivore because larvae and juveniles usually began life feeding on zooplankters. There are many species that depend on intake of plant material throughout adult life and show appropriate structural modification for gathering, processing and digesting it. Those species feed on phytoplankton have long fine and closely spaced gill rakers so they are engaged in filter feeding. There is a number of species that browse on large filaments algae or vascular plants. The grass carp, tilapia species, rabbitfishes, triggerfishes, orangespot surgeon fishes are herbivore fishes. Numerous species in both marine and freshwater habitat are adapted to films of diatoms and vegetation from substrate. This grazing is accomplished by means of modified jaw edges and in some by teeth. Some special feeding habit has developed in the Amazon basin. Many characiform fishes commonly feed on fruit, nuts and other flowers of plants growing over the waterways or in the seasonally flooded forests of this area.

***Omnivores***

Although they may be specialized for a narrow diet, some species turn to wider choice of food when the opportunity arises. A variety of herbivores can be caught with animal bait. Many of the cichlids of the African great lakes have teeth, jaws and pharyngeal teeth that are morphologically specialized for feeding on a narrow range of foods also opportunistic and advantageous to take easily obtained food. Some species appear to be omnivorous commonly taking a variety of foods in their daily fare. The common carp is the best examples of fish that will eat various kinds of animals including fishes and also eat plant material as well. The rainbow trout and channel catfish have wide taste in food.

## Digestion

In most fishes, chemical digestion begins in the stomach which differs from the esophagus in the composition of the wall and in the type of gland in the mucosal lining. In addition to secreting a protective mucus and pepsin, a protease, the gland of stomach secret hydrochloric acid. pH value of about 1.5 to 4 is common in the stomach of predatory or insectivore's species and some herbivore fishes have acidic stomach for digestion of algae.

Fishes secrete gastric enzymes in addition to pepsin; proteases are optimally active at pH 3 to 5. Also chitinase has been obtained in insectivores and in species that feed on crustaceans. Amylase has been identified in some clupeids, lipase also in clupeids and Mozambique tilapia. Fishes that habitually ingests a large proportion of indigestible material with their food appears to have the longest relatively gut length and this increase the retention time of food and allow more efficient digestion of materials.

Digestion proceeds in the intestine, enzymes are secreted by the pancreas, intestine mucosa and other organs. The amount of enzyme depends on the species feeding habit. Pancreatic tissue is the source of many of the digestive enzymes and the protease enzyme, trypsin is secreted by the pancreas. Surface epithelial cells of the intestine in the vertebrate secrete a variety of enzymes that act on carbohydrates, but the knowledge of intestinal enzyme is by no means complete. The liver secrets emulsifiers carried to the intestine in bile that aid in fat digestion. Lipase and esterase cannot hydrolyze fats that are not in solution.

Rates of digestion are variable. Depending on type of foodstuff, species of fish, temperature and amount of food ingested. There are some small fishes of a given species that digest food more rapidly than larger individuals.

## Nutrition

Fishes, like other animals, require the common components of food (protein, carbohydrates, fats, minerals, vitamins and water) for maintenance, movement, normal metabolic functions and growth. Fish can obtain their energy and nutrients from natural food in ponds, from feed supplied by the farmer or from a combination of both sources. The food requirements of fish vary in quantity and quality according to their feeding habits and digestive anatomy as well as their size and reproductive state. Food requirements are also affected by environmental variations such as temperature and the amount and type of natural food available.

Most information available on fish nutrition pertains to species that are reared in captivity, including the following species, Salmonidae, Japanese ell (*Anguilla japonica*), some members of cyprinidae, madai (*Pagrus major*), channel catfish (*Ictaiurus punctatus*). Because fish culturists need means of producing more and better fish at lower cost, there is a practical value in studying fish nutrition. Fishes differ from warm blooded animals in that their metabolism is directly influenced by temperature, so some species are adapted to cold water and others to warm water. Furthermore, fishes of various species, especially carnivores, can utilize protein and fat for energy source more effectively than mammals.

**Proteins:** Most species of fishes subjected to intensive aquaculture are known to require high dietary protein level. Protein requirement of salmonid fish is studied and it differs with temperature. ; Less protein is required at low temperature than at higher one. Channel catfish production contains 32 to 36 percent protein. In general, age and temperature are considered to have effect on the total dietary protein required by fishes.fry of channel catfish need about 40% protein and fingerlings about 30-35%. Salmon fry require 45-50%protien and yearling about 35%.

**Carbohydrates:** Inclusion of carbohydrates in the diet can spare some protein for use in growth rather than for energy expended in activity. Carbohydrates are usually much more inexpensive than proteins, so there is an economic advantage if they can be fed to cultured fishes.

Omnivorous species such as carp can digest Carbohydrates better than other carnivorous and can have a higher percentage in the diet. Carnivorous species may show nutritional disorder if fed an excess of digestible carbohydrates. Digestibility of carbohydrates by trout ranges from 100% for some simple sugars to about 30% for row starch and 0% for fiber. Salmonids usually respond to high levels of dietary carbohydrate by depositing an excess of glycogen in the liver and excess fat, including infiltration of fat in the liver and kidneys. Trout are naturally diabetic and will retain high level of glucose in the blood when feed excess carbohydrate.

**Lipids:** Fats provide an energy source for fishes but can be used only in limited amounts. If fed in excess, fat will infiltrate the liver and possibly cause death. Fats differ greatly in digestibility (those with high melting points are difficult for fish to digest). When digestible fats are used in balanced diets, some of the dietary protein is spared for growth or other purposes in addition to energy. Rancid fats are harmful in fish diets; fishes fed oxidized fats have been noted to develop fatty generation of the liver. Some naturally occurring oils are known to contain substances toxic to some fishes. For instance, cotton seed oil contains cyclopropene fatty acids, which are harmful to trout if fed above certain level. Fishes are not capable of synthesizing all the fatty acids necessary for growth, but a relatively few have been studied either qualitatively of quantitatively. Fats can constitute as much as 20% of properly compounded diets for salmon and trout; this level approximates the highest level of lipids usually found in natural diets of trout. Most trout feeds contain 15% or less of fats.

**Vitamins:** are needed in the diets of all fish species for which this aspect of nutrition has been studied. Essential vitamins for salmonid(trout) includes; ascorbic acid(C), thiamine($B_1$), riboflavin($B_2$), pyridoxine($B_6$), vitamin $B_{12}$, biotin(H), chaline, folic acid(folacin), inocitol, niacin, pantothenic acid, tochopherol (E), vitamin K and A. Vitamin requirements are usually determined by experimental feeding of fish diets which specific vitamins have been withheld. Deficiency of ascorbic acid in Salmonid (trout) can cause abnormal spinal curvature, internal bleeding, poor or no growth is a consequence of withholding several vitamins. Also excesses of some vitamins are detrimental, for instance, excess of vitamin A causes pathological changes in Salmonid (trout), including enlarged liver and abnormal growth of bone.

**Minerals:** There has been some difficulty in assessing the dietary requirements of minerals and other trace elements in fishes because of their ability to absorb elements directly from the water.

Calcium, chloride, cobalt, phosphorus, strontium and sulfate can all be taken out of the water. In addition, many elements are required in such small amounts that quantitative assessment is difficult.

Minerals and related substances required in large quantity by most animals are calcium, phosphorus, magnesium, potassium, sulfur and chloride. Many others are known to affect the health and growth of animals even though they are present in trace amounts. Calcium and phosphorous are important to bone growth and deficiency of either can result in abnormal skeletons. Magnesium is essential to the proper development of bone, to normal growth and appetite. Fresh water need about 0.05% magnesium in their diet. Iron is essential for cellular respiration is usually sufficiently supplied to fish in diets both natural and artificial. Iodine is necessary for production of hormones from the thyroid and the deficiency of this element in the diet can cause goiter.

***In-text question:*** *Do you see any difference in the nutritional needs of fishes and humans?*

## Growth

Although most fishes have indeterminate growth, individuals of a given fish species have a genetic potential for reaching a maximum size under the most favorable circumstances. Some gobies never reach more than a few centimeters in length but sharks and tunas may reach many meters. Under less favorable environmental conditions, fishes reach a size smaller than physiological attainable for the species. Growth is usually faster in warm weather than in cold and may decrease during migrations or spawning, sometimes even being negative when metabolic demands exceed the food energy in take. In addition to annual fluctuation, fish's growth may occur in 'stanzas' during the normal life history. Each stanza is being defined by a sigmoid curve showing a slowing down of growth before resumption of more rapid growth with entry in to the next stanza. Growth stanza generally results from physical, physiological, and ecological changes.

A migratory fish might end its first growth stanza; begin its second by moving from stream in to lake or ocean. And begin a third, when it is large enough to feed on other fishes rather than small invertebrates. Factors involved in irregular or limitation of growth may be environmental or may be concomitants of the fish's physiology. Environmental factors include water quality such as dissolved oxygen, carbon dioxide, salinity, ammonia, pH, and chemical pollutant. Physical factors include temperature and light, both changes with the season. Physiological factors that can influence on growth include age and sexual maturity. Behavioral factor may include spawning activity, migration, and defense of territory. Production of gametes and reproductive activity can require significant proportions of ingested energy.

However, there is a need to maintain the level of dissolved oxygen at the saturation level which will not affect its physiological or metabolic activities, so as to have high production in any culture system. More than that, one has to keep in mind that the oxygen level requirement depends on the species, but also on fish size and activity of the fish. Oxygen requirements per unit weight of fish significantly decline with increasing individual weight. In carp species this reduction may be expressed by the following ratios: yearling = 1, two-year-old = 0.5–0.7, marketable = 0.3–0.4. Significant differences in oxygen demand are also found for different species. Generally, food and temperature favorable for growth occur during spring, summer, and fall in temperate area, but most species do not grow at a constant rate during this periods. Summer- spawning species like bluegill may put on most of the years growth in the spring and then grow slowly through the spawning period and the warmest part of the summer. Spring spawners grow best following spawning.

In addition to food source and temperature, growth rate is regulated by hormones. Thyroid hormones are thought to bring about increase in fish growth by increasing appetite and by increasing the efficiency of food conversion. Physiological changes influenced by hormones affect growth rate during migration, spawning, and wintering, all natural segments of the life cycle. Hormonal differences can be seen in the differential growth of the sexes. In some species males are of much smaller maximum size than females. This occurs in many species that have internal fertilization, but the most extreme examples of sexually dimorphic size are the ceratioid anglerfishes, in some of which the males parasitize the females. Fertilization is external in the ceratioids. In species that the males are larger than females, size is related to function, and the males are involved in building, guarding nests or in other activities that require size and stamina.

Hormones are involved in the response of fishes to stress full situations. Most fishes grow at a slow rate under stress such as overcrowded. Even when sufficient food is made available, fishes held in overcrowded ponds grow poorly. That is probably caused by tertiary effects of stress. Growth may be studied in terms of nutritional bio-energetic considerations, with expectation that the knowledge gained will aid in growing fishes faster on less expensive rations than currently used.

Many marine species live to advanced ages. For example, the short raker rock fish (*Sebastes borealis*), is known to live 120 years and the rougheye rock fish (*Sebastes aleutianus*) reaches 140 years. In many species, interpretation of recognizable marks left periodically in scales or other hard structures can result in determination of age. In those species that lay down compressed circuli in the scales during winter, slow growth and form annuli, age can be determined. Then there might be relationship between growth of the scale and growth of the fish, measurement of a selected scale dimensions, such as the radius to each annulus and to the edge of the scale, can allow a back calculation that results in an estimated length of the fish at each annulus.

Validation of the result of such studies can be accomplished by research on individuals that are captured, measured, marked, released and later recaptured. Comparison of scales or fin ray sections taken at initial capture and recapture of the same individual can be useful to validate or invalidate the use of these methods for estimation of age and growth for the species involved. Age and growth in fishes are being studied by such relationships and methods also RNA-DNA ratios, uptake of radioactive amino acids and amino acetic acid.

## Methods of Food and Feeding Determination

Fish should be preserved soon after capture to prevent continued digestion. Fish digestive tracts can be extracted and placed in 4-10 percent buffered formalin immediately after capture. Though formalin quickly halts digestion, it may also cause the food mass to solidify, making prey identification difficult.

Several different ways of measuring prey use and analyzing feeding habits have been proposed and used, but little agreement exists that would enable uniformity in analyzing food habit data.

Most methods use one or more of the following three measures:

1. ***Frequency of occurrence:*** the proportion or percent of fish guts in which a particular food item was found;
2. ***Numerical abundance:*** the number of individuals of a particular food item found in each gut or the percent of all gut contents combined that the prey type comprised;
3. ***Volumetric (weight) importance:*** the quantity of each item measured either by water displacement (usually in a graduated cylinder) or scale (after the item is blotted dry), or the percent by volume or weight that a given prey type comprised of the total volume of all gut contents

Any one of these measures can be ranked, creating rank-hierarchy lists.

***In-text question: Why do you need to determine the feeding habits of fishes qualitatively and quantitatively?***

## Reproduction

***The natural history of fish reproduction***

Fish have remarkably diverse reproductive behaviors. Mating systems range from pelagic group spawning to cooperative breeding to social monogamy. Subsequent to spawning, adult care of fertilized eggs and larvae may be nonexistent, confined to one gender, biparental, or communal. When parental care is offered, it may take such varied forms as oral or gill brooding, use of natural or constructed nests, internal gestation by a pregnant mother or by a pregnant father, or open-water guarding of fry. Also interesting for genetic analysis are Alternative Reproductive Tactics (ARTs) within a species, or sometimes even within an individual during its lifetime. An example of the latter occurs in sequential hermaphroditic species in which an individual fish may switch its gender (and associated mating behavior) from female to male or vice versa. Both sex-changing and non-changing fish are present in some populations. Most fish species are gonochoristic (separate sexes).

Each fish species has evolved in response to a unique set of selective pressures, hence species often differ in their life-history strategies; each life-history strategy is a set of developmental adaptations that allows a species to achieve evolutionary success. Each life-history stage (i.e., egg, larval, juvenile, adult) has a number of possible alternative states, but the life history of a given species consists of only one of these states for each life-history period. Since each fish species evolves under a unique set of ecological conditions, it has a unique reproductive strategy with special adaptations including anatomical adaptations, developmental adaptations, behavioral adaptations, physiological adaptations, and energetic adaptations. The reproductive process allows species to perpetuate themselves. Almost all fishes reproduce sexually, thus permitting mixing of the genes of the two sexes. Fishes reproduce in fresh and marine waters, have external and internal fertilization, have short annual reproductive periods, or produce gametes at regular intervals throughout the year. For instance, sharks and rays have internal fertilization and produce small numbers of large, yolky eggs. Some retain the developing embryos in the parent and give birth to miniature copies of the adults. Others lay the eggs in elaborate egg cases where embryonic development occurs. In either case, this reproductive pattern is quite different from that seen in most bony fishes where larger numbers of small eggs are produced. Maximum egg sizes in bony fishes are up to 10 mm in salmons and 15 mm in sea catfishes. Diagram shows the variety of reproductive patterns of marine fishes is given in Fig. 2.

***Reproductive anatomy***

The reproductive strategies of fishes are often clearly reflected in the anatomical easily distinguished by examination of the gonads at least during the spawning seaso n. Both the testes of males and the ovaries of females are typically paired structures that are suspended by mesenteries across the roof of the body cavity, enclose association with the kidneys. During the spawning season, the testes are smooth, white structures, while the ovaries are large yellowish structures, granular in appearance. While the internal differences between the sexes generally obvious in mature fish, it is frequently difficult to distinguish the sexes externally. Indeed, many fishes that are mass spawners show virtually no sexual dimorphism or dicrhomatism (color differences), even when spawning. The most widespread type of sexual dimorphism is size. In egg laying fish in which the males are territorial during the breeding season, the males are often larger than the females, as in salmon. However in such species there are also non territorial males that are typically smaller than the females. Among live bearing fishes, females as a rule are larger than males. Sexual dichromatism is mostly seasonal phenomenon among fish, because bright colors that are likely to increase reproductive success by attracting mates are also likely to attract predators.

***Gonadal development***

Female fish have paired ovaries that produce eggs, and male fish have paired testes that produce sperm, which along with seminal fluid is termed milt. Although this is the general rule, there are many exceptions. Some fish change sex during their lifetime, some from male to female (protogynous hermaphrodites) and some from female to male (protandrous hermaphrodites), whereas some even produce both sperm and eggs simultaneously (synchronous hermaphrodites). Most fishes are capable of spawning several times during their life (semelparous); however, a few (e.g., Pacific salmon, fresh water eels [anguillids]) spawn once and die (iteroparous).

*Range of sexuality in fish*

Fishes have a large range of sexuality (they stand out amongst vertebrates). Fishes may exhibit hermaphroditism, unisexuality (parthenogenesis), bisexuality (gonochorism), or a combination of sexualities.

*Hermaphroditism*

Hermaphroditism may be genetically programmed or a function of the social surrounding and is particularly prevalent in tropical reef regions. In synchronous or simultaneous hermaphroditism, the left gonad is the ovary and the right one is the testis or vice versa. Although self-fertilization exists, it is rare. Synchronous hermaphroditism is usually found in species where potential mates are sparsely dispersed because if the energy costs are the same for a synchronous hermaphrodite as for a male or female, it is clearly advantageous. It is common among bathypelagic and mesopelagic species living in the darkness of the ocean depths in low-population densities.

*Unisexuality or Parthenogenesis*

Rarer than hermaphroditism, but it is found in some live-bearers (only females). Development of young is without fertilization and females produce only female offspring. There are two ways this is done. In gynogenesis, the sperm of a closely related species is used to trigger development of the egg nucleus but does not fuse with it; and in hybridogenesis, fusion occurs but only the haploid female genome is transmitted to the developing ovum.

*Bisexuality: live-bearing*

Several groups of fishes have developed a live-bearing (i.e., giving birth to free-living larvae or juveniles, rather than laying eggs) life-history pattern. A prerequisite to this pattern is mating, copulation, and internal fertilization.

**Viviparous** fishes have internal fertilization and are characterized by the embryo developing in close contact with the nourishing maternal tissue-no egg membrane covers the embryo. There are very few truly viviparous species. One of the best known examples is the surfperches (embiotocids) of the coastal waters of the Northeast Pacific, which produce well-developed young with the males of some species capable of breeding when born. In such fishes parental care of the eggs is maximum since the eggs are within the mother throughout development. Fecundity is low, usually < 100, and nourishment is primarily from the parent, not the egg (eggs small, embryo large), with the weight of the embryo increasing from fertilization to birth.

**Ovoviviparous** characterized by having internal fertilization. The mother may or may not nourish the embryo, but at any rate the embryo and the maternal tissue are separated by the egg membrane that is, no "placenta-like" structure is present. Typically, the eggs hatch internally and are released as early larvae. Again, the parental care of eggs is maximum since the eggs are retained internally, but fecundity may be much higher (e.g., in the case of rockfishes tens of thousands of young may be produced per year). Golden redfish mate in the winter when the male is ripe but the female eggs are not yet ripe, so the female stores the sperm until early spring at which time fertilization occurs. Within a single female it has been found that the embryos are all the same size, indicating a single fertilization event. The eggs hatch internally, and then are extruded (born) as early larvae, which is 2-3 months after fertilization and 6-7 months after mating. Egg laying actually, internal fertilization is very rare among teleosts.

**Oviparous** fishes "egg-laying" fishes. Males and females swim close together so that the eggs are shed into a cloud of spermatozoa. Because mating and courtship occur in man12y oviparous species, one important aspect is that the activity of sperm depends on small concentrations of Ca or Mg ions, which allows sperm to remain active in salt water for up to an hour or so as opposed to a minute or so in fresh water. The eggs are then fertilized and develop in the environment outside the female. An egg membrane is present, and the embryonic stage is nourished entirely by the yolk. The eggs of most fishes develop either in nests constructed by the adults, or they develop in the environment at large. In a wide variety of fishes the eggs are laid in nests constructed by the parents. In most cases the male builds the nest and attracts the female to lay her eggs there, where he fertilizes them. In many fishes the eggs are guarded from predators, aerated, and cleaned during development by one or both parents. Care often extends for some time after the eggs hatch. Examples of fishes exhibiting the guarding behavior mode include most sunfishes (centrarchids) and sculpins. However, some fishes that build nests for the eggs or hide them take no further care of them. For example, Pacific salmon (*Oncorhynchus* spp.) lay their eggs in depressions they dig in the gravel of the streambed, but the adults die shortly thereafter. As previously mentioned, the male and female swim close together and the eggs and sperm are broadcast into the water. No parental care is involved with the eggs and the spent (spawned-out) adults may resume their pre spawning activities. This is the most common spawning mode in the marine environment. The large number of eggs produced and their rapid dispersal makes it impossible for the adults to show any form of parental care.

***In-text question:*** *Which of the reproductive strategies is most advantageous to the survival of fishes? Why?*

***Factors triggering maturation and spawning***

There are three primary factors that influence the events leading up to spawning: nutritional state of the female, physiological factors (hormones), and ecological factors.

<u>*Nutrition of the female:*</u> The feeding condition of the mother can have an important effect on the final maturation of the eggs. Two examples from show that in some of the Atlantic herring populations spawning may occur only every other year if environmental conditions, particularly those affecting food supply are poor. Also, it has been found in the laboratory that in Atlantic

sole (*Solea solea*) no spawning occurred when the flatfish were fed a diet (mussels only) deficient in certain amino acids; however, when the flatfish were force-fed the missing amino acids they spawned, indicating the ovary had been unable to obtain the needed amino acids from maternal tissue when the nutrition of the female had been inadequate.

*Physiological factors:* Hormones govern migration and timing of reproduction, morphological changes, mobilization of energy reserves, and elicit intricate courtship behavior. The pituitary is the major endocrine gland that produces gonadotropin, which controls gametogenesis, the production of gametes, namely sperm (spermatogenesis) and eggs (oogenesis), by the gonads. The pituitary also controls the production of steroids (steroidogenesis) by the gonads; once the gonads are stimulated by the pituitary they begin producing steroids, which in turn control yolk formation (vitellogenesis) and spawning.

*Ecological factors:* Often ecological factors are associated with timing so that food availability is optimal for the larvae. Some ecological factors important to spawning are temperature, photoperiod, tides, latitude, water depth, substrate type, salinity, and exposure. Temperature is an important factor in determining geographical distributions of fishes. Although little is known about the mechanism by which temperature controls maturation and spawning in fishes, for many marine and freshwater fishes the temperature range in which spawning occurs is rather narrow, so that in higher latitudes the minimum and maximum temperature requirement for spawning is often the limiting factor for geographical distribution and for the successful introduction of a species into a new habitat. For example, Pacific halibut (*Hippoglossus stenolepis*) are found spawning primarily in areas with a 3-88 $^{0}$C temperature on the bottom. In fact, even in highly migratory tuna, spawning is restricted to water of specific temperature ranges.

***Methods in studying reproductive behavior in fishes***

Knowledge of the sex ratio and the state of maturity of individuals in a population is useful, and estimates of fecundity (the number of eggs in the ovary that will mature before spawning) are considerably important in studies of population dynamics, productivity, or population estimates. There may be sexual dimorphism in some species of fishes. If examination of the gonads is necessary, mature ovaries and testes are simple to distinguish. Ovaries are tubular and normally pink, yellow, or orange. Ovaries seem to be surrounded by a clear bag. This can be determined by picking at them with forceps. Testes are flattened, often crinkly at the margins, and usually white during spawning season and brownish at other times. Normally, sexes of even older immature fishes can be distinguished using these criteria, though ovaries may be clear and testes string like rather than flattened and ribbon like. Very young, immature fishes, where gonads are extremely small, often must be examined histologically.

*Maturity stages*

Fishes are total (isochronal) or multiple (heterochronal) spawners. Total spawners release eggs or sperm all at once or over a week or so. They generally have short, distinct breeding seasons. A majority of temperate species are total spawners. Multiple spawners like cyprinids spawn over a long period. In these species, eggs in varying stages of development exist in a single ovary. Staging is clear-cut with total spawners. Multiple spawners may have ovaries that fit two or more stages.

**Males**

| | | |
|---|---|---|
| 1 | **Immature** | Testes thread-like and contained within a transparent membrane |
| 2 | **Developing** | Testes uniformly ribbon-like. Surface of testes appears smooth and uniformly textured. |
| 3 | **Mature** | Testes large and highly convoluted; sperm cannot be extruded. Body wall incision causes gonads to be expelled from opening. |
| 4 | **Spawning** | Testes milk freely or extrude sperm when compressed. |
| 5 | **Spent** | Testes large, but flaccid, watery, and bloodshot. |

**Females**

| | | |
|---|---|---|
| 1 | **Immature** | Ovaries small, tapered, and transparent. Will not spawn this year. Sex may be difficult to determine. |
| **2** | **Developing** | Early: Ovaries tapered, forming two distinct, transparent lobes with well-developed blood vessels. No or few individual ova present. Late: Developing lobes fill up to half of the body cavity, with distinctly visible opaque, orange eggs. |
| **3** | **Mature** | Ovaries fill more than half of the body cavity and contain distinctly visible eggs. Eggs are not extruded when ovaries are compressed. Most eggs are opaque, but scattered clear (hydrated) eggs may be present. Eggs cannot be easily separated from each other. |
| **4** | **Spawning** | Ovaries large, filling the body cavity. Most eggs are transparent (hydrated) though some opaque eggs may remain. Eggs are extruded from the body under slight pressure or are loose in the ovary and easily separated from each other. |
| **5** | **Spent** | Ovaries are large, but flaccid, watery, and generally reddish. Scattered unspawned eggs can be seen. Ovaries that are "Recovering" will appear red and contain scattered eggs, but will not be as large or quite as flaccid as very recently spawned ovaries, and should be classified as "Early Developing." |

***In-text question: Why is it important to study the maturity stages of fishes in the wild?***

*Fecundity*

Fecundity is the number of eggs in the ovaries that will mature during a particular spawning season. Fecundity data are used to calculate the reproductive potential of a population. It may also be used (along with the adult sex ratio) to estimate stock size.

*Fecundity estimation*

1. **Total counts**: the most accurate estimate of fecundity is by total count of eggs in a fish. As this is tedious and time consuming, most fecundity estimates are based on sub-sampling.
2. **Subsampling of eggs**:

   **A. Volumetric method**

   1. On a paper towel, air dry the entire lots of eggs for a few minutes and obtain the total volume in a finely graduated cylinder or burette by water displacement.
   2. Take a sample(s) of the ovary. Blot or dry excess moisture and obtain the volume as in N0. 1.
   3. Count the number of eggs in the sample (s).
   4. To obtain the total number of eggs in the unknown volume, use the formula

X/n = V/v, Where X= unknown total number of eggs in the lot

N= number counted in the sample

V=total displaced volume of all eggs

V= volume of the sample

**B. Egg/volume method**

1. Count out 100 eggs and measure the volume of water displaced.
2. Measure the total displacement of the entire lot, including the sample, and calculate as above, n now will be equal to 100.

**C. Gravimetric method**

1. Weigh a known number of eggs or a standard subsample following removal of moisture.
2. Find the total weight of the entire lot similarly dried, and compute the total number by using a ratio similar to that in A4 above.

**D. Wet subsample method:** the wet subsample method has been widely touted, but its accuracy is debated by some workers.

1. Place all eggs in a beaker of water of known volume. Stir the contents using a magnetic stirrer.
2. Using a pipette, take four to six subsamples and count the eggs in each.
3. Estimate fecundity by multiplying the mean number of eggs per milliliter of sample by the volume of water and eggs from which the subsamples were drawn. For example, if all the eggs were placed in 1000ml of water, fecundity equals 1000 n, where n= the mean number of eggs per milliliter in the subsamples.

## Summary

The study of feeding and reproduction are central in the study of fish and fisheries. Food habits and feeding ecology researches are a fundamental tool to understand fish roles within their ecosystems since they indicate relationships based on feeding resources and indirectly indicate community energy flux which allows inferring competition and predation effects on community structure. Moreover, feeding is a major intervention in the aquaculture production systems and the most costly of the venture.

Fishes are either herbivorous, carnivorous or omnivorous in their feeding habits. The type of mouth would give clue as to the mode of feeding and the habitat in which the fishes feed. Like other higher animals they need macro- and micro-nutrients for proper growth and development. Hence they need carbohydrates, proteins and fats as macro-nutrients and the micronutrients are the essential vitamins and minerals that are required, in small quantities, for effective metabolism.

Most fishes exhibit indeterminate growth, which continues throughout their life although the rate of growth decreases as they get older.

Food habits could be studied qualitatively by determining the food items that an individual fish feed on through visual inspection or through gut content analysis. The quantitative analysis is important in determining the relative importance of the food items. The quantitative analysis could be determined by frequency of occurrence, numerical or volumetric (weight) methods.

Reproduction is an essential commitment to future generation. It is also a continuous development process throughout ontogeny, requiring energetic, ecological, physiological, and anatomical and biochemical adaptations. Fishes have diverse breeding behaviors that make them valuable for testing theories on genetic mating systems and reproductive tactics.

Fishes show diverse mode of reproduction, although a large proportion are oviparous. Ovoviviparity, viviparity, hermaphroditism, and parthenogenesis are seen in several groups of fishes.

Determining the sex-ratio, maturity of gonads and fecundity of population of fishes is very important in evaluating the production potential of any fish species.

## Review Questions

1. What are the nutritional requirements for the appropriate growth of fishes?
2. How does the frequency of occurrence tell the importance of any food item?
3. Why do we have to study the reproductive behavior of fishes?
4. Why do we have to take sub-samples in estimating fecundity?
5. What are the factors triggering maturation and spawning in fishes?

## Chapter 4 - Fisheries Production

**Fisheries (Fishery)** is the industry or occupation devoted to the catching, processing, or selling of fish, shellfish, or other aquatic organisms. It could also refer to a place where fish or other aquatic organisms are caught. The aquatic organisms could be different groups of algae, different groups of invertebrates, fishes, amphibians, reptiles and mammals. Strictly speaking Fisheries is divided into two parts: the capture fisheries (capturing fishes from the wild) and culture fisheries (rearing fishes in captivity). Table 1 shows the importance of world fisheries to the production of fishes and to the global economy.

**Table 4. 1. World Productions in 6 years (in Millions of tons) (Source: FAO, 2010)**

| | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **Value (in Billion $)** |
|---|---|---|---|---|---|---|---|
| **Inland** | | | | | | | |
| Capture | 8.6 | 9.4 | 9.8 | 10.0 | 10.2 | 10.1 | |
| Culture | 25.2 | 26.8 | 28.7 | 30.7 | 32.9 | 35.0 | |
| | | | | | | | |
| **Total** | **33.8** | **36.2** | **38.5** | **40.6** | **43.1** | **45.1** | |
| | | | | | | | |
| **Marine** | | | | | | | |
| Capture | 83.8 | 82.7 | 80.0 | 79.9 | 79.5 | 79.9 | |
| Culture | 16.7 | 17.5 | 18.6 | 19.2 | 19.7 | 20.1 | |
| | | | | | | | |
| **Total Marine** | **100.5** | **100.1** | **98.6** | **99.2** | **99.2** | **100.0** | |
| | | | | | | | |
| Total Capture | 92.4 | 92.1 | 89.7 | 89.9 | 89.7 | 90.0 | **94** |
| Total Culture | 41.9 | 44.3 | 47.4 | 49.9 | 52.5 | 55.1 | **80** |
| **Total Fisheries** | **134.3** | **136.4** | **137.1** | **139.8** | **142.2** | **145.1** | **174** |

**Table 4. 2. Leading countries in capture fisheries (Source: FAO, 2010)**

| Country | Production | Country | Production |
|---|---|---|---|
| China | 17000000 | Indonesia | 4100000 |
| Peru | 10700000 | Russia | 4000000 |
| Japan | 5000000 | India | 3600000 |
| USA | 4700000 | Thailand | 2900000 |
| Chile | 4300000 | Norway | 2700000 |
| | | Iceland | 2000000 |
| | | Philippines | 1900000 |

**Table 4. 3. Inland capture fisheries by continent (Source: FAO, 2010)**

| | |
|---|---|
| Asia | 66.9% |
| Africa | 23.5% |
| Americas | 5.9% |
| Europe | 3.5% |
| Oceania | 0.2% |

**Table 4.4. Inland capture fisheries (Source: FAO, 2010)**

| Major species groups | Production (tons) |
|---|---|
| Carps, barbells and other cyprinids | 734000 |
| Tilapias and other cichlids | 723000 |
| Freshwater mollusks | 428000 |
| Freshwater crustaceans | 415000 |
| Salmons, trout | 154000 |
| Miscellaneous freshwater fishes | 7 222000 |

**Table 4.5. Utilization of fishery resources (Source: FAO, 2010)**

| | |
|---|---|
| Human consumption: | 110.4 Million tons |
| Non-food uses | 33.3 Million tons |
| Population: | 6.6 Billion |
| Percapita food fish supply | 16.7 kg |

**Table 4.6. Consumption (Source: FAO, 2010)**

| **Continent** | **Percentage** |
|---|---|
| Far east | 27 |
| Africa | 21.1 |
| Western Europe | 9.7 |
| Latin America | 8.2 |
| Near East | 7.8 |
| N. America | 6.6 |

**Table 4.7. Regional distribution of fishers and fish farmers (Source: FAO, 2010)**

| | | |
|---|---|---|
| Asia | 37338000 | 85.8 |
| Africa | 3637000 | 8.36 |
| North and Central America | 1038000 | 2.39 |
| Europe | 725000 | 1.67 |
| South America | 708000 | 1.63 |
| Oceania | 55000 | 0.13 |

***In-text question:*** *Is the capture or culture fisheries more important for the total production of fishes in the world? Why is that so? Which one shows the fastest rate of growth?*

## Fishing Efforts, Fishing Gears and their Selectivity

### *Fishing effort:*

The fishing effort is a measure of the amount of fishing. Frequently some parameter is used relating to a given combination of inputs into the fishing activity, such as the number of hours or days spent fishing, numbers of hooks used (in long- line fishing), kilometres of nets used, etc.

The European Union defines fishing effort as fleet capacity (tonnage and engine power) x days at sea (time; t); the formulas are GT x t and kW x t.

CPUE standardizes catch data based on the amount of the effort (total time or area sampled) exerted.

### *Fishing gears and their selectivity*

*Passive gears*

Passive gear is stationary. It does not have to be dragged or towed to capture fish. Long lines, traps and gill nets effectively fish by themselves. The catch is recovered by simply removing the gear from the water after a period of time.

*Hooks and lines*

The simplest form of fishing requires only a line and a baited hook. The line is cast into the water where the fish supposedly are; the fish take the bait and are hauled in. A wide variety of sizes and types of hooks can be used, allowing very selective fishing.

Hooks and line fishing is inexpensive and easy. Almost any boat or shoreline can be used and the catch is live and of high quality. In spite of these advantages, line fishing is labor intensive. A very limited number of fish can be captured per line and usually some type of bait is required.

Longlines are unwatched lines with multiple hooks. They can be used at the surface, suspended in the water column, or fixed on or near the bottom. Longlines may be set from the beach by means of sailing rafts or kites if winds are favourable (Fig.4.1).

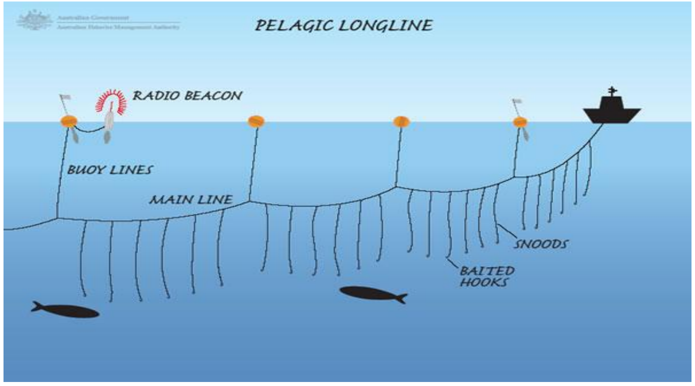


**Figure. 4.1. Longlines (Hooks and lines)**

*Traps and Pots*

Traps are devices that fish or shell fish enter in search of shelter or food, or because an obstacle is placed in the fish's normal path of migration. They are designed so that getting out is harder than getting in. Traps and pots can be quite specifically tailored to species and size. They may be constructed of local materials, generally at low cost, and usually require no bait. An additional advantage of this fishing method is the high quality of the live catch (Fig. 4.2).

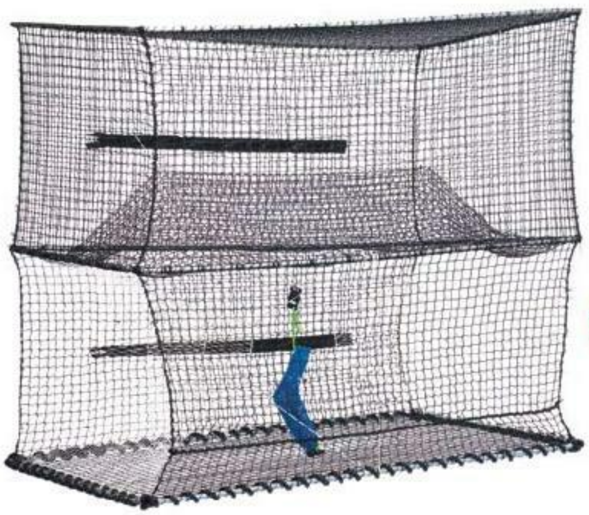

**Figure 4.2. Fish trap**

*Entangling nets*

Entangling nets are net walls placed transversely to the path of migrating fish. The bottom of the net is weighted with sniker while floats support the top. A single walled net (gill net) is used to gill fish, while a triple walled net (trammel) entangles them.

*Gill nets*

A gill net is an upright wall of fiber netting. A fish, of a size for which the net is designed, swimming into the net, can only pass part way through a single mesh. As the fish struggles to free itself, the net twine slips in back of the gill. The fish is thus gilled and can go neither forward nor backward. Various mesh sizes are employed, depending on the species and size of the fish to be caught (Fig. 4.3).

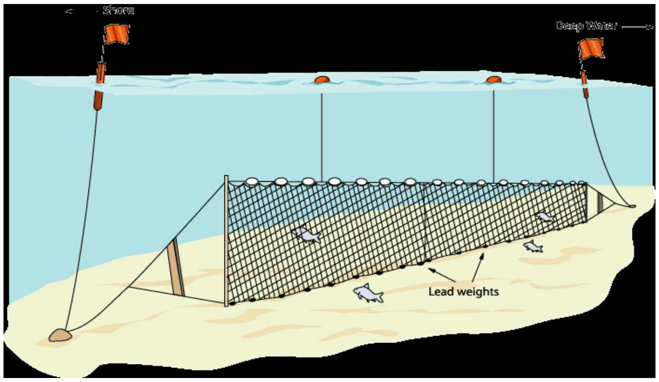


**Figure 4.3. Gill net**

*Trammel nets*

Trammel nets have three panels of netting suspended from a common row of floats and attached to a single bottom line. The two outside walls of netting have a mesh larger than the targeted fish, and the interior netting has a smaller mesh size. The inside net hangs loosely between the two outer nets (Fig. 4.4).

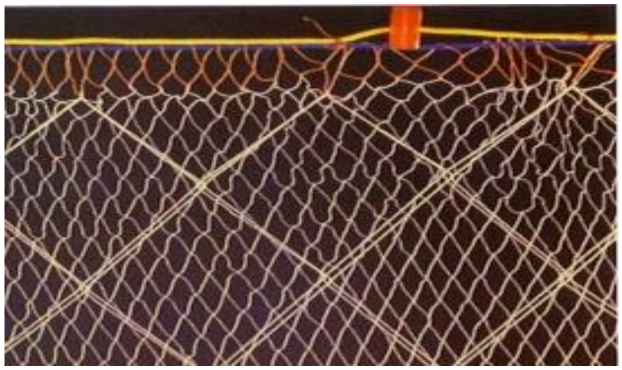

**Figure 4.4. Trammel net**

*Active gears*

Active gear has to be moved, dragged, or towed in order to capture fish. This usually requires engine-propelled boats and usually involves additional investment over passive or stationary gear.

*Seining*

Seines are long nets with meshes small enough to prevent the desired fish from gilling (filtering nets). They are generally set in a semicircle and dragged over a smooth bottom by means of long ropes (sweeps).

*Beach seines*

Beach seines are especially appropriate for catching seasonal pelagic species as they feed near shore. They are most often set from the boat. One end remains on shore, while the rest of the net is set in a curved path and brought back to the beach.

Large beach seines are costly and their use is restricted to large stretches of smooth, shallow bottoms with fairly mild surf. The net is species indiscriminate and may catch juveniles of large sized fish. Small one or two man beach seines are often used for catching live bait or small fish. Beach seines have the potential for increased motorization and mechanization. Shore anchored pulleys, tractors, jeeps, or even animals could be used to make hauling easier Fig.4.5).


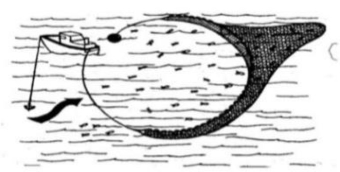


**Figure 4.5. Beach seine net**

*Trawling*

Trawls may be towed behind one or two boats or even dragged by a fisherman in shallow waters. Trawl nets generally have a cone-shaped body with a wide opening between two wings. In bottom trawling, the net is towed on the bottom in order to capture shrimp and demersal fish. Pair trawling uses two small boats to tow the trawl, one on each side. Having two boats keeps the trawl net open. This method also permits boats with small engines to trawl and allows small-scale fishermen to compete with larger trawlers.

With the same total horsepower, more fish can be caught with pair trawling than if a single boat tows the net. Whereas the noise from a single engine directly in front of the trawl net can freighten fish from the path of the net, the noise from two engines on either side of the opening will scare some fish towards the center, directly into the net. Pair trawling has limitations. Two boats must cooperate and work as a team. The fishing area is limited to smooth bottoms. Even in ideal areas, the net can be damaged or lost on a wreck or a rock.

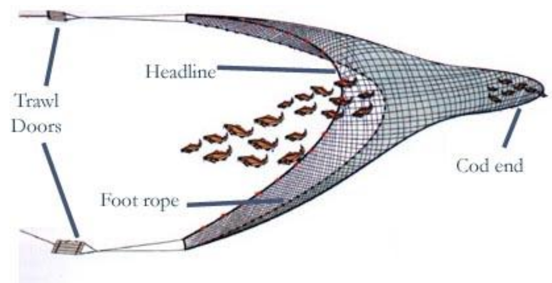


**Fig. 4.6. Trawl net**

*Electronic equipment*

Electrofishing, the use of electricity for fish capture, is a very popular method of estimating species composition and abundance in freshwater systems, particularly streams. A 30 meter stream section is walled off by vertical nets to prevent fish movement into or out of the sample area. A backpack electroshocker with two hand-held poles is used (Fig. 4.7.). Three people seems a good minimum number for this sampling, a shocker and two netters, carrying dip nets to capture stunned fish.  Usage of electric devices in commercial catches is not allowed.

**Figure 4.7. Backpack electro fisher**

*Anaethetics and Piscicides*

Many compounds kill or render fishes unconscious. Fish poisons and anaesthetics are very effective methods of sampling small, enclosed bodies of water, such as tide pools. Secretive or cryptic species, not easily taken by other means, are particularly susceptible to this approach.

Peoples all over the world have used plant products to harvest fish from poisoned waters. Rotenone derived from the root of several species of the South American plant Derris, is the most widely used plant-derived pesticide. Rotenone is a vasoconstrictor and prevents gill respiration so the poisoned fish soon suffocates. Several temperate world plants, such as the wild cucumber, *Marah macrocarpus*, and buckeye, *Aesculus californica*, are also potent piscicides.

Anaesthetics, such as quinaldine and MS-222 can also be useful and in many cases are preferable to rotenone, particularly if small pools are to be sampled. The use of Birbira (*Milletia ferruginea*) seed powders is also common in Ethiopia

The major disadvantage to these chemicals is that they are nonselective, often killing or stunning virtually all fishes (and sometimes many invertebrates) in a treated area. Further, some poisons may have long lasting effects, completely destroying the ability of a water body to support life for years. Usage of chemicals is not allowed for commercial exploitation of fishes.

***In-text question:*** *Why are electrofisher and piscicides not allowed in commercial fisheries?*

### *Selectivity of gears*

Selectivity, when considered in a wider sense, refers to the differential escape of certain sizes of fish after they come into contact with the gear (for example the passage of small fish through the meshes of a trawl).

Selection is simplest in the “bag” type of gear—trawls and seines. For these gears it is usual to assume that the size composition of the fish entering the mouth of the net is the same as that in the immediate vicinity of the gear. The selectivity of such gears therefore becomes a question of escape through the meshes of fish which have entered the net. For many species there is evidence to show that most of this escape occurs through the cod end. Selectivity can therefore be determined directly if the numbers of each size of fish entering the net can be estimated. Either by attaching a small-meshed cover over the cod end or other parts, or from the size composition of the catches of nets of much smaller meshes fished at the same time and place.

Gill nets are about the most selective gear used in commercial fishing. If a gill net is used on a population with a fair spread sizes the length-composition of the catch will be largely determined by the selectivity of the net. Two gill nets with the same overall dimensions can differ in the pattern of fishing mortality caused in at least three ways—the spread of the selection curve, the position of the peak of the curve, and the height of the peak.

All other types of gears are also, at least to some extent, selective and the pattern of selection can often be changed by suitable adjustments to the gear.

In many cases selectivity will be governed by the physical characteristics of the gear, for example, a given size of hook will only capture efficiently fish that are big enough to get the hook into their mouth, yet not so big that the hook cannot hold it.

Selection can depend on more than just the geometry of the gear, and may vary with the characteristics of the population.

## Growth and Mortality of Fishes - their significance in fisheries

### *Growth*

It is the growth of the fish that provides production estimates and the catch (yield) taken by man. Fishes exhibit a 'determinate' type of growth in short-lived species of warmer regions and an 'indeterminate' type in long-lived species of colder regions. In zoology, indeterminate growth refers to the condition where animals grow rapidly when young, and continue to grow after reaching adulthood although at a slower pace. It is common in reptiles, most fish, and many mollusks. The term also refers to the pattern of hair growth seen in humans and a few domestic breeds, but rare in other mammals, where hair continues to grow in length until it is cut.

The growth of fish is quite different from that of man and other homoeothermic animals. They do not get their growth or reach an adult size at a certain age and then stop. Instead most fish continue to grow in length and weight until they die. Further, the growth rate may be very fast or very slow, depending on the amount of food and other conditions.

### *Growth curve*

Growth is measured in units of length and weight and is best represented as the specific growth rate. Nutrition, including the quality and quantity of food, plays a significant role in growth regulation. A number of environmental factors, such as temperature, oxygen concentration, salinity and photoperiod, influence the rate of growth. Recent data suggest that genotypes, hormones and physiological conditions of the individual are also equally important endogenous regulators of growth.

Growth rates measure or express change in size over a given period of time. Change in size means change in length or weight.

Three types of growth rates are in use:

1. Absolute growth rate is absolute change in size over a given period of time, say from time 1 to time 2 calculated as L2-L1 where L1= Length at time 1 and L2= length at time 2. Or for weight w2-w1. Absolute growth rate does not necessarily consider fish age.
2. Relative growth rate: is change or growth over a period of time relative to a previous size, and usually expressed in percentage, calculated as L2-L1/L1 X 100 or W2-W1/W1 X100. It does not necessarily consider age.
3. Instantaneous growth rate: denoted by G. Growth rate at any instant of time during a given period of time (usually one year) calculated as G= ln L2-lnL1/Dt Dt is usually 1 and can be ignored, thus, G= lnL2-lnL1. In terms of weight G=lnW2-lnW1

Growth models are mathematical expressions of the average growth pattern of a fish population or a segment of the population (for the whole population from youngest up to oldest members or for one or two age groups (segment of the population)

Among several types of growth model, two are most widely used. These are:

- The von Bertalanffy Growth Function (VBGF), and
- The Laird-Gompert model.

Detailed discussion of the above models is beyond the scope of this chapter.

Growth determination

The easiest methods involve looking at changes in length and weight. These are measurements that should be taken immediately after capture of the fishes. Total Length, Standard Length and Fork Length (with measuring board) and Total Weight (with weighing balance) will be measured to the nearest 0.1 cm and 0.1 gm, respectively.

*Standard Length (SL):* is the greatest length of a fish from its most anterior extremity (mouth closed) to the hidden base of the median tail fin rays (where these meet the median hypural plate).

*Fork Length (FL):* is measured from the anterior most extremity of the fish to the tip of the median rays of the tail.

*Total Length (TL):* is the greatest length of a fish from its anterior most extremity to the end of the tail fin. The tip of the longer lobe can be considered in forked fins.

Live weight is best taken in water by first weighing a container with enough water to satisfy the needs of the fish to be weighed, and then adding the fish.

The length composition of a population will often exhibit modes among the smaller fish, which corresponds to the youngest age groups. These modes will be pronounced in fish with a short spawning season and rapid and uniform growth, in which event the mean (or at least the modal) length of the first few age groups can easily be determined.

### *Length weight relationship*

Length weight relationship is curvilinear and expressed by the following equation:

$$TW = aTL^b$$

Where:

TW is total weight; TL is total length; “a” and “b” are intercept and slope, respectively.

*Procedures to determine the intercept and the slope*

It follows simple linear regression analysis length as independent variable (X) and weight as dependent variable (Y). The value of "b" ranges from 2 - 4. If b=3, the growth is called isometric growth and there is no change in body proportion with mass and shape hence called cube law.

If b# 3, the growth is called Allometric growth and there is a change in body proportions with mass and shape.

Length-weight relationships give information on the condition and growth patterns of fish (Bagenal and Tesch, 1978). Fish are said to exhibit isometric growth when length increases in equal proportions w ith body weight for constant specific gravity. The regression co-efficient for isometric growth is '3' and values greater or lesser than '3' indicate allometric growth (Fig. 4.8).

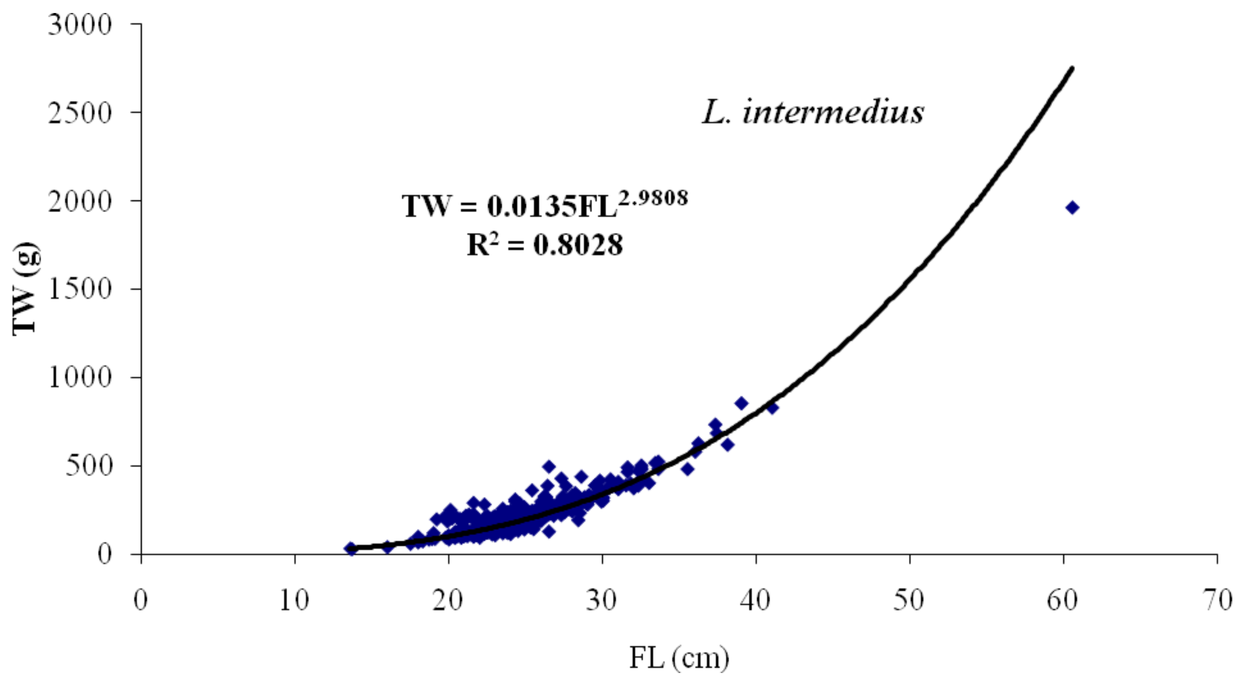


**Figure. 4.8. Length weight relationship for *Labeobarbus intermedius*, one of the common *Labeobarbus* spp. in Lake Tana (Source: Shewit G/Medhin *et al*, 2013)**

***In-text question:*** *What is the significance of having length-weight relationships?*

## Condition Factor

Condition Factor (Index) is a factor that measures the well being of fish. The relative robustness or degree of well-being of a fish is expressed by "coefficient of condition" (also known as condition factor, or length-weight factor). Variations in a fish's coefficient of condition primarily reflect state of sexual maturity and degree of nourishment. Condition values may also vary with fish age, and in some species with sex.

Fulton Condition Factor is calculated for each species as:

$$TW = aTL^{b}$$

Where:

TW= Total Weight; TL= Total Length; "a" is the intercept and "b" is the slope. It assumes that the standard weight of a fish is proportional to the cube of its length. It is another measure of an individual fish's health.

## Anatomical Method of Determining Growth

Unlike most other animals, each fish carries in its body a record of its age and growth that can be read accurately by experts. Their scales show rings that can be counted, one for each year, like the annual growth rings in a tree. Some of the spaces between these rings may be wide and others narrow, depending on how much the fish grew in those years. By measuring these rings we can trace the growth of a fish in each year of its life. In fish without scales, like catfish, their age can be learned from growth rings in their bones.

The otolith (Sagittae) will be removed by making a transverse cut across the dorsal side of the cranium at the bony ridge midway between the eye and the edge of the gill cover.

Polished and ground the increments (the annuli) on otolith will be counted using microscope al low magnifications for macrozones and at higher magnifications for microstructure analysis.

In most teleosts from the northern hemisphere, the otoliths consist of opaque material laid down mainly in late spring, summer and early autumn, and hyaline material laid down mainly during the winter. Against the dark background, the opaque zones appear as white or light colored rings and the hyaline zones as dark rings.

By common usage the age of a fish is usually designated by reference to the annual marks on its hard parts, and to some extent the season of the year, rather than according to its exact length of life (which in any event is usually not precisely known).

A fish is in its first growing season belongs to the age group 0, and its successive stages may be called a larva (fry or sac fry), alevin (advanced fry), and fingerling (young of the year or under yearling). A fish in its second growing season is said to be a member of the age group 1, or simply age 1, and may be called a yearling. In the third growing season the fish is age 2 and is called a 2-year old and so on.

A yearling will typically have one annual mark on its hard parts. However, in some species the time when the annual mark appears may vary over as much as two or three months in different individuals. Scales, operculum, vertebrae, and spines (hard parts) can also be beneficial for temperate water fishes.

## Mortality

Mortality can be defined as a decrease in number of fish with time.

***In exploited stocks***

Total mortality has two components. These are: Natural mortality (M) and Fishing mortality (F)

Total mortality (Z) = M + F

***In unexploited stock:***

F=0

Z=M

How is total mortality estimated? Several methods are available, but two are simple and most commonly used: **catch curve analysis** and **mean length in catch** method. Discussion of these methods is beyond the scope of this chapter.

## Stock Assessment and Yield Estimation

Important Terminologies:

**Production**: is total fish population biomass per unit area and per unit time

**Fish yield:** is the portion of production that can be exploited by man.

**Potential yield:** is the greatest average annual yield that can be taken under average environmental conditions, with any pattern of fishing

**Sustainable yield:** is the ecological yield that can be extracted without reducing the base of the capital itself

**Maximum Sustainable Yield (MSY)**: is the largest yield or catch that can be taken from a species stock over an indefinite period.

**Maximum Economic yield:** is the level of catch that provides the maximum net economic benefits or profits to society.

**Fish Stock**: Any natural population of fish which is an isolated and self-perpetuating group of the same species

**Fishing Effort**: The fishing effort is a measure of the amount of fishing. Frequently it is related to a given combination of inputs into the fishing activity, such as the number of hours or days spent fishing, numbers of hooks used (in long- line fishing), kilometres of nets used, etc.

**Catch per unit effort (CPUE)**: It is the total catch divided by the total amount of effort used to harvest the catch.

Most water bodies are multistock, rather than single stock, because they are inhabited by several species of fish or many stocks of species.

In many discussions of fishery management problems, the terms "sustainable yield" and "maximum sustainable yield" are used. These are particularly, but not exclusively, used in relation to the simple population models, such as those of Schaefer. These terms can often be useful in explaining the results of population analysis to administration; thus a catch equal to the sustainable yield will, on the assumptions of the simple model, leave the situation as it is. The attainment of the maximum sustainable yield is, at least apparently, a reasonable and definable objective of management, so that if the stock abundance is less than that corresponding to the maximum sustainable yield, it should be allowed to increase, i.e. less than the sustainable yield should be taken. Conversely, if the abundance is above this level, more than the sustainable yield should, on this criterion, be taken. Though a detailed discussion of the objectives of fishery management is outside the scope of this manual, it is very doubtful if the attainment of the maximum sustainable yield from any one stock of fish should be the objective of management except in exceptional circumstances. When there is a value of fishing effort which will in the long run give an average catch greater than the average catch from any other level of effort, i.e. there is a maximum in the yield/effort curve, then over some range of effort near this maximum the curve will be rather flat. Within this range a reduction of fishing effort from that giving the maximum catch will result in a decrease in catch that is much less than proportional to the reduction in effort. For economic reasons it will usually be more desirable to fish at this lower level of effort than at that giving precisely the maximum catch. Even when the objective is to harvest as much food as possible, this is most likely to be done by diverting effort to some other less heavily exploited stock.

The term sustainable yield also can be misleading, as it rather implies a degree of constancy in the situation - other than changes due to fishing - which often do not exist. In a fluctuating fishery, e.g. one with big changes in year-class strength, it may be difficult, if not impossible, to adjust the amount caught to maintain the stock abundance at the end of the year the same as at the beginning, and when possible the catch taken would fluctuate very widely.

A more useful concept is that of the potential yield. This is the greatest average annual yield that can be taken over a period or under average environmental, non-fishery-induced, conditions, with any pattern of fishing. The actual average yield over a period will be generally less than the potential because it is impossible or undesirable (e.g. due to high costs) to employ the pattern of fishing giving precisely the potential yield. In any one year the yield may be greater or less than the potential yield, depending on such factors as year-class strength, etc.

**Yield** is the portion of production that can be exploited by the fishery. On the other hand production is the total tissue elaboration of a population per unit of area and per unit of time. Therefore catch is much smaller than production, and quite different from production.

The ultimate aim of a fishery scientist is to estimate the sustainable yield of each stock and give advice to policy makers and fishery managers on the same.

The models to estimate yield of each stock are called **stock assessment models.**

### *Empirical model*

They are based on empirically determined relationship between yield and certain characteristics (factors) that determine production capacity (hence, yield).

The characteristics (the factors) could be

1. **Physical**…e.g. mean depth, shore line development, etc..
2. **Chemical**..e.g. concentrations of nutrients, total dissolved solids (TDS), etc..
3. **Biological**—e.g. plankton (phyto, zoo) biomass, primary productivity, etc..

The levels or values of these and other factors from several but similar lakes can be related to fish yield of each lake. Fish yield can only be represented by catch.

Thus y=f (factors) Yield is a function of factors, but representing y by catch (c)

C=f Catch is the functions of the factors

Therefore, there are empirical equations that relate yield as a dependent variable and the factors as independent variable

e.g. Yield=f (T) or Y= f(nutrients) or Y= fZ(primary production), etc..

Thus, there are several empirical models depending on which factors are used in conjunction with catch.

However, the most widely used models are those based on morphoedaphic index.

### *Morphoedaphic index (MEI):*

MEI uses a combination of physical and chemical characteristics instead of each characteristic taken separately. The index is calculated as:

$$MEI=TDS/Z$$

Where: TDS = total dissolved solids (solutes)

Z= mean depth (Volume/area)

TDS includes nutrients therefore, mostly, fish yield is directly proportional to TDS. But generally shallow lakes are more productive than deep lakes (all other factors being similar).

**Examples of some calculated yield values:**

*For a group of North temperate lakes in Canada:*

$Y = 0.966MEI^{0.5}$

*For several African Rift valley lakes*

$Y = 14.314 \, MEI^{0.468}$

Generally, Y=a constant x the square root of MEI

The constant being 1 for the temperate lakes whereas 14.314 for the African lakes.

The difference in the value of the constant is a reflection of difference in productivity, i.e., the African lakes could be 14.314 times more productive than the Canadian lakes. This is in turn that fish in the tropics enjoy high temperature throughout most of the year and have a much longer growth period.

Empirical models, including MEI, are simple and based on easily measurable variables. For MEI, for instance, Z is volume of a lake divided by its surface area (V/A), and TDS can be instrumentally estimated from water samples. TDS can also be more easily estimated from conductivity because TDS=0.7 X Conductivity.

However, empirical models estimate potential and total yield for a lake, and not yield for each stock (in multistock waters). Therefore, strictly speaking they cannot be called stock assessment models.

## Surplus Production Model (SPM)

One of the most popular SPMs is the Shaefer SPM. Without considering the details, the Shaefer model is based on the relationship between catch (thus yield) and effort for as given fish stock. Generally catch is a function of fishing effort.

C= f (f)

The relationship is illustrated by the figure below: From the figure C (thus, Y) is zero when f is zero as well as when f is infinitely large (i.e. C (or Y)=0 at f-zero and at infinity (f#). Also , C is maximum at an intermediate level of f. The maximum C is called the Maximum Sustainable yield (MSY), whereas the effort that can be MSY is called fMSY or optimum effort (fopt).

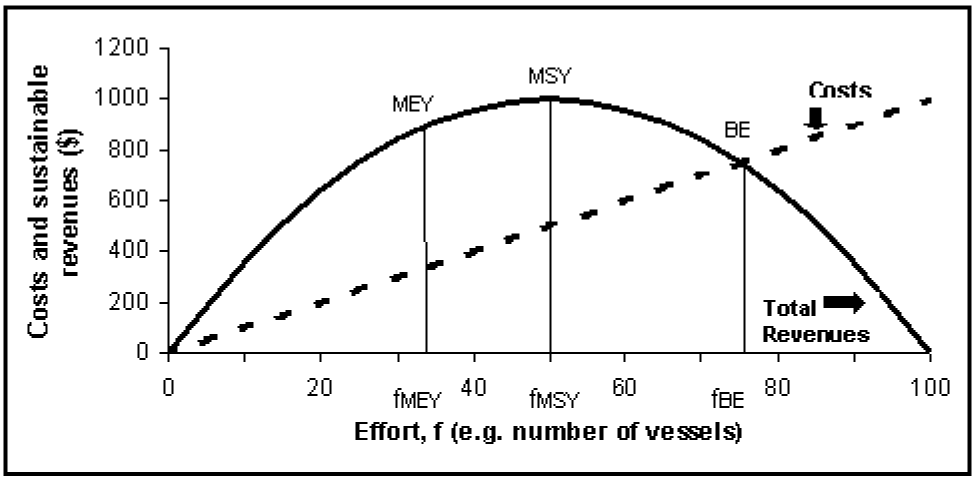


Fig. 4.9. A curve showing Maximum Economic Yield and Maximum Sustainable yield

The curve is parabola whose equation for Y and X variables is

$$Y=ax-x^2$$

a = intercept and b=slope, thus for C (Catch) and effort (f) the equation is $C=af-bf^2$

Replacing Y(Yield) for C, we have $Y=af-bf^2$

a = intercept; b=slope

When we divide both sides by f we get

C/f= a-bf, where **c/f** is called catch per unit effort (CPUE). This equation is equation of a straight line (linear) as shown below:

Intercept (a) and slope (b) are the same in the parabola and in the linear relationship, and can be estimated from catch and effort data for a certain stock.

Catch is divided by the corresponding effort to find c/f. c/f (as dependent variable) and f (as independent variable) are then subjected to a linear regression analysis to estimate "a" and "b".

From "a' and "b" MSY, fopt and Yield at any f can be estimated using the following formulae:

$$MSY=-a^2/4b$$

$$Fopt= -a/2b$$

$$\text{Yet any } f=af-bf^2$$

## Summary

A fishery is the industry or occupation devoted to the catching, processing, or selling of fish, shellfish, or other aquatic organisms. The activity should be for commercial purposes; artisanal and large scale. The organisms may include aquatic plants and algae, aquatic invertebrates, fishes, amphibians, aquatic reptiles and aquatic mammals.

The fishing gears used and their selectivity could be different based on the target organisms and the habitat in which the organisms live. Two categories of fishing gears could be recognized; passive and active gears. The passive gears are stationary and it is the fishes that move to these gears in order to be caught. These include long lines, traps, gill nets and trammel nets. The active gears, on the contrary, actively move towards the fishes to catch them. The gears are beach seine nets, trawl nets and electrofishers.

Growth and mortality are two important parameters in fishery studies. Growth could be estimated by length- weight data and anatomical methods. The slope ("b value") of the length-weight relationship curve determines whether the growth in that particular fish species is allometric or isometric. Values equal to 3 indicate isometric growth while values different from 3 indicate allometric growth. Condition factor of the fishes could also be estimated from length-weight data.

Mortality or death of fishes is another important parameter in the study of fisheries. Mortality ("Z") could be due to natural causes (Natural Mortality or "M") or due to Fishing (Fishing mortality or "F") where there is exploitation by fisheries. Therefore, in exploited stock, Z= M + F whereas in unexploited stock, Z=M.

Stock assessment and yield estimation is another component of capture fisheries. The maximum sustainable yield is a very important estimate for sustainable exploitation of fishery resources. Stocks could be of one species (single stock) or of different species (multi-stock). Multistock assessment could be complicated as compared to single stock assessment. Yield of stocks could be assessed with empirical data (biological, physical or chemical). The morphoedaphic index is one of the best empirical methods that makes use of physical data like Total dissolved solids and the depth of the water body to estimate yield. Another method widely used is the Surplus Production Model which makes use of catch and effort data.

## Review Questions

1. What is Condition Factor and what is its importance in fisheries?
2. Why are growth and mortality important parameters in fishery studies?
3. What is the difference between yield and sustainable yield?
4. What do you think are problems related to empirical methods of estimating fish yields?
5. What does the slope ("b" value) in length-weight relationships indicate?

# Chapter 5 - Aquaculture

Aquaculture could be defined as the farming of **aquatic organisms** under **controlled** conditions. The organisms include aquatic plants/algae, mollusks, crustaceans, fishes, amphibians, crocodiles, etc.

## Historical Background

The driving forces for the development of aquaculture are depletion of the wild natural resources (capture fisheries) and the ever increasing population and demand for food and other utilities.

Historically, it was the Chinese who have, reportedly, started aquaculture practices. In China, fish culture in such ponds was already in use in 1100 B.C., so fish culture can claim an antiquity nearly as respectable as the culture of land animals. A book on the culture of the common carp, *Cyprinus carpio* L., was written in 460 B.C.

About the time of the Tang Dynasty, A.D. 618-904, the cultivation of four others of the local river fish began in China, in addition to the common carp, and these five fish are the basis of Chinese fish culture today. These species of fish are being cultivated on a large scale in Russia, and Chinese emigrants have spread their culture to the countries of South-East Asia.

In India, there has long been a simple form of fish culture, namely, the stocking of ponds, lakes, and irrigation dams with young fish caught in the rivers. Countries of the Indo-Pacific Region (Indonesia, Vietnam, Cambodia, India, Pakistan, Philippines, Japan, and Russia followed suit.

Egyptians and Romans had long time history of practicing aquaculture as their civilizations went back centuries ago. Egyptian bas-reliefs show fishing scenes and the conservation of fish raised in ponds. The Romans reared fish in fishponds.

Europe, during the period of renaissance, has intensified the practices of aquaculture for more production of fish and fishery products. In the Middle Ages, in Central and Occidental Europe, fish culture developed along with the monasteries. At first it was limited to the production of fish for food, carp in particular, but it has been profoundly modified since the nineteenth century. Then after, real farming on an industrial scale began. Simultaneously, the discovery of artificial salmonid reproduction and the development of rearing techniques for these fish as well as improvement in the means of communication gave a great lift to salmonid culture. On the other hand the depopulation of open waters due to the increase in the number of anglers able to move about easily and using perfected tackle, as well as the harm done by pollution and the industrialization of water courses for navigation or by the hydroelectric industry, led to the growth of fish culture for the restocking of open waters.

In Europe, the common carp was brought from the East in the middle Ages, and soon became the most important cultivated fish. Commercial fish farming for food in Europe is best developed in Poland, Germany, Hungary and Russia. More recently, in Europe and North America, the farming of trout has developed, in part as an adjunct to the sport fishing industry, to supply fish for stocking suitable trout waters.

In North America fish culture has developed considerably since the start of the 20th century. The aim is to produce fish for food; principally trout or fish for restocking which, according to the desired purpose can be cold-water fish-different salmonids or warm water fish, principally black bass. Over 100 different aquatic species are grown in the United States and there is a growing demand for domestically produced aquaculture products. Catfish production is by far the most important sector of U.S. aquaculture. Other important aquaculture species grown for food in the United States are Salmon, trout, tilapia, shrimp, oysters, and crawfish.

Fish culture was only beginning in 1975 in Latin America and most of the Middle East, with the exception of Israel where it is well established and is developing rapidly. Since the end of the Second World War three factors have developed simultaneously and have modified the image of fish cultivation while at the same time having an influence on its development all over the world. These factors are: facilities offered by modern forms of transport for fish, the constant extension of artificial reproduction of farmed fish, and the development of the use of concentrates for feeding

In Africa, probably because no settled civilization has ever been established south of the Sahara, fish culture is of very recent introduction. Simultaneously in the Congo and in Zambia, the cultivation of the Tilapia fish begun in 1942-43.

The origins of fish cultivation in Central Africa are far more recent. Only at the end and, above all, after the Second World War, were efforts made to introduce and develop fish cultivation there. It is certain that the development of fish cultivation in these parts is really needed as a contribution to the food supply, which is chronically lacking in animal proteins.

In Ethiopia, attempts to introduce fish in ponds as culture for food and sport fishing started in the 1970s. At this time we see introductions and transplantations of carps (*Cyprinus carpio*- common carp, *Ctenophryngodon idella* - Grass carp and *Hypopthalmichthys molitrix* -Silver carp), Tilapias (*Tilapia zilli*) and salmons (*Salmo trutta* and *Salmo gairdneri* - rainbow trout). The introductions of *Tilapia zilli* in manmade ponds near Dukem and Akaki turned out to be failures. The fields are now growing crops. Recently, several man made ponds have been introduced with fishes. Here mainly we see transplantations of *Oreochromis niloticus* and *Tilapia zilli*. This happened in various parts of the country especially in the north and west. However the construction of the ponds lack planning and necessary protections and hence were quickly filled with silts.

***In-text question:*** *What were the driving forces for the development of aquaculture?*

## Obstacles for the development of aquaculture in Africa

The idea of fish farming is a novelty outside the countries where it is traditional. The entire world over, farmers are a conservative lot, rightly slow to change from ways which have served them well in the past. Moreover, cattle are regarded as walking wealth, conferring prestige on their owner; fishponds as yet are no status symbol.

Some of the main reasons why aquaculture practices are not common in Africa are:

- Water must be reliably available the year round, and fish farming is risky where there is a long dry season.
- There must be security of land tenure, for few would take the trouble, and spend the time and money, to make a fish farm, on land held on an insecure short-term lease.
- Capital is needed to build the embankments and sluices, and canals to bring water to the ponds, and for the ancilliary equipment. But in the developing countries, where the need for protein foods such as fish is greatest, capital is hard to come by, and such as there is goes to more prestigious schemes.

- Finally, though fish farming is neither more difficult nor more laborious than other kinds of farming, it fails unless the people have some tradition of intensive livestock husbandry.

No matter the antiquity of aquaculture, the contribution of the world's waters to man's diet still stems largely from the hunting and gathering of fish and shellfish from untended stocks. There has been a spectacular increase in the production of world fisheries, but wild stocks of aquatic organisms are limited, and ecological reasoning suggests that we must eventually reach a ceiling on the harvest of wild aquatic organisms. Recognition of these facts, coupled with the increasing efficiency of communications and the establishment of international technical agencies, such as the Food and Agricultural Organization of the United Nations, has led to a nearly worldwide interest in the 1950s in the potential of aquatic husbandry.

**Table 5.1. Aquaculture production by region:**

| **Region** | **Production (%)** |
|---|---|
| China | 66.7% |
| Asia and the Pacific (excluding China) | 22.8% |
| Europe | 4.2% |
| Latin America and the Carribean | 3.0% |
| Africa | 1.5% |
| North America | 1.2% |
| Near East | 0.6% |

**Table 5.2. Top ten aquaculture producing countries:**

| **Country** | **Production** | **Country** | **Production** |
|---|---|---|---|
| China | 34429122 | Bangladesh | 892049 |
| India | 3123135 | Chile | 802410 |
| Vietnam | 1657727 | Japan | 733891 |
| Thailand | 1385801 | Norway | 708780 |
| Indonesia | 1292899 | Philippines | 623369 |

Emerging African countries: Egypt, Nigeria, Uganda, Mozambique, Malawi, and Togo

**Table 5.3. Major Aquaculture species groups:**

| Species groups | Production (%) |
|---|---|
| Freshwater fishes | 54% |
| Mollusks | 27% |
| Crustaceans | 9% |
| Diadromous fishes | 6% |
| Marine fishes | 3% |
| Other aquatic animals | 1% |

## The Practice

It is common to distinguish between **extensive, semi-intensive** and **intensive** production, depending on the degree of feeding and fertilization in the farms.

***Extensive farming*** involves no feeding and no, or nominal, fertilization, **semi-intensive** some supplementary feeding and fertilization, and **intensive** steady supply of feed and fertilizers. The more intensive the production, the higher is the density of farm organisms in the farming medium. In intensive farming systems, aimed at a high production, the density of farm organisms is often very high. Moreover, intensive systems are based on the cultivation of only one species (monoculture). The environment therefore becomes very different from a natural one, and the farm organisms may be exposed to stress and a greater susceptibility to diseases. Accordingly, the need for medication will increase in proportion to the degree of intensification. In extensive and semi-intensive farming there will rarely be a need for medication.

Generally speaking, extensive and semi-intensive aquaculture can be said to be more easily adaptable to a particular environment, and the potential environmental problems will be fewer and less serious than those caused by intensive aquaculture. Extensive and semi-intensive farming systems are often technically simple, but can at the same time be biologically complicated. Several species are often cultivated simultaneously (polyculture), exploiting different ecological niches. In the countryside semi-intensive systems often combine agriculture and aquaculture. In this way agricultural refuse, manure from domestic animals etc. are utilized in fish pond production. Fish farming can also be based on other supplies of nutrients such as sewage and septic waste.

Historically intensive farming systems are relatively young. Primarily it is carnivorous species of fish and shellfish that are being cultivated intensively.

***The environments***

Below is an overview of the different ecosystems and environment types in tropical areas and developing countries where aquaculture is being practiced:

*Freshwaters*

Freshwater environments account for the most common aquaculture environments in most developing countries. They comprise farming of various species of fish and freshwater shrimps. Freshwater farming comprises a series of different environments and forms of farming. The most common are:

**Lakes:** These comprise natural lakes as well as large man-made lakes and reservoirs. Semi-intensive and intensive forms of farming are the most common, and these are carried out both in shallow waters by means of enclosures or by the use of pens.

**Large man-made ponds**: Many extensive and semi-intensive farms for fish farming consist of relatively large, shallow ponds, which can be drained and treated before the restocking of new farm organisms. The ponds are usually located in agricultural areas and are commonly run by local farmers and/ or fishermen.

**Small man-made ponds**: These ponds form the basis of a variety of types of extensive and semi-intensive farming, often in combination with other activities such as animal husbandry and agriculture. Farming in these ponds is often complicated as several species are often cultivated simultaneously (polyculture).

**Natural ponds, rivers and major canals:** Such water bodies can be exploited for extensive and semi-intensive farming. This is done by means of enclosures and net pens. Local people usually run the farms.

**Rice fields and irrigation canals:** These can, to a certain extent, be used for fish farming. Wild fish can be enclosed within the rice fields or restocked systematically in a common culture, which can be utilized, by the rice as well as the fish. The introduction of herb-eating fish controls the growth of weeds; some fish also eat vermin living on and off the rice plant or other local species.

*Marine coastal areas*

Aquaculture in marine coastal areas takes place in both saltwater and brackish water, and comprises a series of different forms of farming.

**Salt water:** The most common forms are fish farms in cages, pens and pen culture (bottom of the pen is formed by the lake or sea bottom) and enclosures: these are intensive forms of farming that exploit areas providing the farms with natural protection e.g. boys, inlets etc.

**Intertidal farming of shells, snails and seaweeds:** these are extensive forms of farming that utilize areas offering natural protection against rough weather. The farming may consist of sea floor cultures whereby the shells are scattered directly on the sea floor in the tidal zone or deeper down. Another form involves the placement of various types of stationary racks for the farming of seaweeds, or racks on which baskets for the farm organisms can be hung. A third type involves hanging cultures whereby the organisms hang freely in water in ropes and tapes from rains and sticks.

**Intertidal farming of shrimps and fish**: These are intensive and semi-intensive forms of farming. The areas being used can be marine lagoons and ponds or tanks on land which are situated in the tidal zone or nearby.

**Restocking of fish-sea ranching**: This involves restocking of fry in order to consolidate an existing stock of fish in naturally restricted areas, e.g. a bay, which is subsequently harvested as in ordinary fishing.

*Brackish water*

Farming in brackish water usually takes place in estuaries, which provide the farms with natural protection, and mangrove swamps, where the salinity is conducive to cultivation of both shrimp and fish species by means of methods that are equivalent to those described under salt water above. The methods can be intensive, semi-intensive or extensive.

Because fish are creatures whose body temperature is the same as that of the water in which they live, fish farming is practiced mostly in the warmer parts of the world where there is no severe winter to bring life in water, including the growth of fish, to a near standstill.

Obviously, fish must have water in which to live, and fish farming, like other kinds of farming, can only be done where there is a reliable source of water. In places where rainfall is fairly evenly distributed throughout the year, fish ponds may rely on direct rainfall.

Gravel pits, sand pits, and open cast mining pools, which are often pressed into use as fishponds, may be kept supplied with water by seepage from surrounding land, and are, in fact wells. More usually, however, water to fill the ponds of a fish farm is taken from a stream or river, and the method is the same as taking water for irrigation. A dam may be put across a stream, so that its level is raised and controlled by a spillway; then a canal is taken from the dam, leading along the contours of the land to discharge into the ponds.

The water must be of the right quality. It must contain enough oxygen to support active life, and it must not contain harmful substances.

It has already been stressed that wind action is beneficial in keeping ponds well oxygenated. Therefore fish farms should not be placed in narrow or deep valleys, which are apt to be rather windless; nor there bushes, trees, or reed beds which can ward off the wind and shade out the sunlight.

A pond soil must be impermeable to water, that is, it must be waterlogged; for, if it were porous and contained air, it would not hold water.

## The General Economics of Aquaculture

The success of aquatic farming ventures depends largely on the marketability of the product and the wise and efficient use of certain natural factors, which render a particular site suitable for a particular form of aquaculture. It is often debated whether precedence should be given in aquaculture to development and improvement of programs designed to improve subsistence diets, or whether a more conventional, profit oriented course should be pursued. It is clear that the economic viability of a given aquaculture practice is dependent upon a large number of complex and interacting factors, often more sociological than technical that are peculiar to the region if not unique to the individual enterprise. Commercial aquaculture enterprises can also be evaluated and compared in terms of the tonnage produced per unit of human labor input. The interplay of many biological, social, economic, and other factors on the development of a species for commercial aquaculture is schematized in Fig. 5.1.

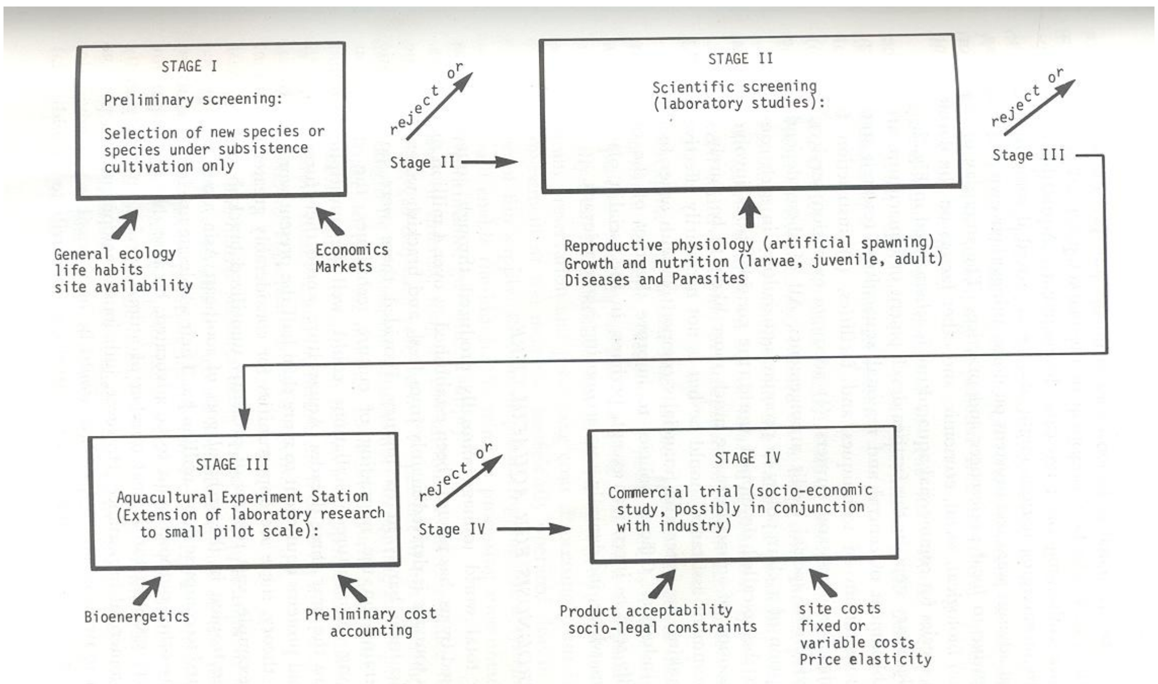


**Figure.5.1. Interplay of biological, social, economic and other factors on the development of a species for commercial aquaculture.**

## Desirable characteristics in a cultured organism

Since aquaculture developed during times when water pollution was not a serious problem, resistance to pollutants was not a consideration in species selection. Today it might reasonably be added to the following list of desirable attributes. Even with pollution resistance off the list, these properties limit choice greatly and explain why, among the 25,000 or so species of fish and the many thousand invertebrates, only a very few have thus far been successfully employed in intensive and commercially feasible aquaculture. In addition to such obvious factors as size, availability, and nutritive or gustatory value, the following biological attributes should be taken into account in considering any aquatic organism for culture:

***Reproductive habits****:* Although it is highly desirable that man be capable of breeding the species in question in captivity, it is not strictly necessary. For example, the important milkfish and mullet industries of Southeast Asia are solely dependent on natural reproduction to maintain their stocks, as are most shellfish culture enterprises. In such cases, the reproductive habits of the culture species lead to the availability of adequate numbers of young where they may be captured for stocking. Culture systems based on capture of wild stock are, of course, ultimately limited by the success of the natural population in reproducing itself.

Many ingenious methods have been devised toward the end of controlled reproduction of aquatic animals, but the most far-reaching advance was the development of the process of hypophysation of fish. In hypophysation, female, and occasionally male breeders are injected with suspensions or extractions of pituitary gland material. The treatment raises the concentration of the sex hormones in the blood stream of the recipient and facilitates maturation and shedding of the sex products. In addition to permitting the controlled breeding of hitherto unspawned species, hypophysation permits the culturist to exercise some control over the time of spawning.

***Requirements of the eggs and larvae****:* The hardier the eggs and larvae, the easier the culturist’s task. In general, it may be stated that animals which produce fewer and larger eggs have larger and therefore less delicate larvae. Such animals, which include most of the intensively cultured species, usually make some provision to protect their eggs (e.g. trout bury their eggs, tilapia hatch them in their mouths, shrimp carry them on the body), but the culturist may often successfully apply artificial means of preventing predation or damage.

***Feeding habits****:* There are two general approaches to feeding cultured aquatic animals. One is to raise animals, which are low on the food chain, supply them with a low-cost feed, if any, and aim to produce a protein product that can be sold in quantity at a low price or consumed at the subsistence level. The second is to select a species high on the food chain, which itself requires a high-protein diet. Usually fertilization of the water, rather than direct feeding, is employed in rearing the first group of animals. As is the case on land, fertilization of waters is as much a matter of art as science, and in the Orient, where pond fertilization is most extensively and successfully employed, local variation of dosage and application is great.

Linked with the process of fertilization is the concept of polyculture- the growing together of different species or age groups. Almost all fertile bodies of water produce a variety of food organisms; for the most efficient utilization of these organisms it is essential that a variety of species be present to crop them. The more completely the culturist can fill the available feeding niches, the greater the total weight of flesh he can produce.

Once again, there is much inefficiency in the food chain. Between green plants, the primary producers, and fish, there may be four or five steps, though seldom more and often fewer. Roughly about 90 percent of potential energy is lost between each step in the food chain. A fish, for example, which has fed on an insect which has fed on green plant material will get only about 1% of the original material (calories), whereas a fish which has fed directly on green plant material gets about 10 %. This is one of the reasons why herbivorous fish are so important in fish farming.

***Adaptability to crowding***

It is obvious that the more individuals of a given size that can be confined in a given space, the greater the potential production of that space. Crowding, however, creates a host of problems, many of them unique to the aquatic environment. Growth of some species of fish has been

shown to depend on population density, yet this most certainly is not true of the common carp. Far too little is known of the behavioural adaptations of fish to crowding.
Concentrations of waste products in standing water increases directly with population density, but this problem and the associated problem of oxygen depletion may be largely compensated for by increasing the exchange rate of water; raceways and net cages may be stocked at densities unthinkable in pond culture. Even such species as the rainbow trout (*Salmo gairdneri*), which has quite a high oxygen requirement, have thus been grown at extremely high densities.

Another concomitant of high population density is the facilitation of transmission of disease. This problem is not usually alleviated by rapid circulation of the water but calls for specific preventive or curative measures. The oldest disease control method is the fallowing of ponds, with or without lime treatment, more recently, chemical treatments have been developed for a number of diseases, and antibiotics are often incorporated in fish diets as a prophylactic measure, though this practice is of doubtful advisability. Present emphasis with many species is on the selective breeding of disease-resistant stock.

Yet another crowding effect sometimes observed is cannibalism, particularly in the early life stages. This problem may be alleviated to some extent by provision of ample amounts of food and shelter.

***Ponds for rearing fishes***

The farming of fish is generally practiced in ponds. In fish cultivation a pond is a section of fairly shallow water used for the controlled farming of fish and laid out in such a way that it may be easily and completely drained. This definition excludes waters, which cannot be drained (pools, natural ponds and lakes).

To construct a pond under good conditions it is necessary to have enough water of good quality and it is also necessary that the topographical characteristics should be satisfactory. To ensure this the following demands are indispensable: topographical characteristics, the soil and the amount and quality of water available.

***Topographical conditions***

Topography is the surface features of the area. Regarding the topographical characteristics, the ground should be neither too hilly nor too flat. The ideal is a slight depression, which can be easily put under water by constructing a single transverse dike.

The place to look for is one with a flat area surrounded on three sides by short, steep slopes. The fourth side, where the area drains out, should be as narrow as possible.

There are several other features that a pond location can have to advantage-its nearness to the home buildings is very important**.** Ponds close to home are a source of water for fire fighting in an emergency.

***Soil***

The laying of ponds is often best on sandy and marshy ground not economically suitable for other forms of exploitation. The dike must always rest on solid and watertight ground. The soil must hold water (i.e. impervious). Such soils are ordinarily quite heavy: clays, silty clay, clay loams. The sites to be avoided are sandy and gravelly soils, or where limestone or shale comes close to the surface.

***Supply of water***

Besides favorable topographical conditions, it is equally necessary to have a sufficient supply of good quality water for the construction of ponds. Feebly flowing brooks cannot supply important fish farms. But it is difficult, on the other hand, to build ponds, even diversion ponds, in valleys through which strong watercourses flow, such as streams or large rivers. These are liable to flood and this would be a grave and permanent danger to the security of the dikes and the ponds.

This means that normally fish farms should be installed in valleys with water courses of small or average importance, such as brooks, streamlets or small streams.

What is important is a sufficient but not excessive quantity of water. First of all it is necessary to assure enough water to compensate for losses through seepage, infiltration and evaporation. This same quantity of water must be replaced by an adequate flow to maintain the level, in addition to enough water to meet the breathing requirements of the fish. This is far higher in cold-water fish than in warm water fish.

From the fish management point of view, all water that flows out of as pond is waste-excess. This must be kept to a minimum, even including the quick surface run-off after heavy rains. Thus the ideal water supply is one that keeps the pond full without any running out.

The usual impression has been that the more water, the better it was for the fish. It is easy to see that it is wrong when one considers that the pond has to be fertilized. The more of this fertile water that leaves the pond, the harder it will be to keep it productive.

The quantity of water needed for fish cultivation depends on the species of fish being raised and the quantity of fish held in a determined volume of water. Certain species need a lot of fresh and well-aerated water such as for example, salmonids and all so-called cold-water fish. Other species require less oxygen and are happy with small quantities of water. In this category are, above all, carp and tench. The same goes for eels and in general for all fish raised in high temperature water.
The size and the surface of the ponds can vary considerably. The smallest cover only a fraction of an acre; the largest can cover several acres even hundreds of acres.

Depth will be chosen to avoid the invasion of emergent vegetation but it must not be excessive so that submerged plants can grow and develop. The ideal depth varies between 0.75 and 2 m.

It should be possible to drain the pond dry easily, rapidly and completely which is achieved by means of a series of drains or ditches comprising one principal ditch and several secondary ditches. This network of ditches should terminate in a monk, the construction of which is where the pond is deepest. It should include a screen in order to avoid escape of the fish, and also a series of small wooden boards, which allow the level of the water to be regulated at will. If possible each pond should be provided with a water inlet, and an outlet independent from those of other ponds.

The principal points which must be considered when constructing a pond are the choice of ground and the preparation of the layout; the construction of the dike, the drainage system, the water inlet, the bypass and the overflow.

## Classification of ponds

According to their water supply, ponds are divided into:

1. Spring water ponds with water supply from a spring in the bottom of the pond, or in close proximity to it or supplied by ground water.
2. Ponds supplied with rainwater or by runoff water. After being drained dry this pond fills up more or less quickly according to its size and to the amount of rainfall.
3. Ponds supplied by a watercourse: These are classified as: a. barrage ponds and b. diversion ponds (Fig. 5.2), according to whether the entire water course or only a part crosses the ponds.

Ponds supplied by springs and by rain water are known as dam or barrage ponds (Fig. 5.2). They are sometimes installed with a by-pass for evacuation of excess water. Diversion ponds are subdivided into "linked ponds" and "parallel ponds". In both cases the by-pass channel evacuates unnecessary and excess water, but in the case of linked ponds the allowed water flow crosses all the ponds, while with parallel ponds each one has its own individual water supply and its own individual outlet.

Ponds may also be classified by the species of fish raised in them (cyprinid ponds, salmonid ponds) or according to their usage (brood ponds, spawning ponds, nursery ponds, fattening ponds, storage ponds etc.).

### *Installation planning*

There is no general rule for planning ponds. Normally depths vary according to the species being farmed. However, as the fish grow, the larger fish will need greater depths. An average depth from 0.75 to 1.25 or 1.50m is generally recommended.

The depths given for the pond are average. At the monk-that is the deepest spot-about 40cm must be added. The depth of the water at the banks must never be less than 0.50m in order to avoid invading emergent vegetation.

Grass is only removed if it is superabundant. The bottom of the pond must be covered with a network of drains or evacuation ditches of "fishbone" design, which will permit complete and easy dry draining.

### *The dike*

The dike is a very important part of a pond-in fact a badly made dike is almost irreparable. The two principal qualities are solidity and water tightness. Trees should not be planted on the dike because the roots can cause water to infiltrate.

### *The monk*

The monk is a construction placed in front of the dike and formed by two lateral and parallel walls, plus a back wall. The monk has two important functions. When the pond is being filled, it controls the level of the water and prevents escape of the fish. When it is being emptied it permits progressive draining of the ponds.

### *The water inlet*

All ponds must be installed with a water inlet with the exception of ponds fed by springs which have a regular though in no way excessive supply. A well-constructed water inlet must fullfill the following conditions:

1. it must assure a regular and regulatable supply of water for the pond;
2. it must prevent the escape of fish, especially the possibility of their escaping into the feeding water course;
3. it must keep out undesirable fish which might come in through the water fed into the pond.

### *The Weir*

In order to evacuate floodwater, or excess water through storms, an overflow is indispensable for barrage ponds. The overflow should not be in the middle of the dike but at the side, at a shallow point, in order to avoid a rupture in the dike. The overflow can be in stonewalling, concrete or cast iron, or it can be an aqueduct or an open channel.

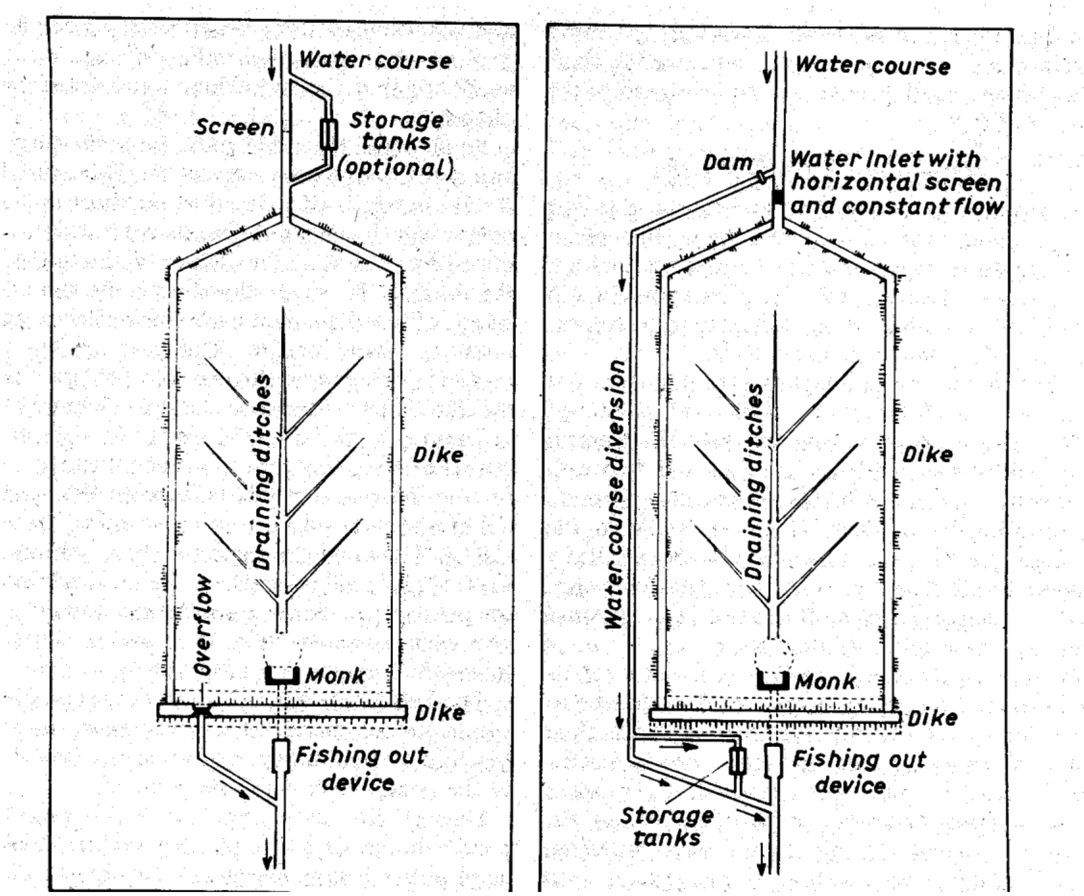


**Fig. 5.2 Schematic drawing of ponds; Left: Barrage pond; Right: Diversion pond**

***Stocking***

After the pond is prepared, fish fingerlings or shrimp post larvae are stocked at the appropriate density depending on the culture strategy, size of pond, and the size of fingerlings, among others.

The fingerlings are properly acclimated and conditioned prior to stocking and weak or diseased fish eliminated. Stocking is usually done in the early morning or late afternoon.

### *Feeding*

Fish/shrimp grown in semi-intensive and intensive culture ponds are given supplementary and full artificial feeds, respectively, the former to augment the natural food in the pond, the latter to totally replace the natural organisms in the water as a source of nutrition.

A wide variety of feed ingredients is used to prepare supplemental/artificial feeds. The simplest fish feeds are prepared at the pond site using locally available raw materials like rice or corn bran, copra meal, and rice mill sweepings as sources of carbohydrates. These are usually mixed with animal protein like trash fish/fish meal, shrimp heads, and snail meat. Supplemental feeds for tilapia are prepared using 80% rice bran and 20% fish meal. Those for shrimps in improved extensive culture (low-density stocking but given dietary supplements for increased growth/production) usually include fresh raw materials like snail/mussel/clam meat or carabao hide and other slaughterhouse leftovers.

Commercial feed preparations are also available now in a wide range of brandnames, mostly for semi-intensive and intensive shrimp culture. (Taiwan (PC), Japan, and the USA are the top producers of commercial fish/shrimp feeds.) These commercial diets consist of a number of ingredients like fish meal, blood meal, bone meat, and shrimp head meal (to serve as attractant for the shrimp), together with vitamin and mineral premix and carbohydrate sources like rice/corn bran or wheat. The crude protein (CP) content of these shrimp feeds is generally not lower than 30% to satisfy the high animal protein requirement of shrimps, actually estimated to be about 40% during the earlier stages of growth.

Commercial feeds usually come in various formulations to match the protein requirement of the culture organism, which as a rule, decreases with age. Thus, fish/shrimp feeds come in different forms as starter, grower, and finisher, with starter feeds having the highest CP content of about 40% and finisher feeds having the lowest CP content of about 20%. Starter feeds are usually given on the first month of culture, finisher feeds on the last month, and grower feeds in between.

Some shrimp culturists prefer not to give artificial feeds during the first two weeks of culture when the newly stocked post larvae can subsist on the plankton available in the water.

The feeding rate is computed as a percentage of the estimated animal biomass in the pond, with higher rations given when the animals are small and gradually decreasing as they become bigger. The daily feeding rate usually starts at 5% and 10-15% of estimated biomass of fish and shrimps, respectively, and decreases to a low of 2% and 5%, for fish and shrimps, respectively, toward harvest.

The daily feed rations are given in equal portions during the course of a day. Freshwater fish like tilapia are usually fed twice a day - early morning and late afternoon. Penaeid shrimps are fed more frequently, from three to four to as often as six to seven times a day.

Feeds are broadcast into the water and/or supplied on feeding trays. In semi-intensive and intensive ponds, small feeding boats are used by caretakers who go around the pond distributing the feed by broadcasting. At certain points along the periphery of the pond, feeding trays are submerged into the water after known quantities of feed are put on the surface, to supply feed to the shrimps in the pond as well as to monitor feed consumption and shrimp growth. The feeding tray is lifted two to three hours after the feed was supplied to check how much of it has been consumed and to see if the shrimps are healthy and feeding. Empty feeding trays may indicate that the quantity given is inadequate and may have to be increased. Conversely, full or slightly touched trays indicate excessive feed quantities and/or sluggish shrimps. The feeding ration is subsequently adjusted accordingly to optimize feed utilization.

By monitoring the feeding tray, one can get a good indication of the sizes and quantity of shrimps present in the pond without a need for cast-netting or actual sampling, since shrimps are invariably found on the tray when it is lifted out of the water.

## Water Management

Water in the pond is kept at certain levels for optimal fish growth. In general, a pond water depth of 1 meter is considered best for culture of tilapia, carps, and shrimps; traditional milkfish ponds can do with just 40-60 cm of water.

Pond water is not just maintained at a certain depth; its quality must also be kept high to ensure optimal growth of the culture organism. This is particularly important in semi-intensive and intensive culture systems where large amounts of metabolites are continously excreted into the pond and where excess, unconsumed feeds add to the bottom load and serve to pollute the water.

To prevent the deterioration of the pond environment, pond water is continuously freshened by the entry of new water from the river or water source (through the supply canal) while old water is drained through the outlet/drainage gate and through the drainage canal into the sea or river.

A flow-through system of water management that allows the simultaneous entry and exit of water into and out of the pond is essential in any high-density culture system. This is effected by the provision of separate inlets and outlets for all the ponds, each inlet regulating the flow of water from the supply canal to the pond and each outlet controlling the discharge of water out of the pond into the drainage canal. Both the supply and drain gates are so designed as to bring water into and drain water out of the lower levels of the pond, where water quality tends to get poorer faster as a result of the accumulation of wastes and their subsequent decomposition.

The regular replenishment of pond water, independent of natural tidal fluctuations, is made possible by the use of pumps which draw water from the source even at low tide. Although there is no hard-and-fast rule as to the rate of water change necessary for medium- to high density aquaculture, semi-intensive culture systems usually change water at the rate of 10% daily for an equivalent total replacement of water every ten days or three times per month. Intensively managed ponds require greater water exchange in view of the much higher organic load on the pond bottom, especially toward the latter part of the culture cycle when the animals excrete more wastes.

Intensive ponds/tanks usually need to provide for aeration facilities/equipment to prevent anoxia that may lead to mass mortalities. Oxygen depletion in high-density ponds results not only from the faster rate of utilization of dissolved oxygen for respiratory activities; it is also caused by the fast rate of decomposition at the pond bottom by aerobic or oxygen-consuming micro-organisms.

Paddlewheels or other types of aerators are thus provided in the ponds to effect the infusion/introduction of greater quantities of oxygen into the water and prevent fish/shrimp mortalities. The aerators are usually operated at regular/periodic intervals for certain fixed durations during the day but especially in the early morning hours when the concentration of dissolved oxygen is known to be lowest (as a result of the absence of photosynthetic, oxygen-producing activity in the pond). Toward the end of the culture period when oxygen demand is highest, aeration may have to be provided continuously and not just sporadically as could be done during the initial stages of rearing. At that time too, water pumps usually need to be run for longer periods to effect greater water exchange.

Pond water is also regularly sampled and measurements taken of basic/essential parameters, particularly dissolved oxygen, pH, and salinity. This is important for the purpose of determining the need for corrective/remedial action to bring water quality to optimum levels and obtain good yields.

Dissolved oxygen levels are kept, as much as possible, above 5 ppm by pumping and aeration. Problems of acidity are corrected by liming. Salinity is an important parameter for penaeid culture and has to be maintained within a range of 15-25 ppt for best results. During summer months, high-salinity water can be diluted by mixing with fresh water from springs or deep wells.

### *Pond Maintenance*

*Fertilization*

Aside from feeds and water management, the following pond maintenance procedures are carried out: regular application of fertilizers, lime, and pesticides; prevention of entry of predators; monitoring of the stock for growth rate determination as a basis of feeds and water management; and regular pond upkeep and maintenance.

Extensive ponds are fertilized regularly using either organic fertilizers like chicken, cow, or pig manure, or inorganic fertilizers like urea, ammonium phosphate, or both, to maintain the plankton population in the pond. The fertilizers are either broadcast over the pond water surface or kept in sacks suspended from poles staked at certain portions along the pond periphery. Semi-intensive and intensive culture systems do not require fertilization since they are not natural food-based, except for those which grow plankton-feeders like milkfish whose diet is largely algae dependent.

*Liming*

In addition to fertilization, ponds also need to be given regular doses of lime to maintain water pH at alkaline or near-alkaline levels (preferably not lower than six). Agricultural lime is broadcast over the pond and applied on the sides of the dikes to correct soil and water acidity.

*Elimination of Pests and Predators*

Unwanted and predatory species which may have survived the application of pesticides during pond preparation or which were able to enter the pond through the gate screens or through cracks in the dikes, are eliminated by the application of pesticides, preferably organic, into the pond.

Crabs, which are a serious problem in shrimp ponds because they are carnivorous and cause damage to the pond dikes, are not usually affected by known pesticides and are therefore best eliminated by the use of crab traps situated in the pond.

It is also important that the gates are properly screened and the screens kept whole, to prevent the entry of small unwanted fish into the pond. Double screens are usually installed at the main intake to ensure that pests and predators are prevented from entering the pond system.

*Stock Monitoring*

The culture organisms are monitored closely and regularly to determine their rate of growth and the general condition of the stock. They are regularly sampled for length-weight measurements as a basis for determining/estimating their biomass in the pond and therefore their daily feed rations, as well as for making projections on harvest schedules and procurement of pond inputs.

In the first few months of culture, the feeding tray is a good tool for stock monitoring, as explained in Section 4.3.5.3. As the organisms grow in size, cast-netting is used as a sampling tool, with those caught in the throw of the cast net providing an indication as to sizes and weights of stock. Based on the sampled weights and the daily feed consumption, it is possible to predict the available biomass (i.e., stock surviving after initial mortalities) and make projections on volume of harvest. For this purpose, it is essential that accurate records are kept for analysis at a later time. Data on initial size/weight and number of fry/post larvae stocked, average body weight at each sampling, and feed consumption on a daily basis, are important to have on file.

*Regular upkeep and maintenance of facilities*

The pond dike and gates are checked regularly for cracks that could lead to seepages and losses of stock. The dikes are best planted with grass or vegetative cover to prevent erosion. The gates and other support infrastructure are properly maintained for efficient operation.

***Harvesting***

Marketable-size fish/shrimps are harvested at the end of the culture period by draining the pond and using harvesting nets to catch the fish or shrimps. The latter are harvested with a bag-net attached to the sluice gate as water is drained out of the pond at low tide. Tilapia are harvested using seine nets after the pond water is drained to half-level the night before.

Harvest of milkfish takes advantage of their behaviour of swimming against the current. The method, known in the Philippines as "pasulang" or "pasubang" involves draining 85-90% of the pond water during low tide and allowing in the water at the incoming high tide so that the fish swim against the current through the tertiary gate and into the catching pond, whose gate is closed once a large number of fish is impounded. The fish in the catching pond are then harvested by seining and the rest hand-picked.

***Cages and Pens***

These are confinement structures used for rearing fish. They can be used for fish fattening or growing. They are made of bamboo frames and nets. They are provided with anchors and floats

Pens are larger than cages. Pens range from some 10,000 sq meters to more than a square kilometer in contrast to a cage that ranges in size from one square meter to several hundreds of square meter.

Cages can be stationary or floating that can be placed in at least one meter depth or in deeper water. Cages and pens should be installed in suitable areas that are protected from strong waves, winds and currents, free from pollution and accessible to the farmers and market

The culture periods range from three to five months. The stocking rate can be 5-20 pieces per square meter.

Pen culture is said to have originated in the Inland Sea area of Japan in the early 1920s, adopted by the People's Republic of China in the 1950s for rearing carps in freshwater lakes, and introduced to culture milkfish in the shallow, freshwater, eutrophic Laguna de Bay in the Philippines in the 1970s. From there it has been successfully extended for the culture of tilapia and carps. Its development and adoption as a popular technology has not been widespread, though, perhaps because of its site-specific requirements like its suitability mainly in shallow lentic environments. At present, it is commercially practiced only in the Philippines, Indonesia, and China.

The wider popularity of cage culture as compared to pen culture may be due to its greater flexibility in terms of siting the structures. For example, cages may be installed in bays, lagoons, straits, and open coasts as long as they are protected from strong monsoonal winds and rough seas. Floating cages can also be set up in deep lakes and reservoirs, and in rivers and canal systems, and even in deep mining pools which could not be used otherwise for culture due to harvesting difficulties.

In general, however, both pen and cage culture have expanded rapidly, especially over the past two decades vis-a-vis the decreasing availability of land-based resources for fish culture and an increasing awareness of their merits over traditional pond culture, such as:

(i) their applicability in different types of open water bodies like coastal waters, protected coves and bays, lakes, rivers, and reservoirs;

(ii) their high productivity (of as much as 10-20 times that of ponds Of comparative sizes) with minimal inputs and at lower costs to develop and operate; and

(iii) the greater socio-economic opportunities they provide to low-income families in the rural areas, particularly those displaced by the reduction of fish catches in over-exploited coastal, municipal waters, because they require comparatively low capital outlay and use simple technology.

Yields from pen and cage culture are generally high, with or without supplemental feeding depending on the natural productivity of the water body. In the Philippines, for example, the yields of milkfish from fish pens in Laguna de Bay were as high as 4 t/ha/crop (compared to a national milkfish fish pond average of 1 t/ha/y in 1980 when the productivity of the lake was very high at 1 700 mg $C/m^3/hr$).

***Advantages of cages and pens:***

- Free flowing water in the cage provides adequate supply of dissolved oxygen critical to fish culture.
- Cheap and easy to construct as compared to ponds and no cost for land.
- Easy to manipulate (artificial feeding and reproduction).
- Easy to harvest
- Can supply fresh fishes

**Integrated Fish Farming**

In a number of countries in Asia (e.g., China, Nepal, Thailand, Malaysia, Indonesia) and in some parts of Africa, freshwater fish culture is integrated with the farming of crops, mainly rice, vegetables and animals (usually pigs, ducks, and chickens). This leads to greater overall efficiency of the farming system as wastes/by-products or one component are used as inputs in another. For example, poultry or pig manure can be used to fertilize the fish pond and the vegetable garden and vegetable waste can be fed to the fish and the pigs.

In Africa, fish culture in rice fields and in combination with pig and duck rearing, is not too widely practiced but has significant potential. Reported annual fish yields ranged from 2 000-4 000 kg/ha with ducks, 8 500-8 900 kg/ha with pigs, and 3 600-4 900 kg/ha with poultry in Gabon. It has also been proven economically viable since it involves minimal investment. Its spread has, however, been constrained by the widespread use of pesticides in many countries (Fig. 5.3).

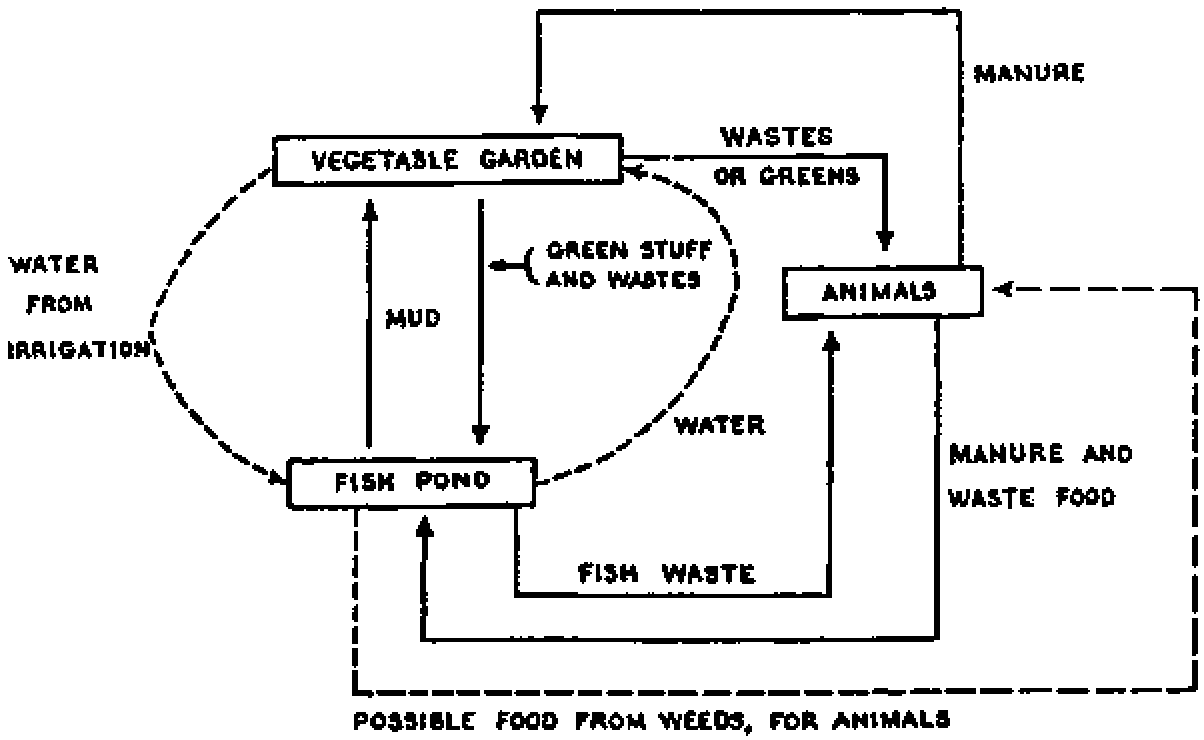


**Figure 5.3. Diagram showing interrelationships among the various components of an integrated fish farming system.**

## Aquaponics

Aquaponics, the combined culture of fish and plants in recirculating systems, has become increasingly popular. Aquaponic systems are recirculating aquaculture systems that incorporate the production of plants without soil. Recirculating systems are designed to raise large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and then reusing it.

In the process of reusing the water many times, non-toxic nutrients and organic matter accumulate. These metabolic by-products need not be wasted if they are channeled into secondary crops that have economic value or in some way benefit the primary fish production system. Systems that grow additional crops by utilizing by-products from the production of the primary species are referred to as integrated systems. If the secondary crops are aquatic or terrestrial plants grown in conjunction with fish, this integrated system is referred to as an aquaponic system. Plants grow rapidly with dissolved nutrients that are excreted directly by fish or generated from the microbial breakdown of fish wastes (Fig. 5.4).

In closed recirculating systems with very little daily water exchange (less than 2 percent), dissolved nutrients accumulate in concentrations similar to those in hydroponic nutrient solutions. Dissolved nitrogen, in particular, can occur at very high levels in recirculating systems. Fish excrete waste nitrogen, in the form of ammonia, directly into the water through their gills. Bacteria convert ammonia to nitrite and then to nitrate. Ammonia and nitrite are toxic to fish, but nitrate is relatively harmless and is the preferred form of nitrogen for growing higher plants such as fruiting vegetables.

Aquaponic systems offer several benefits. Dissolved waste nutrients are recovered by the plants, reducing discharge to the environment and extending water use (i.e., by removing dissolved nutrients through plant uptake, the water exchange rate can be reduced). Minimizing water exchange reduces the costs of operating aquaponic systems in arid climates and heated greenhouses where water or heated water is a significant expense. Having a secondary plant crop that receives most of its required nutrients at no cost improves a system's profit potential. The daily application of fish feed provides a steady supply of nutrients to plants and thereby eliminates the need to discharge and replace depleted nutrient solutions or adjust nutrient solutions as in hydroponics. The plants remove nutrients from the culture water and eliminate the need for separate and expensive biofilters. Aquaponic systems require substantially less water quality monitoring than separate hydroponic or recirculating aquaculture systems. Savings are also realized by sharing operational and infrastructural costs such as pumps, reservoirs, heaters and alarm systems. In addition, the intensive, integrated production of fish and plants requires less land than ponds and gardens. Aquaponic systems do require a large capital investment, moderate energy inputs and skilled management. Niche markets may be required for profitability.

Tilapia is the fish species most commonly cultured in aquaponic systems. Although some aquaponic systems have used channel catfish, largemouth bass, crappies, rainbow trout, pacu, common carp, koi carp, goldfish, Asian sea bass (barramundi) and Murray cod, most commercial systems are used to raise tilapia. Most freshwater species, which can tolerate crowding, will do well in aquaponic systems (including ornamental fish).

**Figure 5.4. An aquaponic system at the College of Natural Sciences (2013)**

## Aquarium

Aquarium is the smallest aquaculture unit to maintain fishes in an artificial environment. The following procedures will help to establish and maintain aquaria in schools and homes.

A pair of fish 10 cm long requires at least 10 liters of water. 40-50 liter tanks are the most suitable for aquaria in the laboratory or classroom. For most purposes, rectangular tanks with slate or glass bottoms and chromium or iron frames in which thick glass is fitted are desirable. Wash the tank with coarse sand and warm water. Avoid using very hot water. After several rinsing with cold water the aquarium should be two-thirds filled with cold water and allowed to stand for a day or so. During this time any leaks may be detected and any soluble matter in the tank will be dissolved. Discard this water.

Cover the bottom of the tank with 2 cm layer of coarse sand (gravel) that has been washed in boiling water. Embed a clean piece of clamshell at each end of the tank to help neutralize acidity and to furnish calcium salts for the shells of the snails. Next, lay a large sheet of paper on top of the sand before pouring water into the tank; the paper will prevent the sand from becoming stirred. Add water to a level of 2-3 cm from the top, and remove the paper. Let the tank stand for 2 or 3 days to bring the water to room temperature, to help dissolve air in the water, and to rid the water of chlorine. Then, plants may be added along with the water in which they have been purchased or collected. Select rooted as well as floating plant for display and protection for young fish.

Place two snails in the aquarium for 4 liters of water. The snails tend to keep the glass clean by removing encrusting algae. In addition, very young snails serve as food for some of the fish.

Keep the aquarium in medium light; strong light favors the growth of algae, which turn the water green.

There are many fish foods on the market; most of them consist of dried, chopped shrimp, brine shrimp, ant pupae, or dried Daphnia. Others have dried vegetables added. Any one of these is satisfactory for tropical and native fish, provided live food is added now and then (once a week is fine).

Avoid overfeeding fish, for the excess food will foul the water, killing the fish. A pinch of dry food daily is enough for tropical fish about 10 cm long. During the first few days watch how much food the fish consume. Remove excess by siphoning. It is better to underfeed than to feed more than the animals take in a day.

Besides feeding the fish, keep the water level constant and remove dead plants or animals. When plants are growing rapidly some should be removed to prevent overcrowding. Also remove excess snails as they increase in number, for excess will destroy plants. It is not necessary, especially for tropical fish, to change the water in the tank except when fouling or special care requires it. There is no cause for alarm if the water becomes yellowish or greenish; water that color is good, “conditioned” aquarium water. A suitable pH range may be as wide as 6.8 to 7.2 for the average tank.

## Aquaculture other than Fish

The farming of molluscs and seaweeds in open marine waters has become increasingly popular in a number of countries, especially in the Third World where it is seen as a viable alternative to municipal or artisanal fisheries or as a means of supplementary income for small-scale fishermen. Because seafarming is generally low-cost and labour-intensive and could thus involve entire coastal communities, it is particularly appropriate in areas where production from municipal fisheries has substantially declined and where, as a result, subsistence fishermen have little or no means of livelihood.

***Mollusc culture***

Bivalves are widely cultured in a number of countries world-wide. In Asia and the Pacific, they represent a high quality food resource with annual production higher than from crustacean culture on a per hectare basis.

The most important species for culture in Southeast Asia are the oysters (mainly *Crassostrea* spp.), mussels (mainly *Perna* spp.), clams, cockles, and scallops.

Oysters are widely distributed in estuaries and bays which receive some run-off from land and have somewhat lower salinity than the open sea. As they filter their food from the water, they grow best in areas with moderate to high concentrations of phytoplankton. Oysters grow best in intertidal areas where they are exposed for some minutes or a few hours during low tide. Mussels, on the other hand, cannot tolerate tidal exposure even during low tide.

The best sites for culturing molluscs are therefore those that meet their biological requirements, including the following:

- Seawater salinity range of 15-35 ppt.
- Water depth of 1-10 m, and
- Muddy bottom for mussels and hard rocky or coralline substrates for oysters.

**Seaweed Farming**

Seaweeds, aside from being used as food, are important sources of colloids or gels, such as agar, as well as minerals of medicinal importance such as iodine. *Eucheuma*, a red algae, is a valuable source of carrageenan, an important industrial compound used in stabilizing and improving the quality of a great number of products. *Caulerpa lentillifera*, a green algae, is economically important because it is a favourite and nutritious salad dish containing essential trace minerals such as calcium, potassium, magnesium, sodium, copper, iron and zinc. It is also known for its medicinal properties, being used as an anti-fungal agent and as a natural means for lowering blood pressure. *Gracilaria*, another red alga, is economically important in Taiwan (PC) for its agar extracts.

The successful cultivation of seaweeds depends on four important factors:

- Type of seaweeds used
- Ecological conditions of the farm
- Access to sunlight
- The seaweed farmer

## Aquaculture and the Environment

Article 2.12 of the Bangkok Declaration states that some poorly planned and managed aquaculture operations have resulted in negative impacts on ecosystems and communities.

The choice of technology, scale and intensity of cultivation will vary a great deal, and will be decisive for the environmental and socio-cultural impacts of aquaculture. Aquaculture projects may vary as to preparation of the production areas, stocking of organisms, and the degree of feeding, fertilization and medication.

Preparing the production areas may involve making enclosures in bays, lagoons, lakes, ponds or man-made ponds/reservoirs, the building of artificial embankments and basins, and the use of cages.

The farm organisms can be restocked at different stages of development. For example, they may be wild fry, which have been collected for further cultivation. In other cases the fry are farm-cultivated. Import of fry from other localities or countries is another alternative.

It is common to distinguish between extensive, semi-intensive and intensive production, depending on the degree of feeding and fertilization in the farms. Extensive farming involves no feeding and no, or minimal, fertilization, semi intensive some supplementary feeding and fertilization and intensive steady supply of feed and fertilizers. The more intensive the production, the higher is the density of farm organisms in the farming medium.

Moreover, intensive systems are based on the cultivation of only one species (monoculture). The environment therefore becomes very different from a natural one, and the farm organisms may be exposed to stress and a greater susceptibility to diseases. Accordingly, the need for medication will increase in proportion to the degree of intensification.

Extensive and semi-intensive farming systems are often technically simple, but can at the same time be biologically complicated. Several species are often cultivated simultaneously (polyculture), exploiting different ecological niches.

Primarily it is carnivorous species of fish and shellfish that are being cultivated intensively.

The requirements as to control and management of the feeding, medication, water quality and volume are higher than those applying to other systems. Further, the hygienic requirements are high, since the risk of pollution from drugs, nutrients and organic matter is high. Regular maintenance and cleaning of the farms is necessary. Intensive farming often requires a considerable capital investment and the availability of a trained and permanently employed work force. The forms of farming involve a great increase in production and will generally require the establishment of facilities for reception, processing and distribution of the farm products.

The development of a reception, processing and distribution apparatus for aquaculture production requires land and a stable supply of energy (oil and electricity) and high quality of water. This especially applies to modern methods of preservation such as icing and freezing, but traditional methods of treatment, e.g. smoking, also depends on an ensured supply of energy. Less energy consuming methods, e.g. drying and salting, may be relevant alternatives. An increased investment in aquaculture, moreover, requires a sufficient supply of building materials, e.g. wood for the building of cages and pens.

Many tropical water bodies are extremely low in nutrients. The nutrients are largely bound up with the existing flora and fauna. By a steady supply of nutrients the ecosystem may acquire a higher substance value. Besides, this may improve the production of other useful plants and animals. Yet problems of pollution and eutrophication in watercourses and coastal areas are more frequently the case.

Tropical water besides are often subject to considerable evaporation. In freshwater environments, therefore, it is important to ensure an adequate and stable water supply to the farms. In dry areas or areas with little rainfall, limited ground-water resources are sometimes used for aquaculture. Such a situation may require a survey of available water sources and other hydrological conditions before aquaculture farms are developed.

Tropical soil often contains pyrite, which makes the water acidic and unsuitable for farming. Areas, which have already been used as embankment ponds, can be treated by covering the dam floor with special tarpaulins, or by adding calcium to the water. Soil test is important prior to development of aquaculture.

The local social conditions relating to a project may vary greatly from place to place. In some places aquaculture may have been practiced for generations, having become part of the local culture and tradition, whereas in other areas it has never been practiced.

In connection to the planning of aquaculture in areas where it has never been practiced, one should be aware that the local population may not have title to land or water.

***Possible environmental impacts***

This covers both direct and indirect environmental impacts. It is often difficult to distinguish clearly between these two types of impacts. The direct impacts may result directly from certain properties of the aquaculture project itself. The indirect impacts may result from other types of activities in association with the project e.g. processing. Indirect impacts can also occur if the project alters socio-cultural conditions in the local community i.e. through changes in the power structure.

### *A. Introduction of new species*

In some cases it may be desirable to farm species that are not naturally existing in the area. Should faults occur, however, or should the farm be wrecked, this may cause new species to be spread into the environment. Generally speaking, one will have to expect some individual escapes from such farms. There is widespread concern that imported organisms may replace local and genetically better adapted fish stocks and variants. Further, there is also a risk of genetic changes in naturally existing fish.

Another impact, which is often associated with the spreading of new species, is the spreading of fish diseases. New species or farm organisms, which have been collected from other geographical areas, may carry bacteria, viruses and parasites, which then spread and cause diseases. This can lead to depletion or extermination of valuable species. One should be aware that parasites, bacteria and viruses that are harmless in some areas could cause catastrophes if transferred to a different environment.

### *B. Impacts on the ecosystem, and the natural and cultural landscape*

Technical installations, pollution, spreading of new species and spreading of fish diseases may, alone or combined, cause such drastic environmental impacts that the original ecosystems are changed. This can affect other forms of economic exploitation of these areas. The occurrence and the produced amount of other utilizable species can be altered, and the suitability of the water body for other uses can be changed.

Large aquaculture farms may entail considerable encroachments on the landscape. The visual character of the natural and cultural landscape may alter so that it becomes less attractive for recreation and tourism etc. Historic remains, buildings and other landscape elements that are important to the local population can also be affected.

### *C. Pollution and waste disposal*

In farms directly connected to sea or watercourse, artificial feeding or supply of fertilizer or organic matter can lead to eutrophication in the water body.

Excessive fertilization of freshwater can cause growth of algae and other aquatic plants, which makes the water unsuitable as drinking water. Furthermore this may hinder fishing and boat transport. In cases of great stress, periodical or constant deoxygenation in the bottom layers may result, bringing damage to the flora and fauna, and problems with smell. Faeces from farm organisms are also a potential pollutant.

Extensive use of drugs to prevent diseases in farm organisms can pollute the surroundings. Many types of antibiotics are not easily broken down in the farm organisms and will be spread to wild fish and other naturally existing organisms.

Pollution problems can also arise in connection with handling, storage and transport of fish and other farm produce. Concentrated handling and processing can create a waste problem. This waste will consist of perishable organic matter. If stored on shore, it can smell and attract insects, rats, birds, etc. Insects and offal-eating animals can spread diseases to the local population. If the offal is dumped into water, it can cause eutrophication, and deoxygenation in the deep water layers if there is insufficient circulation in the water.

***D. Spreading of diseases to humans***

If the project involves the building of artificial ponds and canal systems, this may create improved conditions for the propagation and spreading of water-borne diseases. Stagnant waters can create favourable conditions for the propagation of bilharzias and malaria.

One should take great care if the production is based on sewage or manure and latrine excrements. Bacteria and other pathogens will spread and can pose a health risk to both farmers and consumers.

The use of pesticides should be considered against the potential risk for humans.

***E. Increased demand for water and energy***

Freshwater farming of fish or other organisms requires stable supplies of high-quality water, which is often scarce. One should be particularly alert to the fact that the water supply may vary substantially both seasonally and annually. With respect to projects that require large amounts of water, one should make a survey of water resources and estimate the water supply. In case of permanent or periodical scarcity of water, conflicting demands may arise between aquaculture and irrigation or supply of drinking water. Tropical water bodies are often exposed to considerable evaporation, which in turn leads to an increased demand for water supplies.

In dry areas, ground water is generally used for aquacultural purposes. However, excessive exploitation of ground water can cause problems owing to a lowered ground water table and increased salinity in the water.

Smoking of fish requires wood or other kinds of fuel. The use of wood and bamboo for building cages and stationary enclosures can put pressure on limited resources. Freezing and ice production, and various other industrial processes, require electricity and/ or oil.

***F. Impacts on traditional ways of life and utilization of natural resources***

Aquaculture projects may create changes in traditional ways of life and utilization of natural resources. Generally this can occur in two ways:

1. Those impacts a project may have on the local ecosystem may require that the local, traditional utilization of natural resources must be rearranged.
2. The direct impacts of a project on the local socio-cultural and socio-economic conditions may indirectly create long-term environmental impacts through changed natural resource utilization.

The local social conditions relating to a project may vary greatly from place to place. In some places aquaculture may have been practiced for generations, having become part of the local culture and tradition, whereas in other areas it has never been practiced.

In connection to the planning of aquaculture in areas where it has never been practiced, one should be aware that the local population might not have title to land or water. So an aquaculture project, which does not consider the economic, social and cultural conditions of the project area or its vicinity, may easily create conflicts.

Aquaculture can create conflicts with the local population's use of land, water and other natural resources. Areas utilized for the purposes of agriculture, forestry or animal husbandry can be affected. Aquaculture projects can change the need for labor and training. Transition to a new technology and trade can alter the traditional division of labor between men and women.

### *G. Impacts of new activities, and already existing activities*

Investments in aquaculture can initiate the development of other activities such as industry, transport, water supply etc. Such developments can indirectly lead to environmental impacts, which should be assessed.

Already existing or planned activities may have environmental impacts on aquaculture and aquaculture projects. For example, waste disposal and pollution from industry, agriculture and densely populated areas may reduce the quality of the water being used by the farms.

## Summary

The past two decades have seen the growth of the aquaculture industry from an experimental/pilot stage to a fully grown, important fisheries sub-sector in a number of countries the world over, but particularly in Asia where the bulk of world production comes from.

Aquaculture can provide a cheap source of animal protein for the masses in rural areas, including those countries with no access to the sea; it can be developed on land which is no longer suitable for farming and/or on land in conjunction with other farming systems; it can be operated either on a small scale, at low cost, and utilizing family/community labour, or on a large scale, at high cost, and utilizing more machines and less hands and in both instances fulfill the objectives for which it was established; it can complement capture fisheries in bringing about increased production of fish in open waters like coastal lagoons, man-made lakes, and floodplains; it can provide a viable socio-economic alternative to capture fisheries, especially in over-fished municipal waters; and it can serve to enhance the fishery resources in major water bodies whose natural productivities have shown signs of decline from over-exploitation or environmental degradation.

Aquaculture offers a number of options. It can be small- or large-scale. It can be carried out on land-based sites and in fresh, brackish, or saline environments. It can make use of extensive, semi-intensive, or intensive methods for a great variety of culture species with different economic values.

Its products can be sold fresh or processed in either domestic or international markets. This flexibility notwithstanding, the success of any aquaculture undertaking is possible only if the market for the product is assured; the selected species is amenable to culture and fulfills the standard criteria for a good candidate species; the site selected is suitable for the species to be cultured; the technology for the selected species and type/method of culture is available; the production and support facilities are properly designed and built; the operation is efficiently managed so that the various production inputs are properly utilized and are made available at the right time; adequately trained and skilled labor is available to run and operate the enterprise; and adequate funding is in place and/or credit is available for development and operation.

Production of fish could be integrated with farming of rice or raising livestock, poultry, vegetables and fruits. The byproduct form one system could be used as an input for the other. Aquaponics is one of the integrated systems in which the waste from the fish could be turned into usable nitrates by bacteria that will be utilized by vegetables. The vegetables filter the wastes from the water returning the filtered water to the fishes.

It has been shown that aquaculture has some environmental effect in terms of pollution, introducing alien species, destructing historic sites and natural areas, etc. However, it also plays a positive role in alleviating the pressure that otherwise could have been exerted on the wild fishes.

Clearly, the success of aquaculture can only be obtained through proper management based on a knowledge/understanding of the culture environment and the biological processes involved in the culture operation, as well as on the existence/availability of certain vital infrastructure - such as fry, feeds, labor, funds, and a market.

At the national level, the Government has to ensure that fish farmers are provided with the necessary support in their production endeavors, mainly by way of adequate market infrastructure facilities and services (e.g., farm-to-market roads, fishing ports, processing plants, ice plants and cold storage facilities); effective training and extension services; continuing research and development efforts; and credit/funding assistance, including the provision of financial incentives like tax credits and the tax-free import of essential equipment/machinery and supplies and materials.

The introduction of improved culture systems, highly productive strains, highly improved feed formulations in intensive farming systems, highly improved techniques in the hatchery production of fry, and the expansion of production areas, have all contributed significantly to the exceptionally fast growth of aquaculture in many countries of the world. This rapid expansion of the industry shall undoubtedly be sustained, if not surpassed, in the years to come as improved techniques are refined, even better feeds are developed, and higher yielding strains are genetically engineered.

## Review questions

1. What are the two types of ponds structurally? Which one is better?
2. What is aquaponics and its advantages? What is it best suited for?
3. What are the advantages of cage and pen cultures?
4. What is integrated aquaculture and its benefits?
5. Why is aquaculture not well developed in Ethiopia?

# Chapter 6 - Processing of Fish and Fish Products

Fish processing is often an intermediate step to the production of value-added products (for example, smoked fish, canned fish, frozen breaded or battered fish). Traditional methods often prevail in the design of a process. However, modern scientific food technology is having an increasingly important role in enhancing the preservation and shelf-stability of a product. Regardless of the complexity of a particular process, the production of the desired product relies on the consecutive execution of individual steps.

## Finfish Preparation

The hygienic conditions and technical manner in which fish is prepared are similar and not influenced greatly by the intended purpose (for direct distribution or for further processing). However, variations will exist in the form in which the fresh fish flesh is to be utilized. The forms may include, but are not limited to, **dressed**, **fillets** or **steaks**.

### *Raw, fresh or frozen fish reception*

For raw fish material, product specifications could include the following characteristics:

- organoleptic characteristics, such as appearance, odour, texture;
- chemical indicators of decomposition and/or contamination, for example, total volatile basic nitrogen (TVBN), histamine, heavy metals, pesticide residues, nitrates;
- microbiological criteria, in particular for intermediate raw materials, to prevent the processing of raw material containing microbial toxins;
- physical characteristics, such as size of fish;
- species homogeneity.

Training in species identification and communication in product specification should be provided to fish handlers and appropriate personnel to ensure a safe source of incoming fish where written protocols exist. Warranting special consideration are the reception and sorting of fish species that pose a risk of biotoxins such as ciguatoxin in large carnivorous tropical and subtropical reef fish or scombrotoxin in scombroid species or parasites. Skills should be acquired by fish handlers and appropriate personnel in sensory evaluation techniques to ensure raw fish meet essential quality provisions of the appropriate standard. Fish requiring gutting on arrival at the processing facility should be gutted efficiently, without undue delay and with care to avoid contamination. Fish should be rejected if it is known to contain harmful, decomposed or extraneous substances that will not be reduced or eliminated to an acceptable level by normal procedures of sorting or preparation.

***Sensory evaluation of fish***

The best method of assessing the freshness or spoilage of fish is by sensory evaluation techniques. It is recommended that appropriate sensory evaluation criteria be used to evaluate the acceptability of fish and to eliminate fish showing loss of essential quality provisions of the appropriate standards. As an example, fresh fish species are considered unacceptable when showing the following characteristics:

**Skin/slime** dull, gritty colours with yellow–brown dotting slime.

**Eyes** concave, opaque, sunken, discoloured.

**Gills** grey–brown or bleached, slime opaque yellow, thick or clotting.

**Odour** flesh odour amines, ammonia, milky lactic, sulphide, faecal, putrid, rancid.

***Preservation of fish***

*Chilled storage*

Fish should be moved to the chilled storage facility without undue delay. The facility should be capable of maintaining the temperature of the fish between 0ºC and 4ºC. The chill room should be equipped with a calibrated indicating thermometer. Fitting of a recording thermometer is strongly recommended. Stock rotation plans should ensure proper utilization of the fish.

The fish should be stored in shallow layers and surrounded by sufficient finely divided ice or with a mixture of ice and water before processing. Fish should be stored such that damage from overstacking or overfilling of boxes will be prevented. Where appropriate, replenish ice supply on the fish or alter temperature of the room.

*Frozen storage*

The facility should be capable of maintaining the temperature of the fish at or colder than –18 ºC, and with minimal temperature fluctuations. The store should be equipped with a calibrated indicating thermometer. Fitting of a recording thermometer is strongly recommended. A systematic stock rotation plan should be developed and maintained. Product should be glazed and/or wrapped to protect it from dehydration. Fish should be rejected if known to contain defects that subsequently cannot be reduced or eliminated to an acceptable level by re-working.. For killing parasites harmful to human health, the freezing temperature and monitoring of duration of freezing should be combined with good inventory control to ensure sufficient cold treatment.

*Freezing process*

The fish product should be subjected to a freezing process as quickly as possible because unnecessary delays before freezing will cause temperature of the fish products to rise, increasing the rate of quality deterioration and reducing shelflife owing to the action of micro-organisms and undesirable chemical reactions. A time and temperature regime for freezing should be established and should take into consideration the freezing equipment and capacity, the nature of the fish product including thermal conductivity, thickness, shape and temperature and the volume of production to ensure that the range of temperature of maximum crystallization is passed through as quickly as possible. The thickness, shape and temperature of fish product entering the freezing process should be as uniform as possible. Processing facility production should be geared to the capacity of freezers. Frozen product should be moved to the cold storage facility as quickly as possible. The core temperature of the frozen fish should be monitored regularly for completeness of the freezing process. Frequent checks should be made to ensure correct operation of freezing. Accurate records of all freezing operations should be kept. For killing parasites harmful to human health, the freezing temperature and monitoring of duration of freezing should be combined with good inventory control to ensure sufficient cold treatment.

*Glazing*

Glazing is considered complete when the entire surface of the frozen fish product is covered with a suitable protective coating of ice and should be free of exposed areas where dehydration (freezer burn) can occur. If additives are used in the water for glazing, care should be taken to ensure its proper proportion and application with product specifications. Where the labelling of a product is concerned, information on the amount or proportion of glaze applied to a product or a production run should be kept and used in the determination of the net weight, which is exclusive of the glaze. Where appropriate, monitoring should ensure that spray nozzles do not become blocked. Where dips are used for glazing, it is important to replace the glazing solution periodically to minimize the bacterial load and buildup of fish protein, which can hamper freezing performance.

*Mincing fish using mechanical separation process*

The separator should be fed continuously but not excessively. Candling is recommended for fish suspected of high infestation with parasites. Split fish or fillets should be fed to the separator so that the cut surface contacts the perforated surface. Fish should be fed to the separator in a size that it is able to handle. In order to avoid time-consuming adjustments of the machinery and variations in quality of the finished product, raw materials of different species and types should be segregated and processing of separate batches should be carefully planned. The perforation sizes of the separator surface as well as the pressure on the raw material should be adjusted to the characteristics desired in the final product. The separated residual material should be carefully removed on a continuous or near-continuous basis to the next processing stage. Temperature monitoring should ensure undue temperature rises of the product are avoided.

*Washing of minced fish*

If necessary, the mince should be washed and should be adequate for the type of product desired. Stirring during washing should be carried out with care, but it should be kept as gentle as possible in order to avoid excessive disintegration of the minced flesh, which will reduce the yield owing to the formation of fines. The washed minced fish flesh may be partially dewatered by rotary sieves or centrifugal equipment and the process completed by pressing to appropriate moisture content. If necessary, and depending on eventual end use, the dewatered mince should be either strained or emulsified. Special attention should be taken to ensure mince being strained is kept cool. The resulting wastewater should be disposed of in a suitable manner.

*Blending and application of additives and ingredients to minced fish*

If fish, ingredients and /or additives are to be added, they should be blended in the proper proportions to achieve the desired sensory quality. Additives should comply with the requirements of the *General Standard for food additives*. The minced fish product should be packaged and frozen immediately after preparation; if it is not frozen or used immediately after preparation, it should be chilled.

*Controlled thawing*

Thawing is dissolving the ice from the fish flesh. The thawing method should be clearly defined and should address the time and temperature of thawing, temperature measuring instrument used and placement of device for measurement. The thawing schedule (time and temperature parameters) should be carefully monitored. Selection of the thawing method should take into account in particular the thickness and uniformity of size of the products to be thawed. Thawing time and temperature and fish temperature critical limits should be selected so as to control the development of micro-organisms and histamine (where high-risk species are concerned) or persistent and distinctive objectionable odours or flavours indicative of decomposition or rancidity. Where water is used as the thawing medium, it should be of potable quality. Where recycling of water is used, care should be taken to avoid the buildup of micro-organisms. Where water is used, circulation should be sufficient to produce even thawing. During thawing, according to the method used, products should not be exposed to excessively high temperatures. Particular attention should be paid to controlling condensation and drip from the fish. Effective drainage should be ensured. After thawing, fish should be immediately processed or refrigerated and kept at the adequate temperature (temperature of melting ice).

*Washing and gutting*

Gutting is considered complete when the intestinal tract and internal organs have been removed. An adequate supply of clean potable water should be available for washing of:

- whole fish, to remove foreign debris and reduce bacterial load prior to gutting;
- gutted fish, to remove blood and viscera from the belly cavity;

- surface of fish, to remove any loose scales;
- gutting equipment and utensils, to minimize buildup of slime, blood and offal.

Depending on the vessel or processing facility product flow pattern and where a prescribed critical limit for staging time and temperature regime has been established for the control of histamine or a defect, the gutted fish should be drained and well iced or appropriately chilled in clean containers and stored in specially designated and appropriate areas within the processing facility. Separate and adequate storage facilities should be provided for the fish roe, milt and livers, if these are saved for later utilization.

*Filleting, skinning, trimming and candling*

To minimize time delays, the design of the filleting line and candling line, where applicable, should be continuous and sequential to permit uniform flow without stoppages or slowdowns and removal of waste. An adequate supply of clean potable water should be available for washing of:

- fish prior to filleting or cutting, especially fish that have been scaled;
- fillets after filleting, skinning or trimming to remove any signs of blood, scales or viscera;
- filleting equipment and utensils to minimize buildup of slime and blood and offal;
- for fillets to be marketed and designated as boneless, fish handlers should employ appropriate inspection techniques and use the necessary tools to remove bones not meeting standards or commercial specifications.

The candling of skinless fillets by skilled personnel, in a suitable location that optimizes the illuminating effect, is an effective technique in controlling parasites (in fresh fish) and should be employed when implicated fish species are being used. The candling table should be frequently cleaned during operation in order to minimize the microbial activity of contact surfaces and the drying of fish residue caused by heat generated from the lamp. Where a prescribed critical limit for staging time and temperature regime has been established for the control of histamine or a defect, the fish fillets should be well iced or appropriately chilled in clean containers, protected from dehydration and stored in appropriate areas within the processing facility.

***Weighing***

Weigh scales should be periodically calibrated with a standard mass to ensure accuracy.

***Standard for quick frozen blocks of fish fillets, minced fish flesh and mixtures of fillets and minced fish flesh***

Fish flesh should be clear of the seam area. Packaging material should be inspected prior to use to ensure that it is not damaged or contaminated. Packaging integrity of the finished product should be inspected at regular intervals by appropriately trained personnel to verify the effectiveness of the seal and the proper operation of the packaging machine. Following sealing, products should be transferred carefully and without undue delay to chilled storage. Ensure that adequate vacuum is attained, and the package seals are intact.

***Labeling***

Prior to their application, labels should be verified to ensure that all information declared meets, where applicable, the general standard for the labeling of prepackaged foods, labeling provisions of the appropriate standard for products and/or other relevant national legislative requirements. In many cases, it will be possible to re-label incorrectly-labeled products. An appropriate assessment should be carried out to determine the reason(s) for incorrect labeling and the DAP plan should be modified where necessary.

***Wrapping and packaging***

Packaging material should be clean, sound, durable and sufficient for its intended use and of food-grade material. The packaging operation should be conducted to minimize the risk of contamination and decomposition. Products should meet appropriate standards for labelling and weights.

***Reception – packaging, labels and ingredients***

Only ingredients, packaging material and labels complying with the specifications of the processors should be accepted into the processing facility. Labels that are to be used in direct contact with the fish should be made of a non-absorbent material and the ink or dye used on that label should be approved by the official agency having jurisdiction. Ingredients and packaging material not approved by the official agency having jurisdiction should be investigated and rejected at reception.

***Storage – packaging, labels and ingredients***

Ingredients and packaging should be stored appropriately in terms of temperature and humidity. A systematic stock rotation plan should be developed and maintained to avoid out-of-date materials. Ingredients and packaging should be properly protected and segregated to prevent cross-contamination.

## Summary

Fishes are very fragile and subject to spoilage if not properly and timely preserved. As soon as fishes are caught the gut has to be removed and the cavity washed thoroughly. The fish could be stored in freezing temperature or smoked as whole, or filleted (cut into pieces) and stored in freezing temperatures.

The condition of whole fish could be inspected visually by looking at the eyes, gills and also by smells coming out of it. It is also a symptom of spoilage if the skin is with dull or grity and with yellow brown dotting slimes, then the fish is spoiled. Similarly, if the eyes are concave, opaque, sunken and discolored and the gills are grey=brown, bleached, thick or clotting. The odor is also indicative in that faecal or putrid or rancid smells show that the fish is spoiled.

Packaging material should be clean, sound, durable and sufficient for its intended use and of food-grade material. The packaging operation should be conducted to minimize the risk of contamination and decomposition. Labels that are to be used in direct contact with the fish should be made of a non-absorbent material and the ink or dye used on that label should be approved by the official agency having jurisdiction

## Review questions

1. How do you identify visually that a fish specimen is spoiled and not edible?
2. What are the factors that cause spoilage of fishes?
3. Why do fishermen take out the gut as soon as fishes are caught?
4. What do the smoking and freezing processes do to the fish flesh?
5. What is thawing and what is its purpose?

# Chapter 7 - Status and potential of Ethiopia's Fish and Fishery Resources

## The Ethiopian Fish Fauna: Diversity and distribution

The freshwater fish fauna of Ethiopia is of particular interest since it contains a mixture of Nilo-Sudanic, East African, and endemic forms (Roberts, 1976; Abebe Getahun and Stiassny, 1998). The Nilo-Sudanic forms are represented by a large number of species found in the Baro-Akobo, Omo-Gibe, and Abay drainage basins (e.g. members of the genera *Alestes, Bagrus, Citharinus, Hydrocynus, Hyperopisus, Labeo, Mormyrus* etc.). The southern Rift valley (Lakes Abaya and Chamo), and the Shebele-Genale basins also have elements of these forms. It is believed that these lakes and river basins had former connections with the upper White Nile (through Lake Rudolf in the former case) as recently as 7500 years ago. These Nilo-Sudanic forms are related to West African fishes and this, too, is believed to be due to past connections of the Nile to Central and West African river systems.

The highland east African forms are found in the northern Rift Valley lakes (e.g. Lakes Awassa, Ziwai, Langano), the highland lakes (e.g. Tana and Hayq), and associated river systems, and the Awash Drainage Basin. These include members of the genera *Barbus, Labeobarbus, Clarias, Garra, Oreochromis*, and *Varicorhinus*. They are related to fishes of eastern, northern and southern Africa. Some elements are shared with waters of western Africa. For example, *Garra dembeensis* is a widely distributed cyprinid species found in 6 countries (Ethiopia, Kenya, Egypt, Tanzania, Cameroun and Nigeria). Nilotic fishes are almost entirely absent from the Awash and northern rift valley lakes.

Although extensive review work is currently in progress, it appears that a preliminary listing of about 180 valid indigenous species represents what is so far known from Ethiopian freshwaters. There are additionally 10 exotic species. Of the 180 indigenous species, about 39 species and two sub-species are endemic to Ethiopia. Moreover, the inadequacies of the present study underline the contention that further extensive collections and identifications will raise both the total number and the number of endemic species of the country.

The highest species diversity is recorded from Baro (Openo/Kir) Basin, followed by Abay, Rift Lakes, Wabi Shebele and Omo-Gibe basins. It appears that this high diversity is partly attributable to the presence of highly diverse and rich habitats, but probably also to relatively high level of exploration and collections done in these relatively accessible water bodies. However, endemicity seems to be highest in Abay and Awash Basins. This is due to the endemic "species flock" of Lake Tana and the presence of some endemic fishes adapted to localized habitats in small streams in the highlands of north and central Ethiopia. Lake Tana has 28 species and one sub species of which 20 species and one sub species are Ethiopian endemics. 18 species are endemic to Lake Tana.

The drainage basins that are rich in species like the Baro and Omo-Gibe contribute an insignificant proportion of the country's endemic fauna. Only one endemic species (*Afronemacheilus abyssinicus*) has so far been recorded from these drainages and this species has also been recorded from Lake Tana. Low levels of endemism are probably due to the Baro and Omo-Gibe Drainage Basins having connections (present and past) with the Nile and west and central African river systems and as a result all the fish fauna represent widespread Nilo-Sudanic forms.

The major commercially important fish species of the country include *Oreochromis niloticus*, *Labeobarbus* spp., *Lates niloticus, Clarias gariepinus, Bagrus docmak,* and *Cyprinus carpio* (introduced).

## Ethiopian Ecoregions and Drainage Basins

Much of Africa is arid, and Ethiopia could perhaps be called the "water tower of eastern Africa". The country is endowed with some 7000 km$^2$ of standing water and some 7000 km length of flowing water. Based on similarities of the fauna (especially the fish fauna) and following the model of freshwater ecoregions of Africa (Thieme *et al*., 2006) the freshwater systems of Ethiopia can be conveniently placed under six freshwater ecoregions. These freshwater ecoregions can further be divided into drainage basins. The drainage pattern in Ethiopia is the result of the uplifting during the Tertiary period, which created the Rift Valley and consequently the two separate highlands (Mohr, 1966; Westphal, 1975). Since water bodies found in one drainage basin are somehow interconnected, similarity in their biota is evident. According to Mesfin Woldemariam in Shibru Tedla (1973), the Ethiopian freshwater system can be classified into seven drainage basins. These are the Abay, Awash, Baro Akobo, Omo-Gibe, Rift Lakes, Tekeze and Wabi Shebele-Genale Basins (7.1).

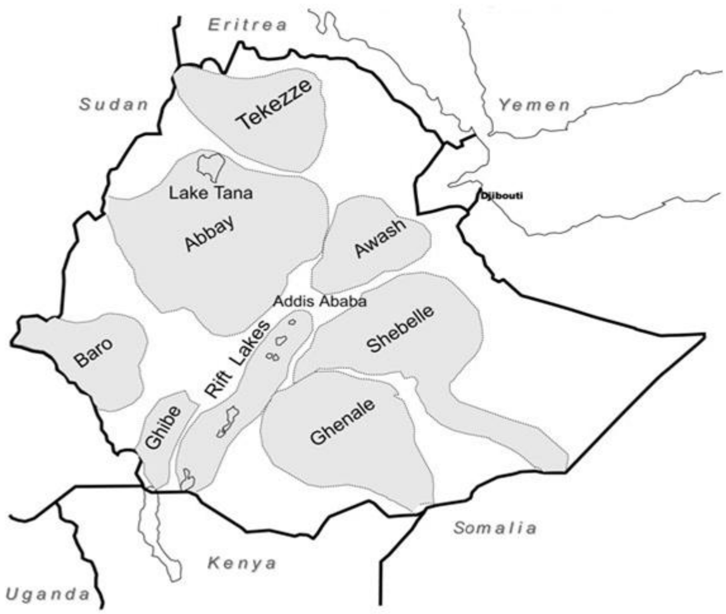


**Figure. 7.1 The main drainage basins of Ethiopia**

The six Freshwater Ecoregions in Ethiopia include the following:

## 1. The Ethiopian Highlands (includes streams, rivers and lakes in the highlands of Ethiopia, but excluding Lake Tana)

The Ethiopian highlands extend from Eritrea in the north to Kenya in the south. Except for their northern part, which continues into the Sudan, they are entirely surrounded by escarpments. The eastern escarpment approximately follows the meridian of $40^{o}$ from Eritrea till the Awash River, where there it curves south and continues to the Kenyan border. In the north it reaches to 2100-

2400 m and dominates like a wall the lowlands east of it some 1200 m below. In the center the Awash valley breaks it, about 1000 m lower. In the south the escarpment is less high and near the Kenyan border the average elevation is ca 1500 m. The western escarpment is in general less high and abrupt, and is considerably more broken. The mountains of Jima area stand out in the south.

The mountainous Ethiopian plateau rises steeply from the Nile lowland. Its highlands are divided into two sections by the East Rift Valley. The N.W. section, culminating in Ras Dashan (about 5000 m or 15,158 ft. high) is the larger and higher of the two; most of it, including Lake Tana, drains west or north into the Nile. In the south, however, it is drained by the Omo River into Lake Turkana. The narrow South West section descends gradually to the semiarid Ogaden plateau, which slopes towards the Indian Ocean. It is drained mainly to the East by the Wabi Shebele (1200 miles long) and the Juba, into the Indian Ocean. This ecoregion contains about 70% of the highlands of Africa. There are some regions over 4000 m, but there is no permanent snow.

The general slope of the Ethiopian highlands is towards the Sudan, whereas that of the Eastern highlands is towards the Indian Ocean. Along the eastern edge of the Ethiopian highlands a major watershed separates the drainage westwards to the Sudan from the drainage eastwards in to the Rift Valley. Similarly, a major watershed following the crest of the Eastern highlands separates the drainage southeastwards towards the Indian Ocean from the drainage into the Rift Valley.

The Ethiopian highlands are drained by the westward flowing rivers (like the Tekezze, Angereb, Atbara, Abay, Baro and Akobo, which form part of the Nile drainage basin) and the eastward flowing rivers draining into the Rift Valley. The south-western part of the Ethiopian highlands is drained by the left bank tributaries of the Abay, the Baro-Akobo River system and the Gibe-Omo River system. The latter occupies a closed basin and drains into Lake Rudolf.

The hydrography of North East Africa is dominated by the drainage of the Nile, which covers 1,100,00 square miles or roughly a tenth of the African surface. The only river longer than it is the Amazon. The Nile has three major tributaries, the most important being the Blue Nile, arising in the central highlands of Ethiopia. Next is the White Nile, draining lakes Albert and Victoria and part of it is the Baro-Akobo Basin found in Ethiopia. The Tekeze (Atbara), arising in the North West highlands of Ethiopia and the last to join the Nile, is of much less importance than the other two. In the lower 1670 miles of its course the Nile flows through arid country where the only tributaries it receives are wadis, which are usually, dry and supply water only during brief periods due to run-off caused by storms. The headwaters of the Blue Nile (or Abay) flow into Lake Tana. The outlet of Lake Tana is the Blue Nile. The Blue Nile, after leaving Lake Tana, makes a U-turn towards the northwest and descends about 1450 m in a distance of 350 km to Khartoum onto the plains. The seasonal (July to October) floodwaters of the Blue Nile carry sediments from the highlands and historically would distribute these over the floodplain in Egypt, increasing the fertility of the soil. The only falls of any height on the Blue Nile are at Tisisat, some 30 km below Lake Tana.

The Blue Nile then enters a ravine, which increases in depth and width until it becomes a rugged valley six to ten miles wide with mountains on either side towering 2000 meters above it. In its upper course the Blue Nile makes a great bend around the Choke Mts., the volcanic peaks of which rise to 4000 meters. Only a small part of the water volume in the Blue Nile is contributed by Lake Tana. Most of its flow comes from intermittent affluents, chiefly the Rahad and Dinder on its right bank and the Didessa and Dabus on its left. The only perennial affluents are relatively small streams arising in the Choke. The rocky streambeds, variable water level, and extreme muddiness of the Upper Blue Nile and its tributaries evidently make them harsh habitat for fishes.

The waters for the Wabi Shebelle and Wabi Juba originate in the highlands located in the southern portion of the ecoregion.

From the biogeographical point of view, despite the fact that Ethiopian highlands are presently separated from both East African and the South Arabian Mountains, the Ethiopian highland riverine fauna resembles that of East and South Africa. There are various endemism in the Ethiopian riverine fauna. The impoverished fish fauna of the Ethiopian highlands is dominated by Cyprinidae. Cyprinids are often the predominant fishes in mountain streams, including the Atlas Mountains, Abyssinian highlands, and South West Cape.

Lakes Hayq, Ardibo, Ashengie, and several highland crater lakes (e.g. Wenchi, Dandi, Zengena, etc...) in the central and northern Ethiopia are included within this Freshwater Ecoregion.

## 2. Lake Tana (because of its unique fish fauna)

Lake Tana is Ethiopia's largest lake (3500 $km^2$) and is situated in the northwestern highlands at an altitude of approximately 1800 masl. The lake is believed to have originated two million years ago by volcanic blocking of the Blue Nile River (Mohr, 1962). It assumed its present shape through blocking of a 50 km long quaternary basalt flow, which filled the exit channel of the Blue Nile River (Chorowicz *et al*., 1998). However, there are strong evidences that Lake Tana had dried up between 25000 and 10000 years ago (Lamb *et al*., 2007).

It is shallow (maximum depth 14 m, mean 8 m) and is meso-oligotrophic (Rzoska, 1976). Several large and small rivers including Gumara, Ribb, Megech, Gilgel Abay, Arno Garno and Dirma (maximum length 60 km) enter the lake, and the Blue Nile is its only outflow.

Lake Tana forms the headwaters of the Blue Nile, which carries more than 80% of the total volume of the Nile River at Khartoum, Sudan. The lake has been isolated from the lower Blue Nile Basin by a 40 m high water fall, 30 km downstream from the Blue Nile outflow. Lake Tana is considered as one of the global top 250 lake regions most important for biological diversity (Lakenet, 2004).

The lake is turbid, well mixed and has no major thermocline (Eshete Dejen *et al*, 2004). Thermoclines of short duration (i.e, several hours) may develop, especially during the dry season (Ayalew Wondie *et al*., 2007).

The seasonal rains cause the lake level to fluctuate regularly with an average difference between minimum (May-June) and maximum (September-October) lake level of approximately 1.5 m. The oxygen content of the water is usually high, ranging from 3.3 to 10.8 ppm in the water column (Nagelkerke, 1997).

Fogera (on the east) and Dembea (on the north) plains border major parts of Lake Tana, and they are considered to be the buffering zones of the lake (Nagelkerke, 1997).

Fogera floodplain lies on the eastern side of Lake Tana in the Southern Gonder Administrative Zone. This floodplain was used for grazing of the renowned Fogera cattle breed but is being now used for cultivation of various kinds of crops such as rice, maize, chickpea, Bukri teff (early maturing local farmers variety) and partly for grazing (mainly before the onset of the major flooding season). Shesher, Welala and Daga-Takua wetlands are located within the Fogera flood plain. These are sites that serve as refuge for wintering migratory birds as well as feeding sites for several species of resident birds. Moreover, they serve as breeding grounds for *Clarias gariepinus* (cat fish). The other wetlands (Dembia, Kunzila and Ambo Bahir) are also part of the Lake Tana sub-basin but are not well studied for their biota.

Due to the high turbidity of the lake, primary production is low and limited to the post rainy season. Despite the high algal species diversity (85 species) primary production in Lake Tana is low (mean chl a 4.5 $mg/m^3$, mean gross primary production 1.43g $O_2$ per $m^2$ per day). This is related to the high turbidity of the lake and high respiratory loss in the deep, non-mixing water column (Ayalew Wondie *et al*., 2007). Highest primary production, dominated by *Microcystis* bloom, occurs during the late rainy season (Sep – Oct) and greens dominate during the dry season (Dec – Apr). Diatoms are present throughout the year. Both emergent and submerged macrophytes play significant role in the lake littoral in terms of trapping silt and nutrients, bank stabilization and as refuge for fish and invertebrates.

The eastern and southern shores of Lake Tana are covered with swamps, especially near river mouths, dominated by papyrus (*Cyperus papyrus*), *Typha latifolia* and waterlilies (*Nymphaea* species). Fig tree or “Warka” (*Ficus sycomorus*) often grow close to the shores.

The dominant macroinvertebrates in Lake Tana are mollusks, insects and crustaceans. The zooplankton includes copepods, cladocerans and rotifers. Brunelli and Cannicci (1940) reported 26 zooplankton species, but recent study by Tesfaye Wudneh (1998) recorded less diversity (17 species). It is evident that zooplankton diversity had declined in Lake Tana during the last seven decades.

Amphibians, especially anurans are present in the lake, particularly in the marshy shore areas. Nile Monitor (*Varanus niloticus*) is the largest reptile in the lake and it is claimed by some farmers that there are also phytons (*Phyton sebae*). Crocodiles are absent from large part of the lake, since the temperature is too low for them to survive and establish themselves.

The aquatic birds around Lake Tana are numerous. A total of 215 bird species have been documented (Shimelis Aynalem and Afework Bekele, 2008). This constitutes about 25% of the total number of 861 bird species in Ethiopia. Piscivorous bird species include residents such as little grebe (*Tachybaptus ruficollis*), Great white pelican (*Pelecanus onocrotalus*), Great and long tailed cormorants (*Phalacrocorax carbo* and *P. africanus*), Darter (*anhinga rufa*), many species of heron (*Ardeola* spp., *Egretta* spp., and *Ardea* spp.) Hammerkop (*Scoppus umbretta*), and African fish eagle (*Haliaeetus vocifer*). Egyptian goose (*Alpochen aegyptiaca*), spur winged goose (*Plectropterus gambensis*) and Pygmy goose (*Nettapus auritus*) are the most conspicuous non-piscivorous aquatic birds. Palearctic migrants that depend on the lake include Osprey (*Pandion haliaetus*), Great black headed, Lesser black headed, and Herring gulls (*Larus ichthyaetus, L. fuscus*, and *L. argentatus*), and whiskered and white-winged black terns (*Chlidonias hybridus*, and *C. leucopterus*). The wetlands and the islands around and within Lake Tana are known to be one of the Important Bird Areas (IBAs).

Hippopotamuses are present in the lake in good numbers while otters are also claimed by farmers to have been seen in some areas. The mammalian gene pool of the lake and its sub basin seems to be threatened. Apart from the Vervet monkeys (*Cercopithecus aethiopicus*) most of the other mammalian species are either vulnerable or critically endangered locally.

There are 28 fish species in Lake Tana out of which 21 are endemic to the country. The fish fauna of Lake Tana are included in the genera *Oreochromis, Clarias*, 'large' barbs (*Labeobarbus*), 'small' *Barbus, Garra, Varicorhinus* and *Nemacheilus. Oreochromis niloticus* has been described as separate sub-species *Oreochromis niloticus tana* (Seyoum & Kornfield, 1992). Before 1990s "large" barb species of Lake Tana were considered as one large complex species *Barbus intermedius intermedius* Banister 1973. Later, after the work of many scientists, (Nagelkerke *et al.*, 1994; Nagelkerke, *et al.*, 1995a and b; Alekseyev *et al*., 1996; Dixon *et al*., 1996; Nagelkerke, 1997; Nagelkerke & Sibbing, 1998; Nagelkerke & Sibbing, 2000; de Graaf, 2003), the large barbs of Lake Tana were recognized as 17 different species. They are the only cyprind species flock in the world, after the ones in Lake Lanao vanished because of overexploitation.

The "small" barbs of Lake Tana are represented by *Barbus pleurogramma* Boulenger, 1902, *Barbus humilis* Boulenger,1902, *Barbus trispilopleura* Lèvêque & Daget, 1984 and *Barbus tanapelagius* de Graaf *et al*., 2000. However, Eshete Dejen (2003) hypothesized that *B. humilis* and *B. trispilopleura* are not separate species. The genus *Garra* is represented in the lake by

*Garra dembecha* Getahun and Stiassny, 2007, *Garra dembeensis* Rüppell 1836; *Garra regressus* Getahun and Stiassny, 2007; and *Garra tana* Getahun and Stiassny, 2007. Two exotic species, *Gambusia holbrooki* Girard 1856; and *Esox lucius* Linnaeus 1758, were reported to have been brought from Italy during the late 1930s and introduced into Lake Tana for malaria control and enhancing the fisheries, respectively (Shibru Tedla & Fisseha H/meskel, 1981). However, there is no trace of these fishes from the lake in recent times.

The families Cichlidae and Clariidae are represented by only one species each, *Oreochromis niloticus* and *Clarias gariepinus*, respectively. *Nemacheilus abyssinicus* is an endemic species belonging to the family Balitoridae and it inhabits the littoral areas of the lake.

Seven of the 28 species recorded from Lake Tana are also found in the rivers. The common species (found both in the rivers and the lake) include *Clarias gariepinus, Garra dembeensis, Garra dembecha, Labeobarbus nedgia, Nemacheilus abyssinicus, Oreochromis niloticus,* and *Varicorhinus beso.*

The relatively high number of species in the lake was possible because the incipient lake offered new habitats for adaptive radiation. It maintained its isolation, since five million years before present, from the lower Blue Nile basin by 40 m high falls at Tissisat. Since there are strong evidences that Lake Tana had dried up between 25000 and 10000 years ago, the evolution of the *Labeobarbus* spp. probably took only 15,000 years or less. Surprisingly eight of these are piscivores and most of them periodically migrate into inflowing rivers for spawning.

### 3. Northern Rift (rift valley lakes excluding Lakes Abaya and Chamo because of the Nilo-Sudanic affinities of the latter's fish fauna)

The Tertiary-Quaternary tectonic formations known as the Rift system is one of the largest structural features of the earth's crust, extending over more than 6000 km from Mozambique to Syria. The system of fractures continues north-north-east across Ethiopia forming the main Ethiopian Rift before opening out into the complex sunken region of Afar. Afar represents the intersection of the African Rift, the Gulf of Aden Rift, and the Red Sea Rift; both the two last rifts are much broader than the typical rifts of the Rift system.

The Ethiopian Rift system is divided into the Lake Turkana Rift, the Chew Bahir Rift, the main Ethiopian Rift running continuously from Lake Chamo to Afar, and the Afar depression.

The present configuration of the lakes and of their drainage system is quite young dating from approximately 5000 yr BP. Previous studies (Mohr, 1962) indicated that there was one single lake during late tertiary, covering the area between the present Lake Zwai and Lake Abaya, which probably drained northward into Awash Basin. Analyses of ostracod, mollusk, fish and algal fossils found in the sediments on the shores of Lakes Zwai and Shala deposited 6000 to 5000 yr BP, indicated that the four lakes were united into a single freshwater lake draining northward into Awash River. Starting about 5000 years BP, a regression in water level took place which led to the separation of the former lake into four present lakes and to a change in the drainage system. The outflow of Lake Zwai into the Awash River was interrupted and this lake along with Lake Langano now discharges into Lake Abijata which serves as a terminal lake for the drainage basin. Lake Shala, located in a caldera, is isolated from the other three lakes at the present time, although it has probably received an inflow in the past from Lake Abijata at times when the water level in that lake was high (Wood *et al*, 1978). Because of high evaporation and lack of outlets, Lakes Abijata and Shala became in time very saline, while Lake Zwai remained a freshwater lake.

The southern part of the rift valley runs in general towards the north-northeast and is enclosed in the east and the west by the escarpments of the Eastern and Ethiopian Highlands, respectively. It contains several lakes. The floor of the valley slopes gradually southwards from an average elevation of nearly 1800 m north of Lake Zwai to about 900 m at Lake Chew Bahir. In general the floor of the valley is from 600 to 900 m below the crest of the escarpments forming its walls although locally there are considerably higher isolated parts. North of Lake Zwai, the rift valley swings to the northeast and then opens out into the Danakil plains. It is drained by the Awash River.

The Northern Rift ecoregion is the most northern extension of the Eastern Rift, located in the valley between the two sections of the Abyssinian highlands and extending 600 km from the northwestern border of Ethiopia southwards to the drainage of Lake Chew Bahir (formerly Lake Stephanie). The valley rises from an altitude of 520 m at Lake Chew Bahir at its lower end to over 1800 m at its northern end. The Awash River flows through the northern portion of the valley. The lakes of the main rift lie within three closed drainage basins. These are (from north to south) the basin including Lakes Ziway, Langano, Abijata and Shala; the basin of Lake Awasa; and the basin of Lake Abaya including Lakes Chamo and Chew Bahir. Lake Chew Bahir is an ephemeral lake that floods during periods of high flow from the Bilate River into Lake Abaya that spills into Lake Chamo and hence, into Lake Chew Bahir (Beadle, 1981).

Lake Zwai is a shallow freshwater lake with a margin of Papyrus sudd and marsh, and is fed by the Meki River on the North West and the River Katar on the North East. Its water flows out through the River Sucsuci (Bulbula) into Lake Abijata. On the east of Lake Abijata lies Lake Chitu, the waters of which appear to be fresh or very slightly alkaline. Lake Chitu is connected to Lake Abijata by a short channel called the Hora Gateau, the water of which is slightly alkaline to the taste. There is no outlet to Lake Abijata and it loses its water by evaporation only.

*Barbus ethiopicus* and *B. microterolepis* are endemic to the Northern Rift, specifically to Lake Ziway. The fish fauna of the lakes is derived from that of the Awash River in which the dominant species are *Oreochromis niloticus, Clarias gariepinus* and *Labeobarbus intermedius*, whereas that of the more southerly Lakes Abaya and Chamo is of Soudanian nature. The diversity in these latter lakes is relatively high and more than 20 species have been recorded. Presumably, the latter lakes were connected to the Nile via high runoff from the Ethiopian highlands causing overflow into Lake Chew Bahir and into Lake Turkana which flowed into the Nile via the Sobat valley (Beadle, 1981).

### 4. Lake Turkana (includes the Omo River and its tributaries as well as Lakes Abaya and Chamo)

Lake Turkana is the largest lake in the eastern portion of the rift valley and the fourth largest lake by volume in Africa. Lying in a low closed basin at approximately 365 m asl, the lake is situated primarily in northwestern Kenya, with only its northernmost end, the Omo Delta, inside Ethiopia. It is 260 km long, with an average width of 30 km, a mean depth of 31 m, and a maximum depth of 114 m. It has an area of approximately 7560 $km^2$ and a volume of 237 $km^3$ (Coulter *et al* in Theieme *et al*., 2005).

The Ethiopian Rift Valley has a mean annual rainfall of 600 mm/year, receiving at least 50% of the precipitation between July and September. The western foothills of the Ethiopian rift escarpment receive up to 1000 mm of rainfall per year. This heavy rainfall causes the Omo River to flood (June-September) bringing nutrient rich waters into Lake Turkana. The northwestern portion of the ecoregion is occupied by the highlands of the Ethiopian massif (above 1500 m a.s.l).

Of the twelve principal rivers that feed Lake Turkana, the River Omo is its only perennial tributary, supplying more than 90% of the lake's inflow (Beadle, 1981). The Omo River drains the southwestern portion of the Ethiopian massif and flows through the Rift Valley into Lake Turkana.

Extensive seasonal flood plains exist along the Omo River Delta, at the northern tip of Lake Turkana. Lake Turkana is unique among larger lakes of the eastern Rift Valley in that its aquatic fauna is dominated by Nilotic riverine species rather than by species of the cichlid family. Compared with other large African lakes, Turkana has low fish species richness, providing habitat for about fifty species, eleven of which are endemic. According to Hopson (1982), four fish communities live in the main lake; a littoral assemblage; an inshore assemblage; an offshore demersal assemblage and a pelagic assemblage. Nearly all endemic species live in the offshore demersal or pelagic zone. Endemic cichlids include three haplochromine species adapted for deep water.

Lake Turkana is an important site for water birds, with up to 220,000 congregants having been recorded at one time and 84 water bird species, including 34 Palearctic migrants, known from the lake (Coulter *et al* in Theieme *et al*., 2005).

Other aquatic animals in the ecoregion include *Hippopotamus amphibious*, *Crocodylus niloticus*, and an endemic freshwater turtle, the recently discovered and imperiled Turkana mud turtle (*Pelusios broadleyi*). Lakes Abaya and Chamo support notably large populations of *Crocodylus* *niloticus* and *Hippopotamus amphibious*. Three frog species are endemic to the ecoregion (*Bufo chappuisi, B. turkanae* and *Phrynobatrachus zavattarii*).

Spawning migrations of fish are synchronized with the ecoregion's seasonal flooding, which occurs from June through September. During this time, various fish species migrate up the Omo River (*Hydrocynus forskalii, Alestes baremoze, Citharinus citharus, Distichodus niloticus* and *Barbus bynni*) and other ephemeral affluents (*Brycinus nurse, Labeo horie, Clarias gariepinus* and *Synodontis schall*) to breed, for periods of both long and short duration.

The northern portion of the ecoregion contains important protected areas. Along the banks of the Omo River, the Omo and Mago National Parks and the Tama Wildlife Reserve protect habitats for the conservation of antelope communities. The Nechisar National Park also covers lands between Lakes Abaya and Chamo.

**5. Shebele Juba catchments (includes tributaries of Wabi Shebele, Genale, Dawa, and Fafan).**

This region is bounded on the west and north by a continuous escarpment running in a wide curve from the Kenyan border to north Somalia; its southern part (about 1800 m high) forms the eastern wall of the Rift valley. The escarpment rises northwards and attains its maximum elevation of over 3000 m near the Chilalo Massif in Arsi. The main rivers have cut deep gorges of which that of the Webi-Shebelle are the deepest (over 1000 m below the level of the plateau). Furthermore, erosion has resulted in a series of more or less parallel ranges or more precisely, narrow plateaus running towards the south-east and separated by the valleys of the Dawa Parma, Genale Doria, Wabi Gestro and Wabi Shebele Rivers.

The southeastern part of the eastern highlands is drained by the headwaters of the Wabi Shebele and the Fafan, but the main stream of the Wabi Shebele does not reach the Indian Ocean. The south-western part of the eastern highlands is drained by the Wabi Gestro, the Genale Doria and the Dawa Parma, which unite into the Juba that drains into the Indian Ocean. The headwaters of the Juba arise just East of Abaya and Chamo but are separated from the lake drainages by a high mountainous divide.

Most of the Nilotic species found in Lake Abaya, with the exception of *Hyperopisus bebe*, are present in the Wabi Shebelle-Juba drainage and in the Omo-Turkana drainage. The only large perennial rivers in Somalia are the Wabi Shebelle and Juba, which arise on the eastern slopes of the Ethiopian highlands and flow across the southern part of the country. Primary division fishes living away from these rivers are subterranean midway between the lower courses of the Wabi Shebelle and the Juba, where they are widest apart; there is a low-lying limestone plateau with extensive underground waterways radiating out from it. These are inhabited by the endemic genera *Uegitglanis* and *Phreatichthys*.

The geographically nearest surface-dwelling populations of *Barbus* sp. are in the Wabi Shebele, over 250 miles distant. There is no evidence, either from distribution of living fishes or the fossil record that the Nilo-Sudanic fish fauna formerly extended into the Eastern rift valley south of Lake Turkana. The Juba and Wabi Shebele are the only rivers on the East coast of Africa having Nilo-Sudanic fishes in any numbers.

### 6. Red Sea coastal (the Awash system and the saline lakes of northern Ethiopia that includes Lakes Abbe, Afambo, Afdera, and Asale)

The Red Sea coastal plains border in the north immediately the east of the plateau, south of Massawa, the Danakil Alps, as a narrow strip along the shore. They consist of recent marine sediments and coral reef formations.

Occasionally cyclonic storms of Mediterranean origin enter the Red Sea area and their effects are felt on both shores. Thus, the dry subsident airstreams moving south over Ethiopia from the Sahara, and Arabian anti-cyclones result in dry weather during the period October-March.

Rainfall regime with maximum in December-February includes the Red Sea-Gulf of Aden coastal plains and slopes of the nearby escarpment and it has a single rainfall maximum in "winter". This region has semi-desert and steppe type vegetation where the annual rainfall is less than 300 mm. The vegetation vary from steppe with perennial shrubs, herbs and grasses through semi-desert and scrub where the vegetation consists mainly of an open formation of grasses, ephemeral herbs and low thorny shrubs, and to semi-desert with Acacia.

**The Awash River** ends in a chain of saline lakes of which the largest are **Gamari, Afambo, Bario** and **Abe**. These all lie to the east of Asaita. Afambo, with a town of the same name, is about 30 km east of Asaita. The Awash enters Lakes Abe and Afambo on their northwestern shores and is the only source of freshwater for these lakes. All the lakes and the woody vegetation around them as well as in the towns are visited by very large numbers of palaearctic migrant birds and it is suggested that the whole area be seen together in relation to conservation of the wildlife of the area. The site is believed to hold more than 20,000 waterbirds. Good numbers of many wet land congregatory species are known to use the area including White-faced Tree Duck, White Pelican, Squacco Heron, Cattle Egret, Little Egret, wood Ibis and Marabou. The site is also an important staging point on the migration route to and from the Arabian Peninsula used by many Palearctic species both in Autumn and in Spring. These include Basra Reed Warbler, Nightingale, Sprosser, Redstart, reed Warbler etc.

**Lake Afdera** is located some 700 km north of Addis Ababa (12.6ºN and 41ºE) at an altitude of 80 meters below sea level. "Afdera" by the local (Afar) language means inaccessible. The depression is under active volcanic and tectonic activities (Williams *et al*., 1977). The molten black rocks and gravels all around the area and the hot springs that drain the lake, the only source of water other than the scanty precipitation, witness this reality. It is a rainfall deficit area receiving an average annual rainfall of about 100 mm (Wood and Lovett, 1979). Similar is Lake Asale found north of Lake Afdera at an altitude of 150 m below sea level. The other lakes in that region (Gamari, Afambo, Bario and Abe) are fed by the Awash River.

Fishes were reported from the vicinity of one hot spring in the southwestern portion of the lake. It is a location where the freshwater enters into the saline lake water. The fishes strategically inhabit areas between the saline waters of the lake and the hot waters of the spring. The species are:

1. *Danakilia franchettii* (Vinciguerra 1931)

Fishes of this endemic genus show noted sexual dimorphism and are found in large numbers at the above site.

2. *Aphanius (Lebias) dispar* (Rüppell 1829)

This Killifish is widely distributed in shores of the Red Sea and Mediterranean Ocean. This killifish was a recently discovered new species from the lake.

3. *Aphanius (Lebias) stiassnyae* (Getahun and Lazara 2001)

The above fishes were collected from a small segment (about 100 $m^2$ area) at the shore where one of the hot springs joins the lake. It is not known whether or not these fishes strive in the interior and even at shores where other springs join the lake. The exact number of springs joining the lake is not also known. Although the lake is reported to be biologically unproductive (Wood and Talling, 1988) no mention was made as to the extent of its life forms (microbial, phytoplankton, zooplankton and others). Based on the fact that one endemic genus and one endemic species of fishes are identified from a small portion of the lake, and the lake's isolation for a long time, it is reasonable to suggest that other novel life forms can also be found in this lake.

**Lake Asale** is found at an altitude of –155 m. The surface area is 55 $km^2$. The maximum depth is 40 m and the salinity is 276.5 g per liter. A modern ingress of sea water by seepage does occur to the saline L. Assal only 10 km from the Red Sea but 155 m lower. The predominance of chloride in Lake Assal makes possible the very high salinity (~300 g per liter) of this lake. Small *Aphanius* species have been reported from this lake, although extensive study of the fish fauna is lacking.

## Fisheries and Aquaculture in Ethiopia

### *Capture Fisheries*

Data on the Ethiopian fisheries is scanty and not very well organized. This is due to the fact that fishery statistics are not properly collected and organized around water bodies of the country where fishery activities are taking place.

Empirical models suggest that current total fish production potential is around 50000 tons. The empirical models generally do not take into account the effects of unsuitable management or fishing practices and have been criticized for consequently grossly overstating the MSY. There are no field surveys to indicate actual production capacity in the lakes.

Management of fisheries is not uniform, resulting in patchy overall data collection and information. In 2007 total production was 13253 tons (up from 10617 tons in 2006), valued at approximately USD 14 Million (FAO, 2011). Capture fisheries make up the entire production in official statistics. In 2010, total production was 18 058 tons and capture fisheries make up the entire production in official statistics. In 2010, export quantity amounted to 849 tons, while imports amounted to 421 tons.

The bulk of fish production in Ethiopia is made of *Tilapia, Clarias, Lates, Barbus, Bagrus,* and *Labeo* species. Approximately 60-80% of the catch is tilapia, although Nile perch is caught in large quantities from Lakes Chamo and Abaya, as well as from Baro (Openo/Kir) River. Most of the remainder of the lake catches consists of catfish and large *Barbus* spp.

Fisheries are mainly artisanal and conducted by reed boats; motorized boats are few and old. Commercial fishery is concentrated at Lakes Tana, Chamo, Ziway, Hawassa, Abaya and Turkana.

**Lake Tana** has an estimated total productivity of 7000 to 10000 tons. Catches in 2007 amounted to approximately 3483 tons and were dominated by Nile tilapia. The fleet currently numbers to 400 reed boats and 25 motorized boats. **Lake Ziway** used to support more fisheries than Lake Tana, but fisheries have declined with increasing degradation of the lake to anthropogenic factors and overexploitation of the resources. In 2007, the catch amounted to 2122 tons. Catfish fishery is increasing in the lake, although tilapia and carps are also caught. **Lake Hawassa** fisheries include tilapia, catfish, barbs and common carp. The present Maximum Sustainable Yield (MSY) is estimated at around 800 tons annually. Catches in 2007 were 770 tons, down from 943 tons in 2005.

**Lake Langano** has little fishery. In 2007, catches amounted to 673 tons, down from 1100 tons in 2002. Lake Abijata is no longer supporting any fishery, due to shrunk water surface (because of soda-ash production) and pollution. **Lake Chamo** fisheries focus on tilapia, but Nile perch, catfish and barbs are also caught. Catches in 2007 were 1796 tons, down from almost 4000 tons in the late 1990s. **Lake Abaya**, close to Lake Chamo, may not be as productive as the latter. Production from Lake Abaya in 2007 was 1232 tons.

A very small proportion of **Lake Turkana** is located within Ethiopian territory; however, 90% of the discharge is from River Omo. Catches from Lake Turkana are reported to include Nile perch and catches in 2007 stood at 1334 tons. **Lake Koka** is an artificial reservoir on the Awash River which supports common carp, barbs, tilapia and catfish and the catches in 2007 were 634 tons (Table 7.1).

There are eight major rivers in the country: Abay (Blue Nile), Baro, Omo, Wabishebelle, Genale, Awash, Tekeze, and Angereb. Riverine fishing activities are performed mostly on two of the rivers, the Baro near Gambela in the western part of the country and the Omo in the southern area near the border with Kenya. Riverine fisheries generally remain on subsistence level.

The primary sector in fisheries employs an estimated 13200 people of which 4052 are full time fishers. The secondary sector is believed to employ another 20000.

**Table 7.1. The Fisheries status in Ethiopia (2007 data)**

| **Water body** | **Production** |
|---|---|
| Chamo | 4000 |
| Ziway | 2500 |
| Tana | 1200 |
| Hawassa | 650 |
| Koka | 600 |
| Abaya | 500 |
| Langano | 400 |
| Wollo lakes | 300 |
| **Total** | **10150 tons** |

### *Aquaculture in Ethiopia*

Aquaculture in Ethiopia is at its preliminary stage. There are some experimental ponds around some Research Stations (e.g. Sebeta, Bahir Dar, Ziway, Guder) and at the backyard of some selected farmers in different locations. Several scientific experiments had been conducted on cage and pond cultures in the country and are showing promising future in Ethiopia. The development of the sector should, thus, be seriously considered, given the available water resources, suitable climate, soil, and inexpensive labor. Recently, a National Aquaculture Development Strategy document has been developed with the assistance from FAO, which is a positive move towards development of aquaculture in the country. There is no reliable statistics indicating the contribution of existing aquaculture to the fisheries in the country, although a very recent report (FAO, 2013) indicated 20 tons of annual production of fish from the aquaculture sector.

## Legislations Governing Fish and Fisheries in Ethiopia

The Federal regulation set the Fisheries Development and Utilization Proclamation in February 2003. The proclamation is divided into four parts: The first part consists of definitions of terms, objectives and scope of application. The second part states about fisheries resource utilization that includes capture fisheries from natural and manmade water bodies; Aquaculture; issuance of Fisheries Resource Concessions; Environmental Protection; Transboundary and Transregional Fisheries Resources; Handling of fish products; Fisheries Information Exchange; and Basic principles of fisheries development and utilization laws. Part three is about Enforcement of the proclamation that includes powers and responsibilities of a fishery inspector and seized fish, fishing gears and other goods. The last part is about offense and penalty; other sanctions and related subjects. The proclamation is presented in the following pages.

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# FEDERAL NEGARIT GAZETA

OF THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

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9th Year No. 32
ADDIS ABABA–4th February, 2003

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ይህ አዋጅ "የዓሣ ሀብት ልማትና አጠቃቀም አዋጅ ቁጥር ፫፻፲፭/፲፱፻፺፭" ተብሎ ሊጠቀስ ይችላል።

፪· **ትርጓሜ**

የቃሉ አገባብ ሌላ ትርጉም የሚያሰጠው ካልሆነ በስተቀር በዚህ አዋጅ ውስጥ፤

፩· "ዓሣ" ማለት ማንኛውም የዓሣ ዝርያ፣ ሽርጠን፣ አስተኔ (ክሩስተሺያን)፣ ዛጎል ለበስ (ሞለስክ)፣ እንዲሁም እነሱ የጣሉትን እንቁላል፣የተፈለፈለ ወይም ታዳጊ ጫጩትን ያጠቃልላል፤

፪· "የዓሣ ሀብት" ማለት በተፈጥሮና በሰው ሠራሽ የውሃ አካላት ውስጥ የሚገኝ የዓሣ ክምችት ነው፤

## PROCLAMATION NO. 315/2003

## FISHERIES DEVELOPMENT AND UTILIZATION PROCLAMATION

WHEREAS, Ethiopia has fisheries potential which has importance as source of food and provides economic benefits;

WHEREAS, it has become necessary to give attention for the development and rational utilization of this resource;

WHEREAS, it is necessary to establish a fisheries law to enable a sustainable development of the resource and since such law does not exist so far;

NOW, THEREFORE, in accordance with Article 55 (1) of the Constitution of the Federal Democratic Republic of Ethiopia, it is hereby proclaimed as follows:

### PART ONE
### *General*

1. *Short Title*

This proclamation may be cited as the "Fisheries Development and Utilization Proclamation No. 315/2003."

2. *Definition*

Unless the context requires otherwise, in this Proclamation:

1) "Fish" means any fish species, crustanceans, mollusks, including their eggs, spawn, fries or fingerlings;
2) "Fisheries Resource" means the fish stocks contained in natural and man-made water bodies;

፫· "የዓሣ ግብርና" ማለት ቁጥጥር በሚደረግበት ሁኔታ በተፈጥሮና በሰው ሠራሽ የውሃ አካላት ዓሣን ማርባት እና/ ወይም ማምረትና ከዚህ ጋር የተያያዙ ሌሎች ሥራዎችንም የሚጨምር ነው፤

፬· "የዓሣ ግብርና ተቋም" ማለት የዓሣ ግብርና ሥራ የሚካሄድበት ማንኛውም የተወሰነ ቦታ ወይም አካባቢ ሲሆን ለግል መዝናኛነት የሚዘጋጀውን መርዕየ ጎንጻን አይጨምርም፤

፭· "ዓሣ ማስገር" ማለት ማንኛውንም ዘዴ በመጠቀም ከማንኛውም የውሃ አካል ለተለያየ ዓላማ ዓሣ የመያዝ፣ የመግደል ወይም የማውጣት ተግባር ነው፤

፮· "ለግል ፍጆታ ዓሣ ማስገር" ማለት ዓሣ አስጋሪው ለራሱና ለቤተሰቡ ፍጆታ ብቻ የሚያካሂደው የዓሣ ማስገር ሥራ ነው፤

፯· "ለንግድ ዓሣ ማስገር" ማለት በሙሉ ወይም በከፊል ለመሸጥ ወይም ለመለወጥ ዓሣ ማስገር ነው፤

፰· "ለመዝናኛ ዓሣ ማስገር" ማለት ለመዝናኛ ተብሎ ልሙጥ የሆነ ነጠላ መንጠቆና የናይለን ክር በመጠቀም የሚካሄድ ዓሣ ማስገር ነው፤

፱· "ለምርምር ዓሣ ማስገር" ማለት ለሳይንሳዊ ምርምር፣ ለሙከራ፣ ለሌሎች ጥናታዊ ሥራዎች ወይም ዓሣን በማንኛውም የውሃ አካል ለመጨመር መያዝንና ለመርዕየ ጎንዳና ለቤተመዘክር ዓሣ መሰብሰብን ይጨምራል፤

፲· "ሰው" ማለት ማንኛውም የተፈጥሮ ሰው ወይም በሕግ የሰውነት መብት የተሰጠው ድርጅት ነው፤

፲፩· "ዓሣ አስጋሪ" ማለት የዓሣ ማስገር ሥራ የሚያካሂድ ሰው ነው፤

፲፪· "ጥብቅ የዓሣ ሀብት ክልል" ማለት በማንኛውም የውሃ አካል ውስጥ የዓሣውን ዝርያ ለመጠበቅ ወይም ለሌላ ተግባር ሲባል በሙሉ ወይም በከፊል የተከለለና ለምርምር ካልሆነ በስተቀር ለማንኛውም የዓሣ ማስገር ሥራ የተከለከለ አካባቢ ነው፤

፲፫· "የዓሣ ማስገሪያ ጀልባ" ማለት ለዓሣ ማስገር ሥራ ከብረት፣ ከጣውላ፣ ከእንጨት፣ ከቀርከሃ፣ ከደንገል ወይም ከመሳሰሉት የተሠራ ማንኛውም ተንሳፋፊ አካል፣ ነው፤

፲፬· "የዓሣ ማስገሪያ መሣሪያ" ማለት ለዓሣ ማስገር ሥራ የሚያገለግል ማንኛውም መረብ፣ ወጥመድ፣ ወንፊት፣ ነጠላ የናይለን ክር፣ መንጠቆና እንዲሁም ሌላ ተመሣሣይ መሣሪያ ነው፤

፲፭· "ሚኒስቴር" ወይም "ሚኒስትር" ማለት እንደቅደም ተከተሉ የግብርና ሚኒስቴር ወይም ሚኒስትር ነው፤

፲፮· "ክልል" ማለት በኢትዮጵያ ፌዴራላዊ ዲሞክራሲያዊ ሪፐብሊክ ሕገ መንግሥት አንቀጽ ፵፯ (፩) መሠረት የተመለከተ ማንኛውም የክልላዊ መስተዳድር ሲሆን ለዚህ አዋጅ አፈጻጸም የአዲስ አበባና የድሬዳዋ አስተዳደሮችንም ይጨምራል፤

፲፯· "የዓሣ ሀብት ተቆጣጣሪ" ማለት ይህን አዋጅና በአዋጁ መሠረት የሚወጡ ደንቦችንና መመሪያዎችን ከስልጣናቸው ኃላፊነት አንፃር ለማስፈፀም እንዲችል በሚኒስቴሩ ወይም በሚመለከተው የክልል ባለሥልጣን ሥልጣን የተሰጠው አግባብ ያለው ማንኛውም ሰው ነው፤

፫· ዓላማ

የዚህ አዋጅ ዓላማዎች፣

፩· የዓሣ ብዝሀ-ሕይወትና አካባቢው እንዲጠበቅ፣ ዓሣ ሀብቱ ከሚገባው በላይ እንዳይመረት መከላከልና መቆጣጠር፣

፪· ጥራቱና ንጽሕናው የተጠበቀ የዓሣ ምርት አቅርቦትን ማሳደግና ለምግብ ዋስትና የሚያበረክተውን አስተዋጽዖ በዘላቂነት ማረጋገጥ እና፣

፫· የዓሣ ግብርና ልማትን ማስፋፋት፣

ናቸው።

3) "Aquaculture" means the breeding and/or cultivation of fish, and including other related activities, in natural and man-made water bodies under controlled condition;

4) "Aquaculture Facility" means any specific place or area where aquaculture activity is undertaken but does not include a personal aquarium;

5) "Fishing" means the catching, killing or taking of fish for whatever purpose using any method from any water body;

6) "Subsistence Fishing" means fishing solely for the purpose of self and family consumption;

7) "Commercial Fishing" means fishing for the purpose of commercial or monetary gain where all or part of the catch will be destined for sale or bartering;

8) "Recreational fishing" means fishing solely for the purpose of pleasure using single hood and mono-filament nylon line;

9) "Research Fishing" means fishing for the purpose of scientific, experimental, and other studies or for the purpose of stocking fish into any water body including collecting fish for aquarium, museums and zoo;

10) "Person" means any natural person or juridical entity;

11) "Fisher" means a person who physically undertakes fishing;

12) "Protected Fishery Area" means a fully or partially demarcated geographical area of any water body where, except for research, fishing is prohibited for the protection of the inhabiting fish species or for other purposes;

13) "Fishing Boat" means any floating vessel made of steel, timber, wood, bamboo, reed or other similar material used for fishing;

14) "Fishing Gear" means any net, trap, sieve, mono-filament nylon line, hook, and any other similar equipment used for fishing;

15) "Ministry" or "Minister" means the Ministry or Minister of Agriculture respectively;

16) "Region" means any Regional Administration specified under Article 47 (1) of the Constitution of the Federal Democratic Repubic of Ethiopia and includes, for the purpose of this Proclamation, Addis Ababa City and Dire Dawa Administrations;

17) "Fishery Inspector" means any appropriate person duly authorized by the Ministry or by the concerned Regional Authority to implement this proclamation as well as regulations and directives issued hereunder with respect to its power.

3. Objective

The objectives of this proclamation are:

1) to conserve fish biodiversity and its environment as well as to prevent and control over-exploitation of the fisheries resource;

2) to increase the supply of safe and good quality fish and to ensure a sustainable contribution of the fisheries towards food security; and

3) to expand aquaculture development.

፬· የአፈጻጸም ወሰን

ይህ አዋጅ በኢትዮጵያ ውስጥ ዓሣ በሚረባባቸውና በሚመረትባቸው የውሃ አካላት ሁሉ ማለትም በሐይቆች፣ በወንዞች፣ በጅረቶች፣ በግድቦች፣ በኩሬዎችና በረግረጋማ ቦታዎች እንዲሁም የዓሣ ምርት ዝግጅትና ግብይት በሚካሄድባቸው ቦታዎች ተፈጻሚነት ይኖረዋል።

## ክፍል ሁለት
## የዓሣ ሀብት አጠቃቀም

፭· ከተፈጥሮና ሰው ሠራሽ የውሃ አካላት የሚገኝ የዓሣ ሀብት

፩· ለንግድ ሥራ ከተፈጥሮ እና ከሰው ሠራሽ የውሃ አካላት ዓሣ ለማስገር የሚፈልግ ማንኛውም ሰው ሕጋዊ የዓሣ ማስገር ፈቃድ መያዝ አለበት።

፪· የዓሣ ማስገር ፈቃድን በማንኛውም መልኩ ለሌላ ሰው አሳልፎ መስጠት የተከለከለ ነው።

፫· ማንኛውም ሰው ከብሔራዊ ዱር እንስሳት ፓርክ ወይም ጥብቅ ቦታ ለፍጆታ፣ ለንግድ ወይም ለመዝናኛ ዓሣ ለማስገር ፓርኩን ለማስተዳደር ሥልጣን ከተሰጠው አካል የተሰጠ የፅሑፍ ፈቃድ መያዝ አለበት።

፬· ከጥብቅ የዓሣ ሀብት ክልል ለፍጆታ፣ ለንግድ ወይም ለመዝናኛ ዓሣ ለማስገር የፈለገ ማንኛውም ሰው ከሚኒስቴሩ ወይም ከሚመለከተው የክልል ባለሥልጣን የፅሑፍ ፈቃድ ማግኘት አለበት።

፭· ለመዝናኛ ዓሣ ለማስገር የሚፈልግ ማንኛውም የውጭ ሀገር ዜጋ እንደአግባቡ ከሚኒስቴሩ ወይም ከሚመለከተው የክልል ባለሥልጣን የፅሑፍ ፈቃድ ማግኘት አለበት።

፮· ማንኛውም ሰው ለፍጆታ፣ ለንግድ ወይም ለመዝናኛ በዚህ አዋጅ አንቀጽ ፯ በተደነገገው መሠረት በኮንሴሽን ከተሰጠ የዓሣ ሀብት ዓሣ ለማስገር ኮንሴሽን ከተሰጠው ሰው ፈቃድ ማግኘት አለበት።

፯· ለምርምር ሥራ ካልሆነ በስተቀር ሕጋዊ ከሆኑ የማስገሪያ መሣሪያዎች ውጭ በፈንጂ፣ በጦር መሣሪያ፣ በመርዝ፣ ዓሣውን በሚያደነዝዝ ዕፅ ወይም በኤሌክትሪክ ሞገድ ከማንኛውም የውኃ አካል ዓሣ ማስገርና እነዚህን ነገሮች በውሃ አካላት ላይና ዳርቻ ይዞ መገኘት የተከለከለ ነው፣

፰· ከማንኛውም የውሃ አካል ውሃውን በማጠንፈፍ ዓሣን ማስገር የተከለከለ ነው።

፱· በሀገሪቱ የውኃ አካላት ለምርምር ዓሣ ማስገር የሚፈልግ ማንኛውም ሰው የምርምር ሥራን ለመምራት እና እንደአስፈላጊነቱ ውሃን ለማስተዳደር ሥልጣን ከተሰጠው የፌዴራል ወይም የክልል መንግሥት አካል ፈቃድ ማግኘት አለበት።

፲· ማንኛውም ሰው ከውጭ ሀገር ማንኛውንም ዓይነት ሕይወት ያለው የዓሣ ዝርያ ወደ ሀገር ውስጥ ለማስገባት ወይም ከሀገር ለማስወጣት፣ከሚኒስቴሩ የጽሑፍ ፈቃድ ማግኘት አለበት።

፲፩· ማንኛውም ሰው ከውጭ ሀገር በፈቃድ ወደ ሀገር ውስጥ የገባውን ወይም በሀገር ውስጥ የሚገኘን ማንኛውም ሕይወት ያለው ዓሣ ከአንዱ ክልል የውሃ አካል ወደ ሌላ ክልል ለማዘዋወር ከሚኒስትሩ የጽሑፍ ፈቃድ ማግኘት አለበት፡፡

፲፪· ማንኛውም ሰው ሙሉ በሙሉ በክልሉ ውስጥ በሚገኙና ወደ ውጭ የመፍሰስ ባህርይ በሌላቸው የውሃ አካላት መካከል ከአንዱ የውሃ አካል ወደ ሌላ የውሃ አካል የዓሣ ዝርያ ለማዘዋወር ከሚመለከተው የክልል ባለሥልጣን የጽሑፍ ፈቃድ ማግኘት አለበት።



4. *Scope of Application*

This proclamation shall be applicable to all water bodies found within the boundary of Ethiopia such as lakes, rivers, streams, reservoirs, ponds, and marshy areas where fish are bred and where fishing, preparing, activities and marketing takes place.

## PART TWO
## *Fisheries Resource Utilization*

5. *Capture Fisheries from Natural and Man-made Water Bodies*

1) Any person who wishes to undertake commercial fishing from natural and man made water bodies shall do so upon acquisition of a legal fishing permit.
2) Transferring a fishing license by any means to another person is prohibited.
3) Any person who undertakes subsistence fishing, commercial fishing or recreational fishing within a national park or a reserved fishery area shall hold a written permit from the authority responsible to administer the parks.
4) Any person who wishes to undertake subsistence fishing, commercial fishing or recreational fishing within a protected fishery area shall obtain a written permit from the Ministry or concerned Regional Authoritym.
5) A non-national who wishes to undertake recreational fishing shall do so upon acquisition of a written permit from the Ministry or from the concerned Regional Authority.
6) Any person who wishes to undertake subsistence fishing, commercial fishing, or recreational fishing on a fisheries resource, subject to a concession granted according to Article 7 of this proclamation, shall do so with permission from the concerned concessionaire.
7) Fishing using illegal fishing materials, and presence near and on the water bodies holding things such as explosives, ammunition, poisons, fish narcotising plant or any device capable of producing electric current is forbidden except for the purpose of research.
8) Fishing from any water body by way of sifting is prohibited.
9) Any person who wishes to undertake fishing research on the water bodies of the country shall do so by obtaining a permit from the authorized Federal or Regional Government organ designated to direct research activities and, as may be necessary, the body authorized to administer water resources.
10) Any person who wishes to import or export any type of exotic live fish species shall have a written permit from the Ministry.
11) Any person who wishes to transfer live fish which has been exported with permit, or an indiginous species from one Regional water body to another Regional water body have to do so with a written permit from the Ministry.
12) Any person who wishes to transfer live fish from one water body fully contained in the region into another water body which is also fully contained in the same region shall do so with a written permit from the Ministry.

፮· <u>የዓሣ ግብርና</u>

፩· ማንኛውም ሰው ለንግድ የዓሣ ግብርና ተቋም ለማቋቋም ወይም የዓሣ ግብርና ለማካሄድ እንደአግባብነቱ ከፌዴራል ወይም ከክልል ባለሥልጣን ፈቃድ ማግኘት አለበት።

፪· ለንግድ የዓሣ ግብርና ተቋም ለማቋቋም ወይም ለማካሄድ ለሚፈልግ ማንኛውም ሰው ፈቃድ የሚሰጠው፣

ሀ) በቂ መሬት ያለውና ለሥራው የሚያስፈልገውን የውኃ መጠን ለመጠቀም ወይም ከመሬት ውስጥ ለማውጣት ወይም በተፈጥሮ የውሃ አካላት ላይ ለመጠቀም ሥልጣን ካለው አካል ፈቃድ የተሰጠው፣ እና

ለ) የሚቋቋመው የዓሣ ግብርና ተቋም አካባቢን የማይበክል ወይም በተፋሰሱ ባሉ የውሃ አካላት በሚገኙ የዓሣ ዝርያዎች ላይ ጉዳት የማያደርስ፣

መሆኑ ሲረጋገጥ ብቻ ነው።

፫· የዓሣ በሽታ ከዓሣ ግብርና ተቋም ወደ አካባቢው ወይም ተፋሰሱ ሊዛመት ይችላል ብሎ ሲያምን ሚኒስቴሩ ወይም አግባብ ያለው የክልል ባለሥልጣን አስፈላጊውን እርምጃ ይወስዳል፣

፬· የዓሣ ግብርናና የዓሣ ግብርና ተቋም ማንባታና አጠቃቀም ደረጃዎችን በተመለከተ ሚኒስቴሩ እንደ አስፈላጊነቱ መመሪያ ያወጣል።

፯· <u>የዓሣ ሀብትን በኮንሴሽን ስለመስጠት</u>

የሚኒስትሮች ምክር ቤት ወይም ክልላዊ መንግሥታት የአንድ የውሃ አካል ዓሣ ሀብትን ለአንድ ወይም ለብዙ ሰዎች በኮንሴሽን የሚሰጡበትና የዓሣ ሀብቱ በዘላቂነት መልማቱን የሚቆጣጠሩበት ሕግ ማውጣት ይችላሉ።

፰· <u>አካባቢን ስለመጠበቅ</u>

በማናቸውም ተፋሰስ ለማካሄድ የሚታቀዱ የልማት ፕሮግራሞችና ፕሮጀክቶች በቀጥታም ሆነ በተዘዋዋሪ በተፋሰሱ በሚገኝ የዓሣ ሀብት ላይ አሉታዊ ተፅዕኖ የማያደርሱ መሆናቸውን በሚመለከተው የፌዴራል ወይም የክልል መንግሥት አካል መረጋገጥ አለበት።

፱· <u>ወሰን እና ክልል ተሻጋሪ የዓሣ ሀብት ልማት</u>

፩· ወሰን ተሻጋሪ የዓሣ ሀብት ልማትን በተመለከተ ሚኒስቴሩ ከሚመለከታቸው ጎረቤት ሀገሮች ጋር መደራደርና ስምምነት ማድረግ ይችላል፣

፪· እያንዳንዱ ክልል ከሌሎች ክልሎች ጋር በሚያዋስኑ የውሃ አካላት ውስጥ የሚገኝ የዓሣ ሀብት በዚህ አዋጅ በተደነገጉት መርሆዎች መሠረት መጠበቁን ለማረጋገጥ መተባበር ይኖርበታል፣

፫· ክልሎችን በሚያዋስኑ የውሃ አካላት የሚገኝ የዓሣ ሀብት በሚመለከታቸው ክልሎች መካከል ሀብቱን በጋራ ለማልማት በሚደረግ ስምምነት መሠረት አለመካሄዱ ሲረጋገጥ የዓሣ ሀብቱን በአግባቡ ለማልማት የሚያስችል ደንብ የሚኒስትሮች ምክር ቤት ሊያወጣ ይችላል።

፲· <u>የዓሣ ምርት አያያዝ</u>

የዓሣና የዓሣ ውጤት አያያዝ፣ዝግጅት፣ ክምችት ፣ማጓጓዝና ንግድ ሥራዎች ተገቢውን የጥራትና የንግድ ደረጃዎችንና ሥርዓቶችን የጠበቀ መሆን አለበት። ዝርዝሩም በዚህ አዋጅ መሠረት በሚወጣ ደንብ ይወሰናል።



6. *Aquaculture*

1) Any person who wishes to establish aquaculture facility or undertake aquaculture for commercial purpose shall do so upon acquisition of a permit, as may be appropriate, from the Federal or Regional Authority.

2) A permit shall be issued to any person who wishes to establish an aquaculture facility of practice aquaculture only when it is verified that:

a) there is sufficient land and surface/ground water and there is a permit from the appropriate federal or regional administrative organ to utilize water that is required for the aquaculture facility or to establish the facility on natural water bodies; and

b) establishment of the aquaculture facility does not have a negative impact on the surrounding environment or on the fish species inhabitting the water bodies in the basin.

3) The Ministry or the concerned Regional Authority shall take an appropriate measure when it is convinced that there is a risk that a fish disease in the aquaculture facility may spread into the surrounding or into the water basin.

4) The Ministry shall, as may be necessary, issue directives regarding standards for the establishment and operation of aquaculture facilities and aquaculture.

7. *Issuance of Fisheries Resource Concession*

The Council of Ministers or Regional Governments may issue laws regarding the issuance of concession to one or more than one person as well as to regulate the utilization and sustainable development of the fisheries resource of any water body subject to concession.

8. *Environmental Protection*

The concerned organs of the Federal or Regional Governments shall ensure that development programmes and projects are drawn up in such a way that they will not have direct or indirect negative impact on the fisheries resource constituted in the basin where the programmes or projects are intended to be implemented.

9. *Transboundary and Transregional Fisheries Resources*

1) The Ministry may negotiate and enter into agreements with the respective neighboring countries regarding the development of transboundary fisheries resources.

2) Regional Administations shall co-operate to ensure that fisheries in transregional water bodies are managed according to the principles set out in this Proclamation.

3) The Council of Ministers may issue regulations to appropriately develop trans regional fisheries resources when it is verified that the implementation of the agreement entered into between the concerned regions, regarding the development of the fisheries resources shared between them has failed.

10. *Handling of Fish Products*

Fish and fish product handling, processing, storage, transportation and trade shall meet the requirements of fish quality and trade standards procedure. Details shall be determined by regulations issued pursuant to this proclamation.

፲፩· የዓሣ ሀብት መረጃ ልውውጥ

፩· ለዚህ አዋጅ አፈፃፀም እንዲረዳ ክልላዊ መስተዳድሮች የዓሣ ሀብት መረጃዎችን በመሰብሰብና በማጠናቀር ለሚኒስቴሩ ይልካሉ፤

፪· ሚኒስቴሩ ከተለያዩ ምንጮች ስለ ዓሣ ሀብት የሚሰበስባቸውን መረጃዎችና የምርምር ውጤቶች በመገምገምና በማዘጋጀት ለክልል መስተዳድሮችና ለሌሎች ተጠቃሚዎች እንዲደርሱ ያደርጋል፤

፲፪· የዓሣ ሀብት ልማት እና አጠቃቀም ሕግ መሠረታዊ ጉዳዮች

በዚህ አዋጅ መሠረት የሚወጣ ማንኛውም የዓሣ ሀብት ሕግ ጥብቅ የዓሣ ሀብት ክልልን፣ ዓመታዊ የዓሣ ምርት መጠንን፣ የማስገሪያ መሣሪያ ዓይነትንና ብዛትን፣ የማስገሪያ ወቅትን፣ የማስገር ፈቃድ አሰጣጥን፣ እድሳትንና እገዳን፣ የዓሣ ዝውውርን፣ የዓሣ ግብርናን፣ የዓሣ ንግድን፣ የዓሣ ውጤቶች ጥራትና የንጽሕና ደረጃን፣ የተከለከሉ ተግባሮችን፣ የኅብረተሰብ ተሳትፎን፣ የአካባቢ ተፅዕኖ ግምገማንና ሌሎች ተዛማጅ ጉዳዮችን በግልጽ ያስቀመጠ መሆን አለበት።

## ክፍል ሦስት
## አዋጁን ስለማስፈጸም

፲፫· የዓሣ ሀብት ተቆጣጣሪ ሥልጣንና ኃላፊነት

ይህን አዋጅና በአዋጁ መሠረት የሚወጡ ደንቦችንና መመሪያዎችን ተግባራዊነት ለማረጋገጥ የዓሣ ሀብት ተቆጣጣሪ ሥልጣን የተሰጠው መሆኑን የሚገልጽ መታወቂያ በማሳየት ያለ ፍርድ ቤት ትዕዛዝ፣

ሀ) በማንኛውም የውኃ አካል ላይ የሚገኝ ዓሣ አስጋሪን አስቁሞ መፈተሽ፣ ጀልባውን ወይም የማስገሪያ መሳሪያውን መመርመር፣

ለ) ይህን አዋጅና በዚህ አዋጅ መሠረት የሚወጡትን ደንቦችና መመሪያዎች ጥሷል ተብሎ አጥጋቢ በሆነ ሁኔታ የተጠረጠረ ማንኛውንም ሰው ስሙንና አድራሻውን እንዲነግር፣ መታወቂያውንና ሌሎች ከዚህ ጋር አግባብነት ያላቸውን መረጃዎች እንዲያሳየው ወይም እንደአስፈላጊነቱ እንዲሰጠው መጠየቅ፣

ሐ) ማንኛውም ዓሣ የተያዘው፣ የተጓጓዘው፣ ለገበያ የቀረበው፣ ወደ ሀገር እንዲገባ የተደረገው ወይም ከሀገር እንዲወጣ የተዘጋጀው ይህን አዋጅ በመጣስ ነው ብሎ አጥጋቢ በሆነ ምክንያት ሲያምን ዓሣውን መያዝ፣

መ) ማንኛውም የዓሣ ማስገሪያ ጀልባና መሣሪያ ይህን አዋጅ እና፣ በዚህ አዋጅ መሠረት የሚወጡትን ደንቦችና መመሪያዎች በተፃረረ ሁኔታ ጥቅም ላይ መዋሉን አጥጋቢ በሆነ ሁኔታ ሲያረጋግጥ እነዚህን መሣሪያዎች መያዝ፣

ሠ) ማንኛውንም ሰው ይህን አዋጅ በመተላለፍ ወንጀል ፈጽሟል ብሎ አጥጋቢ በሆነ ምክንያት ሲያምን በተቻለ ፍጥነት ሥልጣን ባለው አካል ክስ እንዲመሠረት ማድረግ፣

ረ) ማንኛውም ዓሣ መታመሙን ፣ መበከሉን ወይም መበላሸቱን አጥጋቢ በሆነ መንገድ ሲያረጋግጥ ዓሣው እንዲወገድ ወይም ጉዳት እንዳያደርስ ማድረግ፣

ሰ) ማንኛውንም ዓሣ አስጋሪ ስለተጠቀመበት ማስገሪያ መሣሪያ፣ ስለያዘው ዓሣ ዓይነትና መጠን፣ እንዲሁም ዓሣውን ያስገረበትን አካባቢ መረጃ እንዲሰጠው መጠየቅ፣

ሸ) ማንኛውንም የዓሣ ግብርና፣ የዓሣ ማዘጋጃ፣ ማከማቻ፣ ማጓጓዣና መሸጫ ተቋማትንና መሳሪያዎችን መፈተሽና ተፈላጊውን ደረጃ አሟልተው በማይገኙበት ጊዜ ማሸግ ወይም ማገድ፣

ይችላል።

11. *Fisheries Information Exchange*

1) To assist the implementation of this proclamation, the Regional Administrations shall collect and compute data regarding fisheries and submit same to the Ministry,

2) The Ministry shall, by evaluating and interpreting the fisheries data and research results it collects from different sources, disseminate same to Regional Governments and other users.

12. *Basic Principles of Fisheries Development and Utilization laws*

Any fisheries law that may be issued pursuant to this proclamation shall clearly stipulate about protected fishery areas, annual fish catch, types and number of fishing gears, fishing seasons, procedures for issuing, renewal and suspension of fishing license, fish transfer, aquaculture fish trade, safety and quality standards of fish products, prohibited activities, community participation, environmental impact assessment and other related matters.

## PART THREE
## *Enforcement of the Proclamation*

13. *Powers and Responsibilities of a Fishery Inspector*

In order to ensure the implementation of this proclamation, regulations and directives issued hereunder, a fisheries inspector having shown authorization to do so may, without a court warrant,

(a) stop and search any fisher found on any water body and inspect the fishing boat and / or gears.

(b) demand any person reasonably suspected of contravening this proclamation and regulations or directives issued persuant to this proclamation to give their names and addresses and to show or as may be appropriate, to produce their identification cards and any other relevant information.

(c) seize any fish which the inspector has reasonable grounds to belive that the fish has been caught, transported, is being marketed, imported or prepared for export in contravention of this proclamation.

(d) seize any fishing boat and gear which the inspector has reasonable grounds to prove that the same has been used in contravention of this proclamation and regulations or directives issued thereof.

(e) cause, as soon as possible, a legal action to be instituted against any person when the inspector has reasonable grounds to believe that the person has committed an offence by contravening this proclamation.

(f) destroy or otherwise render harmless any fish the inspector has reasonable grounds to prove that it is diseased, contaminated or spoiled.

(g) demand any fisher to provide information regarding the gears used, the type and size of fish caught, and the fishing area from which the fish were caught.

(h) inspect any aquaculture, fish processing, storage, transport and marketing facilities as well as equipment and suspend the permit or close the facilities when they are found to have failed to operate upto the standards.

፲፬· የመተባበር ግዴታ

ማንኛውም ሰው የዓሣ ሀብት ተቆጣጣሪ ለሥራው የሚፈልጋቸውን መረጃዎች በመስጠት የመተባበር ግዴታ አለበት።

፲፭· ስለተያዘ ዓሣ፣ የማስገሪያ መሳሪያና ሌሎች ዕቃዎች

፩· የዓሣ ሀብት ተቆጣጣሪ፤

ሀ) በዚህ አዋጅ መሠረት የተያዘና ለገበያ መቅረብ የሚችል ማንኛውንም ዓሣ እንዳይበላሽ ለመከላከል ዓሣው የተያዘበት ሰው ባለበት በህጋዊ መንገድ እንዲሸጥ ያደርጋል፤

ለ) በዚህ አዋጅ መሠረት የተያዘ የማስገሪያ መሳሪያን ወይም የማጓጓዣና ሌሎች እቃዎችን ፍርድ እስኪሰጥባቸው ድረስ በጥንቃቄ እንዲቆዩ ማድረግ ይኖርበታል፤

ሐ) የተያዘ ዓሣ፣ የማስገሪያ መሣሪያ ወይም ሌላ እቃ ዓይነትና መጠን፣ የተያዘበትንና ዓሣው የተሸጠበትን ወይም የተወገደበትን ቀን እንዲሁም ከሽያጭ የተገኘውን ገንዘብ መጠን የሚገልጽ ህጋዊ ደረሰኝ ለተያዘበት ሰው ይሰጣል።

፪· በዚህ አዋጅ መሠረት ዓሣ የተያዘበት ሰው በወንጀል የመጠየቁ ሁኔታ እንደተጠበቀ ሆኖ፣ ከዓሣ ሽያጭ የተገኘው ገንዘብ ለመንግሥት ገቢ ይደረጋል።

ክፍል አራት

ልዩ ልዩ ድንጋጌዎች

፲፮· ወንጀልና ቅጣት

ማንኛውም ሰው፣

፩· ያለፈቃድ ወይም ከተሰጠው ፈቃድ ተቃራኒ በሆነ ሁኔታ ሕይወት ያለው ዓሣ ከውጭ ሀገር ካስገባ፣ በኢትዮጵያ የውኃ አካላት ከጨመረ፣ ከሀገር ካስወጣ፣ ወይም ከአንድ የውኃ አካል ወደ ሌላ የውኃ አካል ካዛወረ ከአንድ ዓመት በማያንስና ከሶስት ዓመት በማይበልጥ እስራት ወይም እስከ ብር ፲ሺ በሚደርስ መቀጮ ወይም በሁለቱም ይቀጣል።

፪· በዚህ አንቀጽ ንዑስ አንቀጽ (፩) ላይ ከተጠቀሰው ወንጀል ውጪ ይህን አዋጅና በዚህ አዋጅ መሠረት የሚወጡ ደንቦችንና መመሪያዎችን ከተላለፈ በኢትዮጵያ የወንጀለኛ መቅጫ ሕግ መሠረት ይቀጣል።

፲፯· ሌሎች እርምጃዎች

፩· ማንኛውም ሰው ይህን አዋጅ በመተላለፍ ወንጀል ፈጽሟል ተብሎ ጥፋተኛነቱ ሲረጋገጥ በተከሣሹ ላይ ከሚሰጠው ማንኛውም ዓይነት ቅጣት በተጨማሪ ፍርድ ቤቱ፤

ሀ) ለወንጀል ተግባር የዋሉትን ማናቸውንም የዓሣ ማስገሪያ ጀልባና የዓሣ ማስገሪያ መሣሪያ እንዲወረስ፣

ለ) ሕገ ወጥ በሆነ መንገድ የዓሣ ማስገር ሥራ ለማካሄድ የዋለን ማናቸውንም መርዝ ወይም ፈንጂ ወይም ሌላ ዓይነት መሣሪያ እንዲወረስ፣

ሐ) የዓሣ ማስገር ሥራው ወይም የንግድ ፈቃዱ እንዲታገድ፣ እንዲሰረዝ፣

ትዕዛዝ ሊሰጥ ይችላል።

፪· የጥፋተኝነት ውሳኔ ከተሰጠ በኋላ የተያዙት ዕቃዎች እንዲወረሱ ትዕዛዝ ካልተሰጠ በስተቀር ውሳኔው በተሰጠ በ፴ ቀናት ውስጥ የገንዘብ ቅጣቱ ካልተከፈለ የተያዙት ዕቃዎች ተሸጠው ከሽያጩ በሚገኘው ገንዘብ የገንዘብ ቅጣቱ እንዲሸፈን ይደረጋል።

፫· የወንጀል ክስ ከተመሠረተ በኋላ ተከሳሹ በነጻ ቢለቀቅ የተያዘው የማስገሪያ መሳሪያ ወይም ሌላ እቃ ለተከሣሹ ይመለሳል። የተያዘው ዓሣ ከሆነ ግን ዓሣው የተሸጠበት ዋጋ ለግለሰቡ ተመላሽ ይሆናል።



14. *Duty to Cooperate*

Any person shall cooperate with the fishery inspector in providing any evidence and information that may be required in relation to his activities.

15. *Regarding Seized Fish, Fishing Gears and Other Goods*

1) *The fishery inspector:*
   (a) may sell the marketable fish seized, pursuant to this proclamation, in the presence of the person from whom the fish had been seized in order to prevent spoilage.
   (b) shall ensure that the fishing gears, transport and other equipment seized, pursuant to this proclamation, are well taken care of until the court passes a decision.
   (c) shall give the person, from whom the fish, fishing gears, and other goods were seized, an authenticated receipt stating the date of seizure, sale or disposal, the type and quantity of such goods, and if they are sold, the amount realized from the sale.
2) Without prejudice to the Criminal liability of the person from whom fish has been seized due to illegal fishing, the proceeds of the fish seized shall be confiscated.

PART FOUR

*Miscellaneous Provisions*

16. *Offence and Penalty*

Any person who:
1) is convicted of importing and/or introducing live fish into the waters of Ethiopia or same out of the country or transfers same from one water body to another without a permit or in contravention to the terms of the permit shall be punished with imprisonment for not less than a year and not exceeding three years or with a fine up to Birr 10,000 (ten thousand Birr) or with both.
2) commits an offence other than those prescribed in Sub-Article (1) of this Article in contravention to this proclamation as well as regulations and directives issued hereunder shall be punished according to the penal code of Ethiopia.

17. *Other Sanctions*

1) Where any person is convicted of an offence in contravention of this proclamation the court may, in addition to any other penalty imposed on the accused, order:
   (a) the forfeiture of any fishing boat and/or gear used in the commission of the offence.
   (b) the forfeiture of any poison, explosives or any other equipment or substance which has been unlawfully used for fishing.
   (c) the suspension or cancellation of any fishing or fish trade permit.
2) Where, following a conviction, any goods seized are not ordered to be forfeited and if any fines remain unpaid within 30 days of the conviction, such goods may be sold and the proceeds shall be used to cover the fines.
3) Where, following a prosecution, an accused person is acquitted, any seized fishing gear or other goods shall be returned to the person. If what has been seized is fish, the proceeds that have been realized from the sale shall be given back to the person.

## ፲፰· <u>ወንጀል እንደተፈጸመ የሚያስቆጥሩ ሁኔታዎች</u>

፩· ማንኛውም ሰው አግባብነት በሌለው ሁኔታ በኢትዮጵያ የውኃ አካላት ወይም ዳርቻ ላይ ፈንጂ፣ የጦር መሣሪያ፣ የኤሌክትሪክ ንዝረት የሚሰጥ መሳሪያ፣ መርዝ ወይም ዓሣን የሚያደነዝዝ ዕፅ ይዞ ቢገኝ የዚህን አዋጅ አንቀጽ ፭ ንዑስ አንቀፅ (፯) ድንጋጌ በመተላለፍ ሕገ ወጥ ድርጊት እንደፈጸመ ይቆጠራል።

፪· ማንኛውም ሰው ፈቃድ ሳይኖረው ሕይወት ያለው ዓሣ ሲያዘዋውር ቢገኝ የዚህን አዋጅ አንቀጽ ፭ ንዑስ አንቀጽ (፲)፣ (፲፩) እና (፲፪) ድንጋጌዎች በመተላለፍ በሕገ ወጥ ሥራ ላይ እንደተሰማራ ይቆጠራል።

## ፲፱· <u>ከሌሎች ሕጐች ጋር ስላለው ግንኙነት</u>

ይህን አዋጅ የሚቃረን ማንኛውም አዋጅ፣ ደንብ፣ መመሪያና ልምድ በዚህ አዋጅ በተሸፈኑ ጉዳዮች ላይ ተፈጻሚነት አይኖረውም።

## ፳· <u>አዋጁን ለማስፈጸም የሚረዱ ሕጎችን ስለማውጣት</u>

ይህን አዋጅ ተግባራዊ ለማድረግ እንዲረዳ፣

፩· የሚኒስትሮች ምክር ቤት ደንብ፣

፪· ክልሎች የየራሳቸውን ሕግ፣

፫· ሚኒስቴሩ መመሪያ፣

ሊያወጡ ይችላሉ።

## ፳፩· <u>አዋጁ የሚጸናበት ጊዜ</u>

ይህ አዋጅ ከጥር ፳፯ ቀን ፲፱፻፺፭ ዓ.ም ጀምሮ የፀና ይሆናል።

አዲስ አበባ ጥር ፳፯ ቀን ፲፱፻፺፭ ዓ.ም

ግርማ ወልደጊዮርጊስ
የኢትዮጵያ ፌዴራላዊ ዲሞክራሲያዊ ሪፐብሊክ
ፕሬዚዳንት



## 18. *Presumptions of Commission of an Offence*

1) Any person who, with out good cause, is found in possession of explosives, ammunition, devices capable of producing electric shock, poison or fish narcotizing plants on the waters of Ethiopia, their shores or banks shall be presumed to be undertaking an unlawful activity in contravention to Article 5 sub-Article (7) of this proclamation.

2) Any person found transferring live fish without a permit is presumed to be engaged in an unlawful act in contravention to Article 5 sub Articles (10), (11) and (12) of this proclamation.

## 19. *Relation with Other Laws*

Any law, regulation, directive and practice which contravenes this proclamation shall not be applicable on matters provided for in this proclamation.

## 20. *Issuance of Laws to Implement this Proclamation*

To facilitate the implementation of this proclamation:

1) The Council of Ministers may issue regulations;
2) The regions may issue their own laws; and
3) The Ministry may issue directives.

## 21. *Effective Date*

This proclamation shall enter into force as of the 4th day of February, 2003.

Done at Addis Ababa, this 4th day of February, 2003.

GIRMA WOLDE GEORGIS
PRESIDENT OF THE FEDERAL
DEMOCRATIC REPUBLIC OF ETHIOPIA

ብርሃንና ሰላም ማተሚያ ድርጅት ታተመ
BERHANENA SELAM PRINTING ENTERPRISE

## Summary

The diversity of the freshwater fishes of Ethiopia is ever increasing and has now reached more than 180 indigenous species and 10 exotic species. Of the indigenous species 40 species are endemic.

The fishes are distributed in seven drainage basins (Abay, Awash, Baro Akobo, Omo-Gibe, Rift Lakes, Tekeze and Wabi Shebele-Genale Basins) and six freshwater Ecoregions (Ethiopian highlands, Lake Tana, Rift Valley, Omo-Turkana, Wabi Shebelle-Ghenale, and Red Sea Coastal). Diversity of fishes is highest in Baro-Akobo Basin, where the dominant forms are Nilo-Sudanic, because of past and present connections with other water systems in Central and Western Africa. Endemicity is highest in Abay Basin, largely contributed by the *Labeobarbus* spp. flock of Lake Tana. The *Labeobarbus* spp. flock of Lake Tana are the only remaining specie flock of cyprinids in the world. These are 17 very closely related species confined in the Lake Tana ecosystem and its tributary rivers.

The potential of the capture fisheries has been estimated to be about 50,000 tons per year while the actual production is less than half of the potential (about 24,000 tons according to the recent report of the Ministry of Agriculture in 2012). The production comes mainly from some of the rift valley lakes and Lake Tana. It is, thus, simple to calculate the per capita production of fish in Ethiopia which is only about 260 grams per person per year (dividing the total production by the total population), one of the lowest in the world. The per capita consumption of fish in the world is about 18 kg, on the average, per person per year, while it is about 8 kg, on the average, in Africa. Some of the rift valley lakes from where the main production comes are overexploited. The Freshwater systems of Ethiopia and their resources are open access and there is no serious control and regulation over them, although there is proclamation on the use of the fishery resources (see in the following pages).

The aquaculture sector is very much undeveloped, despite the fact that the country is endowed with all the favorable conditions for the development of the sector. The policy for the development of aquaculture is also in place, its implementation being anxiously awaited.

## Review Questions

1. Why do you think the diversity of fishes in Ethiopia is highest in Baro-Akobo Basin?
2. Which of the Rift Valley lakes have Nilo-Sudanic fishes? Why?
3. Mention five species of fishes that are endemic to Ethiopia.
4. Which three lakes supply the highest amount of fish production in Ethiopia?
5. Why do you think aquaculture is not well developed in Ethiopia?

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