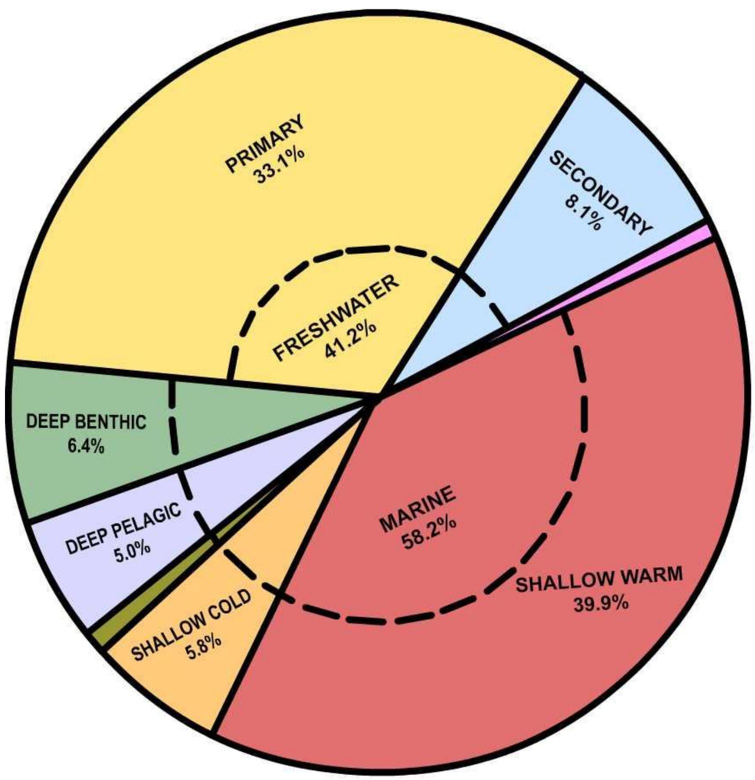
Unit 1: World Inland Capture Fisheries

Chapter 1: Introduction

1.1.1. Freshwater ecosystems and biodiversity

Aquatic biodiversity is the variety of life and the ecosystems that make up the freshwater, tidal, and marine regions of the world and their interactions. It encompasses both freshwater and marine ecosystems. Freshwater ecosystems are aquatic systems which contain drinkable water or water of almost no salt content (<.0.5 ppt). They are created by water that enters the terrestrial environment as precipitation, and flows both above and below ground towards the sea. These systems encompass a wide range of habitats, including rivers, lakes, and wetlands, and the riparian zones associated with them. Their boundaries are constantly changing with the seasonality of the hydrological cycle. Their environmental benefits and costs are distributed widely across time and space, through the complex interactions between climate, surface and groundwater, and coastal marine areas. The earth is estimated to have only 35,029,000 km^3 of freshwater, or only 2.5 % of all water resources, of which only 23.5 % is habitable.



Percentage of Recent Fish Species Living in Various Habitats
(After Cohen, 1970)
Source: Jyoti, M.K. and Arti Sharma, 2006

The freshwater ecosystem can be divided into lentic ecosystems (still water) and lotic ecosystems (flowing water). Freshwater resources include lakes and ponds, rivers and streams, reservoirs, wetlands, estuaries and backwaters. They provide the majority of our nation's drinking water resources, water resources for agriculture, industry, sanitation, as well as food including fish and shellfish. They also provide recreational opportunities and a means of transportation. In addition, freshwater ecosystems are home to numerous organisms (e.g., fish, amphibians, aquatic plants, and invertebrates). The multitudes of such forms have created varying ranges of habitats that are the home to the great diversity of freshwater fauna, of which the vertebrate fauna in freshwaters accounts for nearly 25 % of the global vertebrate diversity, but these also happen to be among the world’s most threatened ecosystems (Groombridge, 1992). Cohen (1970) professes the percental distribution of living fish in various habitats. Fish do interest people in a number of ways. The world’s smallest known vertebrate is a fish, *Pandaka pygmaea* while the largest aquatic a vertebrate too is a whale shark, *Rhincodon typus* which is a giant and the heaviest fish.

Biodiversity in freshwater systems is distributed in a fundamentally different pattern from that in marine systems. Organisms in the sea live in media that is more or less continuous over extensive regions, and species adjust their ranges to some degree as climate or ecological conditions change. But freshwater habitats are relatively discontinuous, and many freshwater species do not disperse easily across the land barriers that separate river drainages into discrete units. This has three important consequences:

1. Freshwater species must survive climatic and ecological changes in place
2. Freshwater biodiversity is usually highly localized, and even small lake or stream systems often harbour unique, locally evolved forms of life
3. Freshwater species diversity is high even in regions where the number of species at any given site is low, since species differ between one site and the next.

1.1.2. Global freshwater fish biodiversity

Valid scientific descriptions exist for about 27,977 living species of fishes in 515 families and orders (Nelson, 2006). One third of the fish families have, at a minimum, one species with members spending at least part of their life in freshwater. Freshwater fish diversity is therefore large compared to other systems since freshwater lakes and rivers account for only 1% of the earth’s surface and < 0.01% of its water. According to Nelson, 2006, 11952 species are exclusively freshwater in origin.

The largest number of species occurs in the tropics and the diversity of fishes, in general, increases from the poles to the tropics. For example in many Arctic lakes there is only one species, the Arctic char, *Salvelinus alpinus* (Johnson, 1983) compared to Lake Malawi which has at least 500 species of Cichlidae alone (Craig, 1992). The Paleoarctic region is species-poor. Southeast Asia, South America and Africa have the most freshwater fishes although many have not been described. For example the Amazon Basin has about 2,000 species, the Mekong Basin about 1,200 species and the Zaire system about 900 species.

However, only about 100 fish species, or species groups, are listed in FAO statistics as making up inland capture. In this regard, the quantification of the importance of individual species and of species groups as inland fishery resources is severely handicapped by the lack of reporting at these levels. Overall, some 45 percent of inland catch is aggregated as "freshwater fish not elsewhere included" (nei), 7 percent "freshwater molluscs nei" and 6 percent is "crustaceans nei".

1.1.3. Freshwater fish biodiversity in India

India is blessed with the vast and varied fish germplasm resources distributed widely in vivid aquatic ecosystems. The Indian fish fauna is divided into two classes, viz., Chondrichthyes and Osteichthyes. The Chondrichthyes are represented by 131 species under 67 genera, 28 families and 10 orders in the Indian region. The Indian Osteichthyes are represented by 2,415 species belonging to 902 genera, 226 families and 30 orders, of which, five families, notably the family Parapsilorhynchidae are endemic to India. These small hillstream fishes include a single genus, viz., *Parapsilorhynchus* which contains 3 species. They occur in the Western Ghats, Satpura mountains and the Bailadila range in Madhya Pradesh only. Further, the fishes of the family Psilorhynchidae with the only genus *Psilorhynchus* are also endemic to the Indian region. Other fishes endemic to India include the genus *Olytra* and the species *Horaichthys setnai* belonging to the families Olyridae and Horaichthyidae respectively. The later occur from the Gulf of Kutch to Trivandrum coast. The endemic fish families form 2.21 % of the total bonyfish families of the Indian region. 223 endemic fish species are found in India, representing 8.75 % of the total fish species known from the Indian region and 128 monotypic genera of fishes found in India, representing 13.20% of the genera of fishes known from the Indian region.

The Indian fish population represents 11.72% of species, 23.96% of genera, 57% of families and 80% of the global fishes. About 400 species are commercially important which include cultured, cultivable and wild caught species. These fishes have a quite a wide variety of forms and habits which have been reflected in their adaptation to live in markedly varying biotypes, ranging from cold torrential mountain streams to the dark abyssal depth of the seas. The approximate ecosystem-wise distribution of fish germplasm resources of India are: coldwater (73; 3.32%), warm waters of plain (544; 24.73%), coastal brackishwater (143; 6.50%) and marine (1440; 65.45%).

The major groups of freshwater fishes available in india arecyprinids (family: cyprinidae), live fish (family: Anabantidae, Clariidae, Channidae, Heteropneustidae), cat ish (family: Bagridae, Silurdae, Schilbeidae), clupeids (family: Clupeidae), mullets (family: Mugilidae), featherbacks (family: Notopteridae), loaches (family: Cobitidae), eels (family: Mastacembelidae), glass fishes (family: Chandidae) and gobies (family: Gobiidae). Cyprinidae is one of the largest families and is well represented in India with species ranging from few millimeters in length (minnows) to more than a metre (major carps).

1.1.3.1. Coldwater fish biodiversity

The aquatic resources located 914 m above MSL in Himalayas, sub-Himalayan zone and mountains of the Deccan are known as coldwaters. The temperature varies between 0 - 20˚C with an optimal range between 10 - 12˚C. The coldwater lakes and streams of high altitude are characterized by high transparency and dissolved oxygen and sparse biota. Most of the fishes are small-sized showing a distribution pattern depending upon the rate of flow of water, nature of substrata and food availability. Some fishes living in turbulent streams have developed special organs for attachment. The major coldwater resources – upper stretches of Indus, Ganga, Brahmaputra rivers and their tributaries, coldwater lakes and reservoirs of Himalayan and Deccan plateau harbour fishes belonging to six different families Cyprinidae, Cobitiidae, Salmonidae, Sisoridae, Psilorhynchidae and Homalopteridae. Some commercially important species are *Tor tor, T. putitora, T.mosal, T. khudree, T. mussullah, Neiolissochielus hexagonolepis, Schizothorax richrdsonii, Schizothoraichthys progastus, Barilius bendelisis, Labeo dero. L. dyocheilus* and *Garra gotyla.*

1.1.3.2. Fish biodiversity in warm waters

The freshwater of inland resources below coldwater zone are known as warm waters. Coming to the plains, the rivers become wider, the slope is slight and the current is moderate to slow. The warm water aquatic resources harbour abundant fish species. In India, fourteen major river systems share about 83% of the drainage. The important rivers are: Ganga river system, having a stretch of 1600 km from Hardwar (Uttar Pradesh) to Lalgolaghat (West Bengal), Brahmaputra, Indus, Mahanadi, Godavari, Krishna, Cauvery, Narmada and Tapti. The river Ganga harbours 382 species, Brahmaputra 126, Mahanadi 99, Cauvery 80, Narmada 95 and Tapti 57 fish species of warm water origin. However, many species are common to different river systems. There are about 450 families of freshwater fishes globally. Roughly 40 families are represented in India (warm freshwater species). About 25 of these families contain commercially important species. Among 544 endemic warm freshwater fish species in India, Cyprinidae accounts for nearly 24.12% of them.

Some commercially important carps include *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, *L. calbasu*, *L. gonius*, *L. bata*, *L. fimbriatus*, *L. kontius*, *Cirrhinus cirrhosa* and *C. reba.* Cat fishes are important groups contributing significantly to the riverine catches and include *Aorichthys aor, A. seenghala, Wallago attu, Pangasius pangasius, Silonia silondia, Bagarius bagarius, Rita rita and Eutropiichthys vacha.* Finfishes adapted to swampy areas owing to their accessory respiratory organs are known as air breathing fishes. Murrels and other important species of the group are *Channa striatus, C. marulius, C. punctatus, Clarias batrachus, Heteropneustes fossilis, Anabas testudineus, Notopterus notopterus* and *N. chitala.*

1.1.3.3. Fish biodiversity in brackishwater

The brackishwater i.e., estuarine regions are considered as transition zone between freshwater of the rivers and saline water of seas. The salinity of brackishwater ranges from 0.5 ppt to 30 ppt. The major estuarine systems of India are Hooghly-Matlah estuary, Mahanadi estuary, Godavari estuary, Krishna estuary, Cauvery estuary and other estuaries of east and west coasts, Chilka Lake, Pulicat Lake and Kerala backwaters. The important species contributing significantly to the brackishwater fisheries are *Mugil cephalus, Liza macrolepis, L. tade, L.*

parsia, Rhinomugil corsula, Hilsa ilisha (*Tenualosa ilisha*), *Chanos chanos, Etroplus suratensis* and *Lates calcarifer*. The brackishwater also harbour lucrative shellfish species like *Penaeus monodon, Fenerropenaeus indicus, Metapenaeus monoceros, M. dobsoni, M. affinis* and *M. brevicornis.*

1.1.3.4. Exotic fishes in inland ecosystems

Some exotic fishes have been introduced in the Indian waters for sport, food, vector control and ornamental purposes. A few important exotic species are *Salmo trutta fario, Salmo gairdneri gairdneri* (*Oncorhynchus mykiss*), *Cyprinus carpio* var. *specularis, C. carpio* var. *communis, C. carpio* var. *nudus, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Oreochromis mossambicus, Clarias gariepinus, Gambussia affinis, Lebestes reticulatus, Betta splendens, Xiphophorus hellerii* and *Carassius auratus*.

While the trouts (*Salmo* spp.) have filled in a vacant niche in upland coldwaters, the grass carp (*Ctenpharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio var. communis*) have helped in enhancing the aquaculture production in India, but a few others like tilapia (*Oreochromis mossambicus*), *Gambussia affinis* and even common carp in some natural waters created competition with native species with adverse influences.

Chapter 2: Distribution of major inland water bodies and freshwater fishery regions of the world

1.2.1. Distribution of natural waters

Fishes and other aquatic resources are captured from a great variety of freshwater ecosystems, most of which are natural. Natural aquatic ecosystems include lakes , swamps and floodplains , collectively called standing waters, and rivers and streams , collectively called running waters.

The distribution pattern of natural freshwaters among the continents is uneven which has important implications for aquatic production (inland capture fisheries and aquaculture). For example, the greatest occurrence of standing waters is in the relatively unproductive northern areas of the Northern Hemisphere. In contrast, the distribution of running waters in the form of perennial rivers is more homogeneous, with the exceptions of the great deserts of North and Southwest Africa, the Arabian Peninsula and Australia.

The status and trends of aquatic ecosystems, both natural and modified , are closely linked to the condition of adjacent terrestrial ecosystems. Therefore, it is essential to view each inland aquatic ecosystem in terms of the watershed , or basin , in which it occurs. This applies particularly to the multiple use aspects of inland systems that require integrated watershed development , integrated watershed management and a framework within which to assess the environmental impacts of land-based activities on inland aquatic ecosystems.

Globally, lakes, reservoirs and wetlands important for inland fisheries cover a total area of about 7.8 million km^2. Relatively high proportions of land area are covered with surface waters in Southeast Asia, North America, east and central West Africa, the northern part of Asia, Europe and South America.

Distribution by continent of major surface freshwater resources

	Surface area								Share of total (%)
	Lakes	**Reservoirs**	**Rivers**	**Floodplain**	**Flooded forest (Km)**	**Peat land**	**Intermittent wetland**	**Total**	
Asia	898000	8000	141000	1292000	57000	491000	357000	3316000	42
South America	90000	47000	108000	422000	860000	--	2800	1529800	20
North America	861000	69000	58000	18000	57000	205000	26000	1294000	17
Africa	223000	34000	45000	694000	179000	--	187000	1362000	17
Europe	101000	14000	5000	53000	--	13000	500	186500	2
Australia	8000	4000	500	--	--	--	112000	124500	2
Oceania	5000	1000	1000	6000	--	--	100	13100	0
Total	**2186000**	**249000**	**358500**	**248500**	**1153000**	**709000**	**685400**	**7825900**	**100**

1.2.1.1. Rivers of the world

Rivers are dynamic systems, with their courses and flows constantly changing due to natural and human responses. The world's main channel river length amounts to about 2,69,000 km, with the highest density of rivers located in South America and the least in Oceania. Globally, the reservoir storage is attained about seven times the standing of water in Rivers. Major river and floodplain systems are very important to Asian countries. Rivers play a substantial role for capture fisheries - their contribution to food security is often underestimated as statistics do not include the component consumed by fishers. Catch statistics from rivers are often of low quality because of the difficulty inherent in collecting data from fisheries which operate from many landings dispersed along a system that may traverse several countries. Extrapolating data from systems well-known to other river systems provides a comparison between the river channel length and catch for selected rivers of the world.

Multiple use of rivers - for transportation, power generation, agriculture and industry - and their abuse as a recipient of wastes and through channelization (especially in Europe, North America and Asia), has led to the loss of their original form and to the progressive loss of biological diversity. In China, the multitude of flood control and other hydraulic structures, together with river pollution, has caused a drastic decline in river fish stocks and fisheries, on which tens of thousands of people fully depended in the past. Although some mitigation measures have been introduced, these have resulted in only minor benefits for fish stocks. The deterioration of rivers on a global scale has led to calls for amelioration of negative impacts and, in some situations, to the reclamation of the natural habitat wherever possible.

The following table shows the longest rivers of the world with their source and outflow.

Rank	River	Source	Out flow	Length (km)
1	Nile (Egypt)	Tributaries of Lake Victoria, Africa	Mediterranean Sea	6,690
2	Amazon (Brazil)	Glacier-fed lakes, Peru	Atlantic Ocean	6,296
25	Brahmaputra	Himalayas	Ganges River	2,897
26	Indus	Himalayas	Arabian Sea	2,897
36	Ganges	Himalayas	Bay of Bengal	2,506

1.2.1.2. Reservoirs of the world

Worldwide there are about 60,000 large reservoirs (>15 m dam height), totalling 4,00,000 km^2 in water surface and about 6,500 km^3 in volume. Asia possesses the greatest amount, followed by North America. Asia possesses nearly 65 % of the global total of reservoirs by number and 31% by volume. Most of the reservoirs are in China. The area of the Chinese reservoirs accounts to about 20,000 km^2. Larger better known reservoirs account for about 25% of the water stored in reservoirs. More than 14,000 small water bodies are found in the countries of South Africa.

List of the world's largest reservoirs by surface area

S.No.	Name of the reservoir	Country	Area (km^2)
1	Lake Volta	Ghana	8,482
2	Small wood Reservoir	Canada	6,527
3	Kuybyshev Reservoir	Russia	6,450
4	Lake Kariba	Zimbabwe, Zambia	5,580
5	Bukhtarma Reservoir	Kazakhstan	5,490
6	Bratsk Reservoir	Russia	5,426
7	Lake Nasser	Egypt, Sudan	5,248
8	Rybinsk Reservoir	Russia	4,580
9	Caniapiscau Reservoir	Canada	4,318
10	Lake Guri	Venezuela	4,250

List of the world's largest reservoirs by volume

S.No.	Name of the reservoir	Country	Volume (km^3)	Volume (cu mi)
1	Lake Kariba	Zimbabwe, Zambia	180	43
2	Bratsk Reservoir	Russia	169	41
3	Lake Nasser	Egypt, Sudan	157	38
4	Lake Volta	Ghana	148	36
5	Manicouagan Reservoir	Canada	142	34

6	Lake Guri	Venezuela	135	32
7	Williston Lake	Canada	74	18
8	Krasnoyarsk Reservoir	Russia	73	18
9	Zeya Reservoir	Russia	68	16

1.2.1.3. Lakes of the world

Among the great variety of inland water bodies, perennial lakes comprise 1.7 million km^2, one million km^2 of which are large lakes (larger than 100 km^2). The distribution and size of lakes vary considerably among continents. North America possesses the greatest freshwater large lake surface area, whereas large lakes are uncommon in South America. Although there is a large number of lakes in the temperate zone of Europe and Asia, lakes are less common in tropical Asia - however some, such as the Great Lake on the Tonle Sap in Cambodia and Lake Tempe in Sulawesi (Indonesia) are of the utmost importance to fisheries. Africa, especially East Africa, is endowed with numerous lakes that support very important fisheries, in turn providing a livelihood to millions of people and contributing significantly to food supply. In many of these lakes, fisheries are reaching a state of maturity and consequently management problems are rising. For 11 lakes, shared by 11 countries of Eastern Africa, fisheries employs close to half a million people, with perhaps three times as many engaged in secondary activities and related services, thus supporting about 4 percent of the population of the region as a whole.

Rank	**Name and Location**	**Area**	**Length**	**Maximum Depth**
		km	**km**	**m**
1	Caspian Sea, Azerbaijan-Russia - Kazakhstan – Turkmenistan – Iran	394,299	1,199	946
2	Superior, U.S.-Canada	82,414	616	406
3	Victoria, Tanzania-Uganda	69,485	322	82
7	Tanganyika, Tanzania-Congo (Deepest No. 2)	32,893	676	1,435
8	Baikal, Russia (Deepest No. 1)	31,500	636	1,741

1.2.1.4. Floodplains of the world

The floodplains are the areas of low-lying land that are subject to inundation by the lateral overflow of waters from rivers or lakes with which they are associated. It includes the flood way, which consists of the stream channel and adjacent areas that carry flood flows, and the flood fringe, which are areas covered by the flood, but which do not experience a strong current. The floods further bring about such changes in the physico-chemical environment that biota react by morphological, anatomical, physiological or ecological adaptations, or by change in community structure.

The floodplains constitute a valuable part of the environment. They filter, store, and release flood waters, recharge aquifers, store a variety of sediments, and provide habitat for a diversity of wildlife. Despite their susceptibility to flooding, floodplains attract settlers who wish to farm the fertile land and take advantage of the proximity to water and river transportation. Unfortunately, in many areas, the development of floodplains has not been planned or managed adequately, resulting in damage to their natural functions.

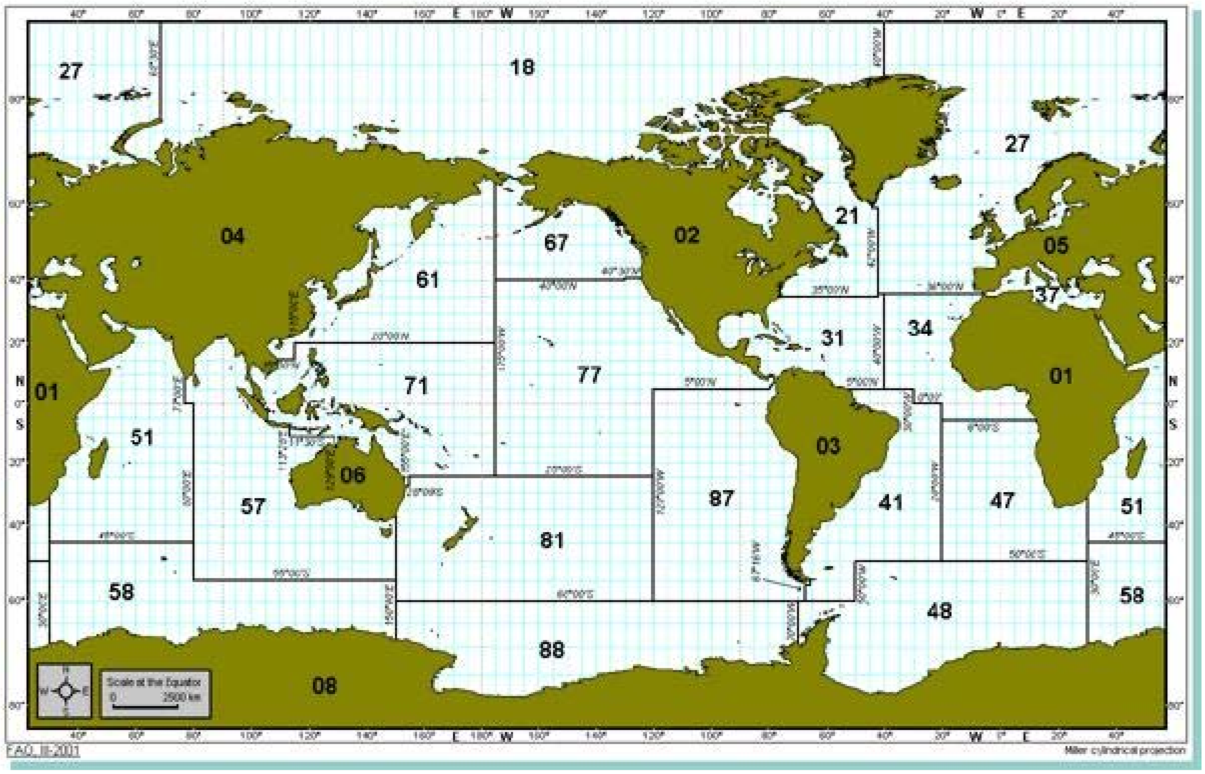
Swamps, marshes and other wetlands amount to about 4 million sq kms of which the countries of USSR share more proportion. The fish communities of flood plain rivers have been the subject of special considerations as they are particularly vulnerable to changes in water quality and quantity induced by human activities. The seasonal flooding of river floodplains, along with their lakes, is among the most important factors determining river fish production. The timing and duration of flooding are highly variable, greatly affecting growth and survival of fish. When inundated, the plain contains a rich mosaic of habitats that provide shelter, breeding, nursery and feeding sites for a variety of fish species. Floodplain capture fisheries are mostly seasonal. The fishing is usually indiscriminate, with the removal of all fish.

Many people live along and around rivers and floodplains. Fish and aquatic products provide essential nutrition and buffer food insecurity. In many areas of the world, floodplain fisheries have maintained the same level of catch despite the increasing fishing pressure on fish stocks. Initially, this reduced the average age of stocks fished and increased the efficiency of utilization of their food. Acceleration in growth rate and reduction in the size of maturation of the exploited species has also been common. Subsequently, larger, slower-growing, longer-lived species are apt to be replaced with smaller species of a higher turnover rate. The ability of floodplains to act as sink for carbon and nutrients is conducive to maintaining the stability of this ecosystem.

Restoration of fish stocks is necessary when the tolerance of floodplains to environmental degradation is exceeded - a case often accompanied by high fishing pressure and by the introduction of mitigating measures, such as habitat and fish stocks enhancements .

1.2.2. FAO’s world major fishing areas

The term "Inland Waters" may be used to refer to lakes, rivers, brooks, streams, ponds, inland canals, dams, and other land-locked (usually freshwater) waters (such as the Caspian Sea, Aral Sea, etc.). For statistical purposes, 27 major fishing areas have been internationally established to date by Food and Agriculture Organization (FAO) of the United Nations, Rome. These comprise eight major inland fishing areas covering the inland waters of the continents, nineteen major marine fishing areas covering the waters of the Atlantic, Indian, Pacific and Southern Oceans, with their adjacent seas. The major fishing areas, inland and marine, are identified by their names and by two-digit codes.



(**Source : FAO, 2010)**

The world major inland fishing areas are as below:

1. Africa (Fishing Area – 01)
2. North America (Fishing Area – 02)
3. South America (Fishing Area – 03)
4. Asia (Fishing Area – 04)
5. Europe (Fishing Area – 05)
6. Oceania (Fishing Area – 06)
7. Former USSR *(Fishing Area – 07)
8. Antarctica - inland waters (Fishing Area – 08)

The fishing area 07 ("Former USSR area - Inland waters") referred to the area that was formerly the Union of Soviet Socialist Republics. Starting with the data for 1988, information for each new independent Republic is shown separately. The new independent Republics are: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan (statistics are assigned to the fishing area "Asia - Inland waters") and Belarus, Estonia, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine (statistics are assigned to the fishing area "Europe - Inland waters").

Chapter 3: Major fish species composition of freshwater fishery regions of the world

1.3.1. Freshwater fishery regions and their major fish species composition

In the 21st century, the most popular in North America and Europe include carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), crappie (*Pomoxis nigromaculatus* and *Pomoxis annularis*), eel (*Anguilla anguilla* and *A. Japonica*), lake herring (*Coregonus artedi*), mullet (*Mugil* spp), muskellunge or musky (*Esox masquinongy*) , yellow perch (*Perca flavescens*), yellow pike / pickerel / walleye (*Stizostedion vitreum*), salmon (*Salmo* sp), suckers (Family: Catostomidae), sunfish (*Lepomis* spp), tilapia (*Oreochromis* spp), trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), and whitefish (*Coregonus clupeaformis*). In Asia, carp (*Cyprinus carpio*), ayu (*Plecoglossus altivelis*), and eel are important freshwater food fish. In Indonesia, the Philippines, and Taiwan, milkfish (*Chanos chanos*) have been used for food for centuries.

1.3.1.1. Africa

Africa stands in second position in the world inland fish production. This region is further subdivided as,

A. North Africa

i. Major countries:

Egypt, Algeria, Morocco, Libea Arab etc.

ii. Major fish species:

Freshwater fin fishes such as carps, fraud, cells etc. In Egypt, common carp, nile tilapia, mullets etc can be seen. In Moracco, silver carp, grass carp etc are present.

B. Sub Saharan Africa

i. Major countries:

Ethiopia, Ghana, Nigera, Kenya, Tanzania, Uganda, Zimbabwe, Mali, Malawi, Senegale. The most important producers are Magenta, Madagascar, Tanzania and South Africa.

ii. Major fish species:

Tilapia (*Oreochromis* sp;), African catfish, cyprinids.

1.3.1.2. North and Central America

i. Major counters:

Canada and U.S.A. Greatest producer is U.S.A.

ii. Major fish species:

Common carp, perch, Smelt (fam: Osmeridae), etc are the important species in cold and subtemperate region. Blue Tilapia (*Oreochromis aureus*) is an important warm water species.

The important lake in this region are Lake Superior, Michigan lake, Haran lake.

1.3.1.3. South America

i. Major countries:

Argentina, Brazil, Chile, Columbia, Bolivia.

ii. Major fish species:

It includes freshwater siluroids, characins, cichlids, including *Oreochromis,* river prawns, carps such as silver carp and common carp.

1.3.1.4. East Asia

i. Major countries:

Japan and Korea.

ii. Major fish species:

Japanese eel, Hulleti, *Lates calcarifer* and *Macrobrachium rosenbergii*.

B. South-East Asia :

i. Major countries:

Indonesia, Phillippines, and Thailand.

ii. Major fish species:

Chanos chanos, *Lates calcarifer,* crabs and molluscs like *Anadara granosa*.

C. South Asia:

i. Major countries:

Srilanka, Pakisthan, India, Nepal.

ii. Major fish species:

Indian major carps, tilapia and crustaceans such as mud crab and giant freshwater prawn.

D. West Asia:

i. Major countries:

Israel, Saudi Arabia etc.

ii. Major fish species:

carps , mullets and tilapia

E. China

It is the world's largest inland fish producing country.

i. Major fish species:

Chinese carps, common carp, bighead carp, crussian carp, tilapia, crab, prawns etc.

1.3.1.5. Eurasia

i. Major counties :

Europe and USSR. European countries are spain, Norway, Italy and France. USSR mainly consisted of Russian federation, Belarus, Uzbaikisthan, Ukraine.

ii. Major species:

Cyprinids (Bighead carp), mullets, catfish, freshwater breams, freshwater crustaceans etc.

1.3.1.6. Oceania

i. Major countries :

Newzeland and Australia

ii. Minor areas:

Island groups like Fiji, Cook Island, French Polynesia etc.

iii. Major fish species:

Lates calcarifer, *Oreochromis mossambica*, short finned eel etc. Oyster like *Crassostrea gigas* and many crustaceans. In Fiji island, *Macrobrachium rosenbergii* is seen.

1.3.2. Most common freshwater fish species of the world

1. Ayu

The ayu (*Plecoglossus altivelis*), also known as ‘sweet fish’ in Japan and aroma fish in China, is an extremely popular and economically important freshwater food fish in many Asian countries. In the 21^{st} century, it is wild-caught in rivers by sport and commercial fishermen or raised commercially for both restaurant consumption and home use.

2. Carp

Carps (*Cyprinus carpio*) are the largest members of the minnow family. Although greatly underutilized in North America, the common carp has always been a widely popular freshwater food fish in the rest of the world. In the 21^{st} century, carps are wild-caught or grown for food in Russia, Ukraine, Hungary, Poland, India, China, Japan, Latin America, Egypt, Iran, Indonesia, and Israel, to name only the major consumer nations. The world's leading producer is China, where carps are often grown in rice paddies in rotation or even simultaneously.

3. Catfish

The channel catfish (*Ictalurus punctatus*), native to warm water lakes and rivers in North America, is a traditional food fish in the southern United States. Consumer demand has moved from regional to national and even international. In the United States, the per capita consumption of catfish is exceeded only by that of tuna, shrimp, pollack, and salmon. To satisfy American consumer demand, several hundred thousand metric tons of channel catfish are produced by aquaculture each year in the southern United States. Imported catfish from Vietnam has been marketed aggressively to restaurant chains and food service companies with considerable success. Another catfish species, the walking catfish, *Clarias batrachus* is a popular food fish in tropical regions and even in some European countries, especially the Netherlands. Catfish are traditionally wild-caught and marketed as iced whole dressed fish.

4. Eel

Although appreciated before the Civil War in North America, freshwater eels (primarily *Anguilla anguilla* and *A. japonica*) are a widely popular food item in Asian countries, particularly Japan, Korea, China, and Taiwan. Eels are also an important delicacy in Europe, particularly Italy, where they must be produced commercially by aquaculture to satisfy consumer demand. Overall, however, China produces more than 70 % of the eels sold in the world, and many rice paddies have been converted to eel production. Japan is the world's largest eel consumer. Eel consumption in North America is minor. However, freshwater eel, unagi is common in Japanese restaurants in the United States. In addition, each year many tons of market-sized eels are wild-caught by U.S. fishermen and exported to Europe.

5. Milkfish

Milkfish (*Chanos chanos*) have been an important food fish for people in Southeast Asia for many centuries. Although they are an oceanic fish, milkfish spawn in shallow coastal areas, where fry and fingerlings are collected in nets and carried to freshwater or brackish water ponds for rearing to market size. Milkfish have been raised in this fashion for at least seven hundred years in the Philippines and Indonesia. Taiwan is also a major producer. It is also exported frozen to North America.

6. Tilapia

Although relatively new to North American fish markets, tilapia are actually a group of fish (cichlid) that traces its origins to North Africa and the Middle East. Because of their versatility, tilapia have been nicknamed "the aquatic chicken". Only Chinese carp and salmon or trout exceed tilapia in total worldwide fish production. Although they are less popular in the United States, tilapia consumption has grown to rival trout among the commercially raised fish species. Since relatively modest numbers of tilapia are produced by U.S. aquaculture, large quantities of frozen fillets are imported from Indonesia, Taiwan, and Mexico to satisfy consumer demand.

7. Trout

Many trout species have historically been used for food, but rainbow trout (*Oncorhynchus mykiss*) have been by far the most popular. Originally native to cold water environments in the north temperate zone, this prized food fish has been transplanted around the world and is well established in North and South America, Japan, China, Europe, Australia, New Zealand, and parts of Africa. Top trout-producing countries include Chile, Denmark, France, Italy, and the United States.

8. Walleye pike

Walleye (*Stizostedion vitreum*), a member of the perch family with an excellent reputation for its food quality, is a widely sought cool-water fish mostly caught by anglers for home use but also available in fish markets and restaurants in much of the northern United States and Canada. In the United States, a limited commercial harvest comes from the Great Lakes. However, most of the commercial harvest is from Canadian fishing on Lake Erie and the inland waters of Ontario and Saskatchewan. The walleye is Canada's most economically valuable freshwater fish.

9. Whitefish

Lake whitefish (*Coregonus clupeaformis*) native to the deep cold lakes of North America are popular food fish in the United States and Canada. A large commercial fishery for whitefish exists in Lake Superior and the other Great Lakes of the midwestern United States. In Canada, close to 600,000 kilograms of whitefish a year is caught and sold by tribal fishermen of the Great

Slave Lake alone. White-fish eggs, termed freshwater or golden caviar, are sometimes sold as a less-expensive substitute for sturgeon caviar.

10. **Nile perch and Nile tilapia**

At present, the Nile perch, *Lates niloticus* and one of the introduced tilapiine species, Nile tilapia, *Oreochromis niloticus,* form the basis of the fisheries of Lakes Victoria and Kyoga in Africa.

11. C*larias gariepinus*

One of the commercially most important freshwater fishes in Africa. Caught with drawnets. The total catch reported for this species to FAO for 1999 was 27,220 t. The countries with the largest catches were Mali (15,091t) and Nigeria (9,994t).

It has been imported for purposes of aquaculture and game fish. Marketed live, fresh and frozen; eaten broiled, fried and baked.

1.3.3. Major inland fish species composition of Asia

In Asian freshwater fish fauna, the dominant groups are cyprinids (Cyprinidae, about 1,000 species), loaches (about 400 species) of the families Balitoridae and Cobitiidae, gobids (Gobiidae, 300 species), catfishes (Bagridae, about 100 species), and the Osphronemidae (85 species). In most countries in Asia, the main species in inland fisheries tend to be indigenous species, at times translocated across their natural range of distribution within the country boundaries. For example, the inland fisheries in China are predominated by major Chinese carp species, such as silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), common carp (*Cyprinus carpio*) etc., whereas those in India and Bangladesh are predominated by Indian major carps, such as rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigal*), catla (*Catla catla*) etc. Similarly, in Thailand the inland fisheries are predominated by indigenous catfish and snakehead species, as well in some waters by the native pelagic freshwater clupeid, the river sprat, *Clupeichthys aesarnensis* (Jutagate *et al*., 2003). However, in Sri Lanka, an island state with a relatively depauperate native fish fauna, the backbone of the inland fishery, particularly those based on self-recruitment, in large reservoirs, is almost entirely predominated by exotic tilapias. In Vietnam, the inland fisheries in the past was based primarily on alien species, regularly stocked, but in the last decade there had been a gradual shift to a predominance of indigenous species, small cyprinids species such as *Toxobramis houdemeri, Pseudohemiculter dispar, Coulter erythropterus, Cranoglanis* spp., etc.

Chapter 4: Status of global inland fish production

1.4.1. Introduction

Inland fisheries are a vital component in the livelihoods of people in many parts of the world, in both developing and developed countries. Inland fisheries provide high quality protein, essential nutrients and minerals that are often difficult to obtain from other food sources. In developing areas, inland fisheries provide economic opportunities and a “safety net” that allows for continued food production when other sectors may fail. In developed countries, and in an increasing number of developing countries, inland fisheries are used for recreation rather than for food production, another avenue to economic development and growth. However, the status of inland fishery resources and the ecosystems that support them is generally poorly known. This has led to differing views on the actual status of many resources. One view maintains that, because of the multiple uses of and threats to inland water ecosystems, the sector is in serious trouble. The other view holds that the sector is infact growing and that much of the production and growth has gone unreported. The statistics reported to FAO indicate an overall increase of 1.6 million tonnes in the period 2004–08, and in 2008 the sector contributed 10.2 million tonnes to global capture fisheries production – a record contribution.

1.4.2. Fisheries resources: Trends in production and utilization

The total world fish production from both capture and culture fisheries was just 142.3 million tonnes in 2008. Of this, 115.1 mt of fish was used for food, providing a per capita supply of 17.1 kg, remaining 27.2 mt was destined for non-food uses in particular, the manufacture of fish meal and oil and direct feed for aquaculture. The following table shows the world fisheries and aquaculture production and utilization.

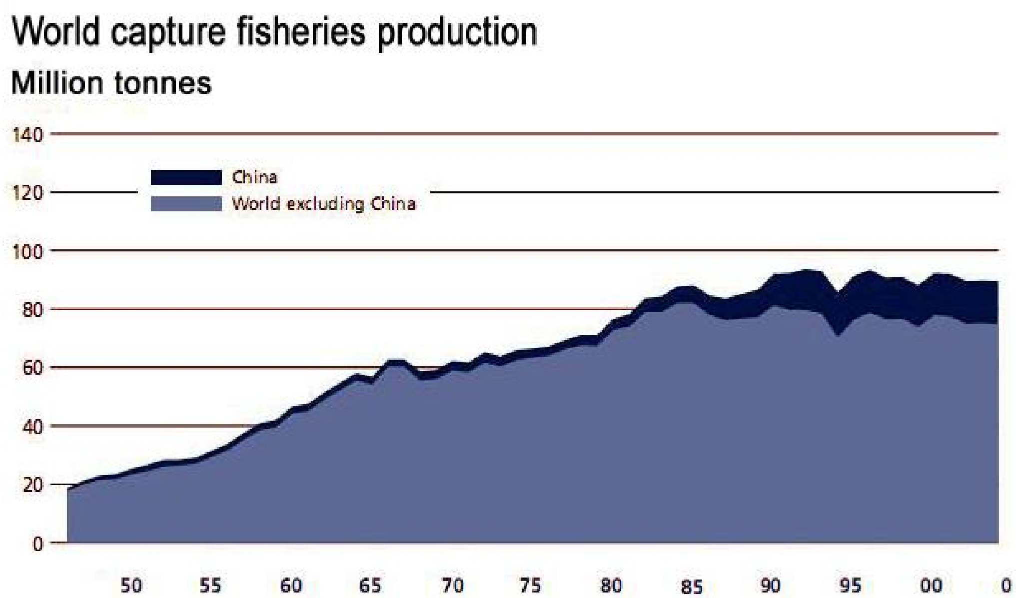
Table 1. World fisheries and aquaculture production and utilization

PRODUCTION	2004	2005	2006	2007	2008	2009*
	(Million tonnes)					
Inland						
Capture	8.6	9.4	9.8	10.0	10.2	10.1
Aquaculture	25.2	26.8	28.7	30.7	32.9	35.0
Total inland	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
Aquaculture	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
TOTAL AQUACULTURE	41.9	44.3	47.4	49.9	52.5	55.1
TOTAL WORLD FISHERIES	134.3	136.4	137.1	139.8	142.3	145.1
UTILIZATION						

Human consumption	104.4	107.3	110.7	112.7	115.1	117.8
Non-food uses	29.8	29.1	26.3	27.1	27.2	27.3
Population (billions)	6.4	6.5	6.6	6.7	6.8	6.8
Per capita food fish supply (kg)	16.2	16.5	16.8	16.9	17.1	17.2

1.4.3. Total capture fisheries production

Global capture fisheries production reached 89.7 million tonnes in 2008. Of the total fish production of 142.3 million tonnes, capture fisheries accounted for about 63% in 2008. Of the total capture fisheries production, inland capture fisheries constituted 11.37%. Preliminary estimates for 2009 based on reporting by some major fishing countries indicate that total world fishery production reached almost 145.1 million tonnes, representing an increase of over 2.8 million tonnes compared with 2008 and a record high production. The inland capture fisheries production was reported to be 10.1 million tonnes in 2009. China remains by far the largest producer, with reported fisheries production of 47.5 million tonnes in 2008 (32.7 and 14.8 million tonnes from aquaculture and captures fisheries respectively). China, Peru and Indonesia are the top three countries in capture fisheries production. Catches from inland waters, about 90% of which occur in Africa and Asia, have shown a slowly but steadily increasing trend since 1950, owing in part to stock enhancement practices, and reached a record 10.2 million tonnes in 2008.



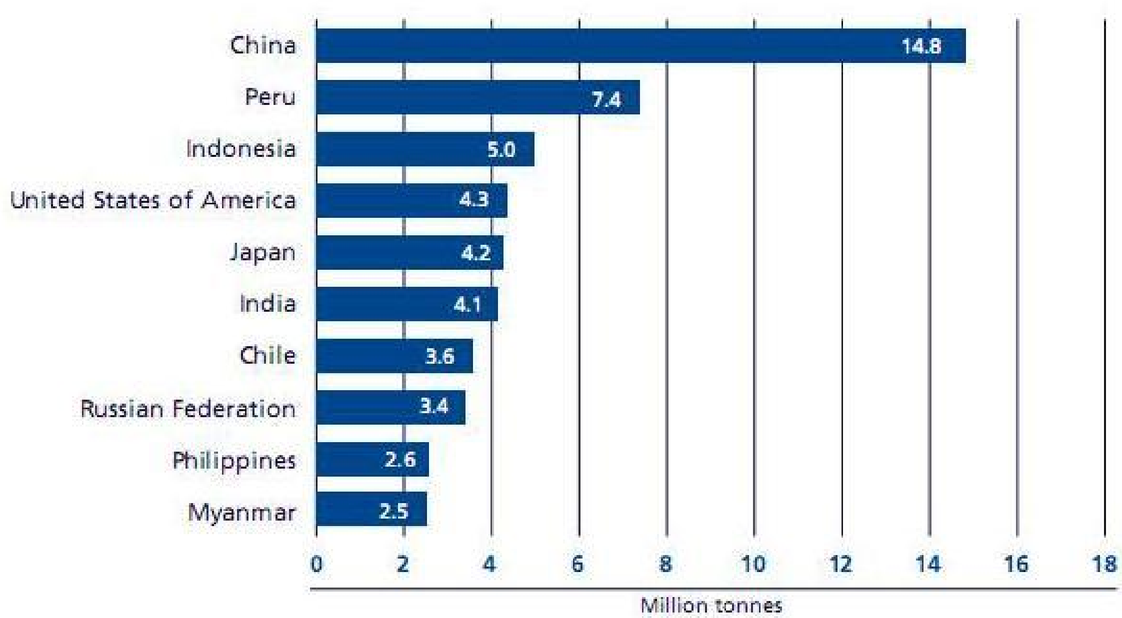
1.4.4. Top ten principal producers in total capture fisheries production

The following is the list of top ten fish producers in the world through capture fisheries (both marine and inland). These top ten countries alone contributed 51.9% to the total global capture fisheries production. The most significant change in the ranking of the top ten producers was the gaining of a position by two Asian countries (i.e. Indonesia and India), which surpassed two American countries (i.e., the USA and Chile) whose total capture production decreased by

10 and 15 percent, respectively in comparison with 2006. In addition to the performance of the Asian countries mentioned above, other major Asian fishing countries (i.e. Bangladesh, Myanmar, Philippines and Vietnam) have been reporting regularly increasing capture fisheries in the last ten years despite well-known cases of local overfishing and natural disasters such as the December 2004 tsunami and cyclones, that have occurred in their area in recent years.

Figure 3:

Marine and inland capture fisheries: top ten producer countries in 2008



1.4.5. Total inland capture fisheries: major producers countries

Global inland capture fisheries production was fairly stable between 2000 and 2004 at about 8.6 million tonnes, but in the following four years it showed an overall increase of 1.6 million tonnes, reaching 10.2 million tonnes in 2008 (Table 1). Asia accounted for two-thirds of the world production (Figure 5). The table 2 shows the variations between 2004 and 2008 for the 14 countries with catches of more than 200000 tonnes each in 2008 and which together represented about 78 percent of the 2008 world catches.

Inland capture fisheries: Major producer countries

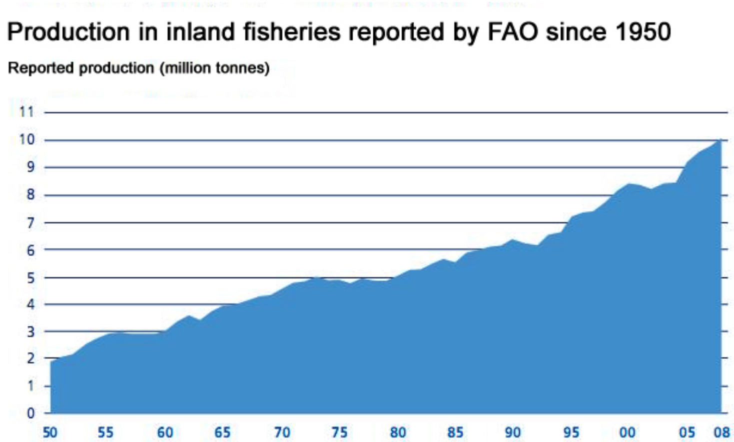
Country	2004	2008	Variation 2004-2008	
	(tonnes)	(tonnes)	Tonnes	Percentage
China	20971671	2248177	151010	7.2
Bangladesh	732067	1060181	328114	44.8
India	527290	953106	425816	**80.8**
Myanmar	454260	814740	360480	79.4
Uganda	371789	450000	78211	21.0
Cambodia	3250000	365000	115000	46.0
Indonesia	330879	323150	-7729	-2.3
Nigeria	182264	304413	122149	67.0
United Republic of Tanzania	312040	281690	-30350	-9.7
Brazil	246101	243000	-3101	-1.3
Egypt	282099	237572	-44527	-15.8
Thailand	203200	231100	27900	13.7
Democratic Republic of the Congo	231772	230000	-17772	-0.8
Russian Federation	178403	216841	38438	21.5

(Source: FAO, 2010)

1.4.6 Production trend in world inland capture fisheries production

In 1950, inland fisheries produced about 2 million tonnes in terms of fish landings. The figure was about 5 million tonnes in 1980, and, after steady growth of 2–3 percent per year, 10 million tonnes in 2008. This growth occurred mainly in Asia and Africa, with Latin America making a small contribution. Asia and Africa regularly account for about 90 percent of reported landings. The remaining 10 percent is split between North and South America and Europe. However, much uncertainty surrounds both the trend in and the level of production.

Figure 4: Production in inland fisheries reported by FAO since 1950



The following table (Table 3) shows the contribution made by the inland capture fisheries sector to the total world capture fisheries production (in million tonnes) during 2004-2009.

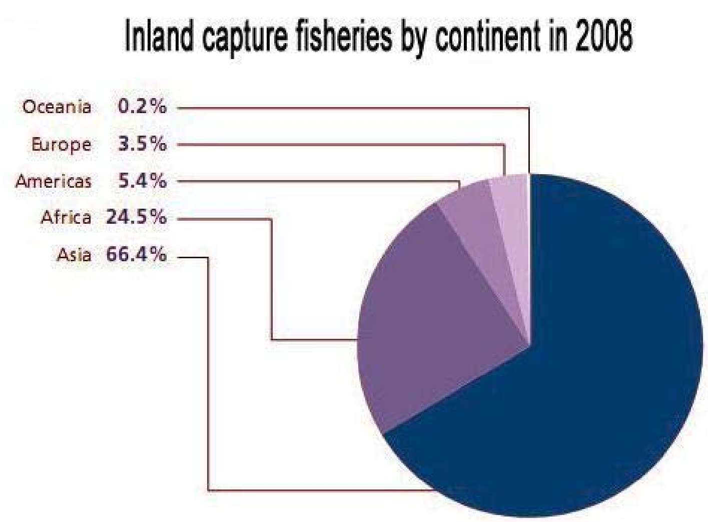
(In million tonnes)	2004	2005	2006	2007	2008	2009
Inland capture	8.6	9.4	9.8	10.0	10.2	10.1
Total capture	92.4	92.1	89.7	89.9	89.7	90.0

The world inland capture fisheries production ranged from 8.6 million tonnes. contributing 9.30% of total capture fisheries production in 2004 to 10.1 million tonnes, contributing 11.22% in 2009. Africa and Asia together continue to contribute about 90% percent of the world total and their shares are also fairly stable. Inland fisheries, however, seem to be in crisis in Europe, where the total catches have decreased by 30 percent since 1999. The decline in professional fishing in European inland waters can be attributed partly to competition with other human activities in the use of the inland water resources and also to the failing economic viability of many commercial inland fisheries. A considerable portion of catches comes from the recreational fishery.

1.4.7 Inland fishing area-wise capture fisheries production in 2008

Of the six inland fishing areas, Asia alone contributed two – thirds of the world production (66.4%) and Asia and Africa together contributed 90.9% to the total inland capture fisheries production in 2008.

Figure 5: Inland caputre fisheries by continenet in 2008

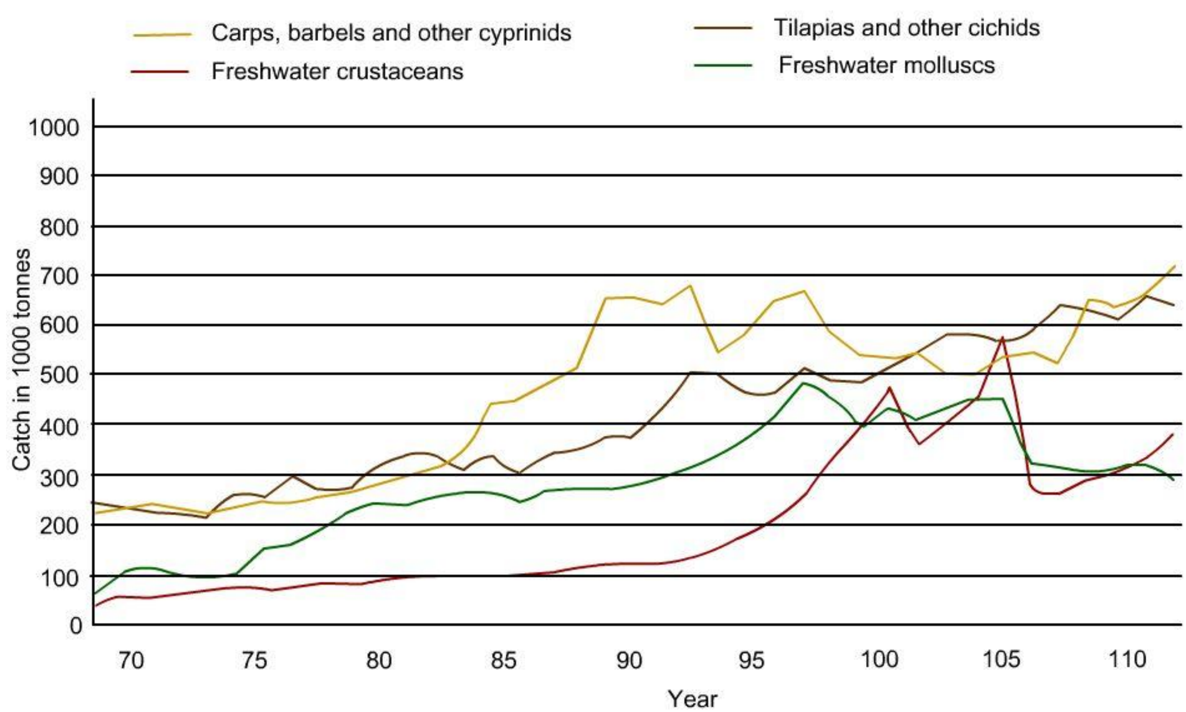


1.4.8 Catch trends by major inland water species groups

The following figure shows catch trends since 1970 by major species groups caught in inland fisheries. In 2005, cyprinids returned as the dominant group after being exceeded for some years by the tilapias group (and in 2002 also by freshwater crustaceans). Catches of freshwater molluscs have decreased significantly since 2002, and this may be due to their extreme vulnerability to habitat degradation, overexploitation, and predation by alien species. It is noteworthy that catch trends for inland water species groups present several more abrupt ups and downs than those of marine species groups.

Figure 6: Catch trends by major inland water species groups

Catch trends by major inland water species groups



1.4.9 Per capita food fish supply and consumption

The fishery sector plays a key role in food security, not only for subsistence and small scale fishers who rely directly on fishery for food, incomes and services, but also for consumers who profit from an excellent source of affordable high-quality animal protein.

Total and per capita fish food supplies have expanded significantly in the last five decades. Total food fish supply has increased at an annual rate of 3.1 percent since 1961, while the world population has increased by 1.7 percent per year in the same period.

The total amount of fish consumed and the species composition of the food supply vary according to regions and countries, reflecting the different levels of availability of fish and other foods, including the accessibility of aquatic resources in adjacent waters, as well as diverse food traditions, tastes, demand, income levels, prices and seasons. Annual per capita apparent fish consumption can vary from less than 1 kg in one country to more than 100 kg in another. Differences are also evident within countries, with consumption usually higher in coastal areas. Of the 111 million tonnes available for human consumption in 2007, consumption was lower in Africa (8.2 million tonnes, with 8.5 kg per capita), while Asia accounted for two-thirds of total consumption, with 74.5 million tonnes (18.5 kg per capita), of which 39.6 million tonnes was consumed outside China (14.5 kg per capita). The corresponding per capita consumption figures for Oceania, North America, Europe, Central America and the Caribbean, and South America were 25.2, 24.0, 22.2, 9.4 and 9.1 kg, respectively.

Annual per capita fish consumption grew from an average of 9.9 kg in the 1960s to 11.5 kg in the 1970s, 12.6 kg in the 1980s, 14.4 kg in the 1990s and reached 17.0 kg in 2007. The estimate for 2008 indicates a further increase in annual per capita consumption to 17.1 kg. The preliminary estimates for 2009 indicate a further increase in annual per capital consumption to 17.2 kg.

Chapter 5: Problems and management of world inland fisheries resources

1.5.1 Introduction

Inland capture fisheries can be considered significant contributors to rural food security and income generation,providing a diverse set of livelihood benefits to some of the poorest household in the rural sector. However, awareness of their socio-economic importance is often lacking in government development programmes. Besides this, this sector is facing several problems. The major issues grounded with the inland capture fisheries sections are as followings:

1.5.2 Under estimation of inland fisheries

Inland fisheries often appear to be undervalued and inadequately addressed in national and international policies or priorities for development. There is a critical need to improve the information on inland fishery resources and on the people that use and depend on them.

1.5.3 Sharing inland fisheries resources with other sectors

Another major issue is how to maintain ecosystem integrity and mitigate impacts on aquatic ecosystems. These ecosystems, so essential for inland fisheries, suffer as hydroelectricity generation and abstraction of freshwater resources for agriculture and other purposes are often given higher priorities. These other sectors, combined with growing populations and ease of travel and trade, are putting pressures on inland fisheries resources that are stronger and more widespread than at anytime in history.

1.5.4 Transboundary waters

Many of the world's large river basins cross one or several international borders and therefore activities in one country may affect fish stocks and fisheries in the others. Many riverine fish species are migratory, so even in situations where an impact on a certain species is confined to a particular area, the effects on the species may be felt by communities exploiting the fish stock in other countries. Thus,there is a need for a system of governance for transboundary and international inland waters. Appropriate fisheries management of transboundary waters requires that suitable policies and strategies for sustaining the shared resources (water and biological resources) are developed at the regional level,and that these are incorporated in international legislation and implemented.The first step would be to identify the species and stocks that are shared and establish whether they are vulnerable and to what threats.

1.5.5 Multi-gear and Multi-species fishery

The nature of many inland fisheries makes assessment of their status extremely difficult. Inland fisheries often use multiple fishing gears to harvest a complex array of species for which catch rates are strongly influenced by seasonality.

1.5.6 Improper and insufficient data collection system

Catches are frequently not recorded by species or not recorded at all. Additionally, inland fisheries are often practised in remote areas by the poorer sectors of society. These factors make collecting accurate information on inland fisheries extremely costly for public administrations and many do not collect such information or make assessments of the status of inland fishery resources.

1.5.7 Non-availability of network of fisheries scientist

To determine the status of marine fishery resources, FAO relies on a network of fishery scientists, the use of expert knowledge and catch and other statistics. No such network exists for inland fisheries and the catch statistics are generally inadequate for use as a measure of stock status. FAO is not therefore in a position to make accurate global statements on the status of inland fishery resources.

1.5.8 Overfishing

Inland capture fisheries are also being affected by developments within the sector itself, such as increasing fishing pressure and illegal fishing. However, the majority of the impacts originate from outside the fisheries sector.

A recent review made by the FAO pointed out the overfished state of many inland fisheries. It identified two types of overfishing: intensive targeting of individual species and assemblage or ecosystem overfishing. Targeted fishing for large freshwater fish species in several major river systems in Africa, Asia, Australia, Europe,the Near East, North America and

South America has led to a decline in fish abundance. Of the fish targeted in these fisheries, 10 out of 21 species were assessed as being vulnerable or in danger of extinction; for the remaining 11species the available data were insufficient to assess their status or no assessment was undertaken. Assemblage overfishing is most common in tropical areas with high species diversity and where local communities depend on a diverse inland fish harvest.

1.5.9 Issues of implementation of fisheries legislation

Rich economies can mitigate influences on inland fish resources through legislation and technical measures to protect aquatic environments. Developing countries have fewer resources for such tasks,or have other priorities to invest resources in. Thus, those who have most need of inland fisheries, in particular rural populations in developing countries,are particularly at risk from these pressures and a lack of policies.

1.5.10 Management issues

Efforts are underway in many areas to improve the status of selected inland fishery resources through restocking programmes, habitat rehabilitation and improved fishery management. While habitat rehabilitation is a widespread activity in many developed countries, it is not common in developing countries and its efficacy in improving fish stocks has not been evaluated in most cases. Also, the management of rice-based ecosystems for biodiversity, together with the use of alien species and stocking of inland water bodies, continues to improve the fishery resources of many areas, primarily in Asia. Globally, inland fishery resources appear to be continuing to decline as a result of habitat degradation and overfishing. This trend which is in large part a result of the growing quantities of freshwater being used for hydro power generation and agriculture is unlikely to be reversed as long as countries do not see inland fisheries as a growth sector. And they are not likely to want to reconsider this view point until they have accurate information on these fisheries and their value to society now and in the future.

In a changing world, it will be a major challenge to sustain the different functions of inland fisheries, such as their role in food security and poverty alleviation and other ecosystem services.

Unit 2: Inland capture fisheries in India

Chapter 1: Inland capture fisheries resources in India

2.1.1 Introduction

India has the distinction of being one of the seven largest producers of fish in the world and ranks third in terms of total inland fish production after China and Bangladesh (FAO, 2010). All in all, this sector has been recognized as a powerful income and employment generator since it stimulates the growth of a number of allied industries and also is source of cheap animal protein. It is an instrument of livelihood for a large section of economically backward population of the country.

Of the two sectors viz. marine and inland in the Indian fisheries, the inland sector remains a sector of much promise. Unlike agriculture, because of expansion of culture based fisheries enterprise, the contribution of inland fisheries sector to grow domestic product has been increasing at a significant rate. This sector is a complex enterprise which operates under the intensified network of natural resources, other enterprises with fisheries and other socio-political variables.

2.1.2 Inland fisheries resources of India

The inland fishery resources of the country comprises of the rivers and canals,reservoirs, tanks and ponds, estuaries, brackish water lakes, backwaters, floodplain lakes (oxbow lakes) etc. while the marine water bodies are mainly used for capture fisheries resources, the inland water bodies are widely used for culture and capture fisheries. Inland capture fisheries of India has an important place; it contributes to about 30% of the total fish production. The large network of inland water masses provides great potential for economic capture fishery.

India has a total water surface area of 3,14,400 sq km with water resources in the form of numerous rivers, streams, wetlands, lakes,etc., and receives an average annual rainfall of 1,100 mm. The country as a whole has a river length (including canals) of 1,95,210 km, reservoirs of 29.07 lakh ha, tanks and ponds of 24.14 lakh ha, flood plain lakes and derelict water bodies of 7.98 lakh ha, and brackish water areas of 12.40 lakh ha. A major part of the river stretches and canals are concentrated in the states of Uttar Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. Much of the reservoir areas falls in the states of Tamil Nadu, Karnataka, Maharashtra, Orissa, Gujarat, Andhra Pradesh,Madhya Pradesh, Uttar Pradesh and Rajasthan. Tanks and ponds are concentrated in the states of Andhra Pradesh,Karnataka, West Bengal, Arunachal Pradesh, Rajasthan and Orissa. A large part of the area under flood plain lakes and derelict water bodies is found in Kerala, Orissa, Uttar Pradesh and Assam. Brackish water areas are concentrated in the maritime states of Orissa, Kerala, West Bengal, Gujarat,Goa, Andhra Pradesh and Tamil Nadu and in the Union territory of Andman and Nicobar Islands. Total area under water bodies (excluding rivers and canals) is found to be maximum in Orissa, followed by Andhra Pradesh, Karnataka, TamilNadu, West Bengal, Kerala, Uttar Pradesh, Gujarat, Maharashtra, Rajasthan, Madhya Pradesh, etc. in that order. There are several wetlands being shared with neighbouring countries too as in case of Ladakh and Sunderbans. The major river basins of the country are the Ganges,Brahmaputra, Narmada, Tapti, Godavari, Krishna and Cauvery.

2.1.2.1 Inland fishery resources by states and union territories

State/Union Territory	Rivers & Canals (km)	Reservoirs (Lakh ha.)	Tanks & Ponds (Lakh ha.)	Flood plain lakes & Derelict water (Lakh ha.)	Brackish water (Lakh ha.)	Total water bodies (Lakh ha.)*
Andhra Pradesh	11514	2.34	5.17	-	0.60	8.11
Arunachal Pradesh	2000	-	2.76	0.42	-	3.18
Assam	4820	0.02	0.23	1.10	-	1.35
Bihar	3200	0.60	0.95	0.05	-	1.60
Goa	250	0.03	0.03	-	Neg	0.06
Gujarat	3865	2.43	0.71	0.12	1.00	4.26
Haryana	5000	Neg	0.10	0.10	-	0.20
Himachal Pradesh	3000	0.42	0.01	-	-	0.43
Jammu & Kashmir	27781	0.07	0.17	0.06	-	0.30
Karnataka	9000	2.27	2.93	-	0.08	5.28
Kerala	3092	0.30	0.30	2.43	2.40	5.43
Madhya Pradesh	17088	2.27	0.60	-	-	2.87
Maharashtra	16000	2.79	0.59	-	1.10	3.48
Manipur	3360	0.01	0.05	0.04	-	0.10
Meghalaya	5600	0.08	0.02	Neg	-	0.10
Mizoram	1395	-	0.02	-	-	0.02
Nagaland	1600	0.17	0.50	Neg	-	0.67
Orissa	4500	2.56	1.14	1.80	4.30	9.80
Punjab	15270	Neg	0.07	-	-	0.07
Rajasthan	5290	1.20	1.80	-	-	3.00
Sikkim	900	-	-	0.03	-	0.03
Tamilnadu	7420	5.70	0.56	0.07	0.60	6.93
Tripura	1200	0.05	0.13	-	-	0.18
Uttar Pradesh	28500	1.38	1.61	1.33	-	4.32
West Bengal	2526	0.17	2.76	0.42	2.10	5.45
A and N Islands	115	0.01	0.03	-	1.20	1.24
Chandigarh	2	-	Neg	Neg	-	0.00
Dadar & Nagar Haveli	54	0.05	-	-	-	0.05

Daman & Diu	12	-	Neg	-	Neg	0.00
Delhi	150	0.04	-	-	-	0.04
Lakshadweep	-	-	-	-	-	0.00
Pondicherry	247	-	Neg	0.01	Neg	0.01
Chhattisgarh	3573	0.84	0.63	-	-	1.47
Uttaranchal	2686	0.20	0.01	0.00	-	0.21
Jharkhand	4200	0.94	0.29	-	-	1.23
Total	**195210**	**29.07**	**24.14**	**7.98**	**12.40**	**73.59**

Source: Department of Animal Husbandry,Dairying and Fisheries, 2005

* Not including river length; Neg –Negligible

2.1.2.2 Open water fishery resources of India

Resources	Resource potential	Mode of management
Rivers (km)	29000	Capture fisheries
Mangroves (ha)	356000	Subsistence
Estuaries(ha)	300000	Capture fisheries
Estuarine wetlands / bheries (ha)	39600	Aquaculture
Backwaters/lagoons (ha)	190500	Capture fisheries
Large & Medium reservoirs (ha)	1667809	Enhancement (stock and species)
Small reservoirs (ha)	1485557	Capture based fisheries
Flood plain wetlands (ha)	202213	Capture based fisheries
Upland lakes (ha)	720000	Not known

Source: Sugunan and Sinha, 2001

The above table shows that large and medium reservoirs constitute the most important resource base for inlandfisheries, followed by small reservoirs, upland lakes, flood plain wetlands,mangroves, estuaries and backwaters/lagoons, in that order.

2.1.3 Riverine fishery resources

The following table provides the details of major rivers of India, their length and distribution over states.

Length of major rivers of India

S.No.	River	Total length (km)	Distribution over states	Length (km)
1.	Ganga	2525	(a) Uttar Pradesh	1450
			(b) Bihar	445

			(c) West Bengal	520
			(d) Boundary of Bihar and U.P	110
2.	Brahmaputra	916	(a) Arunachal Pradesh	218
			(b) Assam	698
3.	Indus	1114	Jammu & Kashmir	1114
4.	Brahmani	799	(a) Orissa	541
			(b) Bihar	258
5.	Krishna	1401	(a) Maharashtra	640
			(b) Andhra Pradesh	386
			(c) Karnataka	375
6.	Mahanadi	851	(a) Madhya Pradesh	357
			(b) Orissa	494
7.	Sabarmathi	371	(c) Rajasthan	48
			(d) Gujarat	323
8.	Narmadha	1312	(a) Madhya Pradesh	1079
			(b) Gujarat	159
			(c) Boundary of M.P and Gujarat	39
			(d) Boundary of M.P and Maharashtra	35
9.	Mahi	583	(a) Madhya Pradesh	167
			(b) Rajasthan	174
			(c) Gujarat	242
10.	Tapti	724	(a) Madhya Pradesh	228
			(b) Maharashtra	228
			(c) Gujarat	214
			(d) Boundary of M.P and Maharashtra	54
11.	Godavari	1465	(a) Andhra Pradesh	771
			(b) Maharashtra	694
12.	Pennar	597	(a) Karnataka	61
			(b) Andhra Pradesh	536
13.	Cauveri	800	(a) Karnataka	320
			(b) Tamilnadu	416
			(c) Boundary of Karnataka and Tamilnadu	64
14.	Subarnarekha	395	(a) Jharkhand *	269
			(b) West Bengal	64

			(c) Orissa	62

*www.dowrorissa.gov.in (earlier, in place of Jharkhand, Bihar was mentioned.

Source: Department of Animal Husbandry and Dairying, 2001

Much of the Ganga flows through Uttar Pradesh, Bahmaputra through Assam, Indus through Jammu and Kashmir, Brahmini through Orissa, Krishna through Maharastra, Mahanadi through Orissa, Sabarmati through Gujarat, Narmada through Madhya Pradesh, Mahi through Gujarat, Tapti evenly through Madhya Pradesh, Maharashtra and Gujarat, Godavari through Andhra Pradesh and Maharashtra, Pennar through Andhra Pradesh, Cauveri through Tamil Nadu and Karnataka and Subanarekha predominantly through Jharkhand.

2.1.4 Reservoir fishery resources

Reservoir is the single largest inland fisheries resource in terms of resource size and production potential. India has 19,134 small reservoirs with a total water surface area of 14,85,557 ha, 180 medium reservoirs with 5,27,541 ha, and 56 large reservoirs with11,40,268 ha.

State and size-wise distribution of reservoirs in India

State	Small reservoirs			Medium reservoirs			Large reservoirs			Total		
	Area (ha)	(% of total)	Yield (kg/ ha)	Area (ha)	(% of total)	Yield (kg / ha)	Area (ha)	(% of total)	Yield (kg/ ha)	Area (ha)	(% of total)	Yield (kg /ha)
Tamilnadu	315941	21.27	48.50	19577	3.71	13.74	23222	2.04	12.66	358740	11.38	22.63
Karnataka	228657	15.39	---	29078	5.51	--	179556	15.75	--	437291	13.87	--
M.P	172575	11.62	47.26	169502	32.13	12.02	118307	10.38	14.53	460384	14.60	13.68
A.P	201927	13.58	188.00	66 429	12.59	22.00	190151	16.68	16.80	458507	14.54	36.48
Maharashtra	119515	8.05	21.09	39 181	7.48	11.83	115054	10.09	9.28	273750	8.68	10.21
Gujarat	84124	5.66	---	57 748	10.95	--	144358	12.66	--	286230	9.08	--
Bihar	12461	0.84	3.91	12 523	2.37	1.90	71 711	6.29	0.11	96 695	3.07	0.05
Orissa	66047	4.45	25.85	12 748	2.42	12.76	119403	10.47	7.62	198198	6.29	9.72
Kerala	7975	0.54	53.50	15 500	2.94	4.80	6 160	0.54	--	29 635	0.94	23.37
U.P	218651	14.72	14.60	44 993	8.53	7.17	71 196	6.24	1.07	334840	10.62	4.68
Rajasthan	54231	3.65	---	49 827	9.45	24.47	49 386	4.33	5.30	153444	4.87	24.89
Himachal	200	0.01	---	---	---	---	41 364	3.63	35.55	41564	1.32	35.55
North-east	2239	0.15	---	5 835	1.11	---	---	---	---	8 074	0.26	--
Haryana	282	0.02	---	---	---	---	---	---	---	282	0.01	---
W. Bengal	732	0.05	---	4 600	0.87	---	10 400	0.91	---	15 732	0.50	---
Total	1485557	47.11	49.90	527541	16.73	12.30	1140268	36.16	11.43	3153366	100.00	20.13

Source: Sugunan, 1995 and Sinha and Katiha, 2002

2.1.5 Coldwater fishery resources

National Commission on Agriculture observed that fisheries in streams and lakes, situated in high altitude regions of the country comprise indigenous fishes, chiefly the mahseer, the snow-trout, and the exotic species, mainly trout. Natural lakes situated in the colder upland regions of India cover an area of 7, 20,000 ha. But, these lakes have not been studied for their fishery potential. Until recently, the developmental work in cold water fisheries was directed towards establishing trout fishery which is the most popular sport fish in the world. There has, however, been growing realization for developing indigenous cold water fisheries. The production from cold water fisheries is however not of much significance in the total inland fish production of the country. On account of their limnological characteristics, they are suitable for developing cold water fisheries.

2.1.6 Estuarine fisheries resources

National Commission on Agriculture stated that "under the term estuarine fisheries is included the fishery output from the mouth of rivers, the large brackish water lakes, the innumerable creeks and backwaters along the coast and the coastal canal system". The fisheries in estuaries of India are above the subsistence level and contribute significantly to the production. The major estuarine systems noted by the National Commission on Agriculture are (1) Hooghly-Maltah, (2) Mahanadi, (3) Godavari (4), Chilka (5) Pulicat and (6) Vembanad. Of these six estuarine systems, Chilka lake, Pulicat lake and Vembanad lakes are considered as the brackish water lakes.

Among the estuaries, the Hoogly Matlah estuarine system is the largest in terms of area, followed by Chilka, Pulicat and Mahanadi estuaries. Mangroves, though apparently the largest in terms of total area reported, are subject to maximum encroachment and destruction, in the wake of other developments in the coastal zones of the country.

2.1.6.1 Major estuaries of India

Estuaries present in India cover an area of 14.22 lakh hectare.

Estuarine system	Estimated area (ha)	Production (t)
Hoogly – Matlah	234000	20000-26000
Godavari Estuary	18000	5000
Mahanadi Estuary	3000	550
Narmada Estuary	30000	4000
Peninsular Estuarine system	---	2000
Chilka lake	103600	4000
Pulicat lake	3900	760-1370
Vembanad lake and Kerala back waters	50000	14000-17000
Wetlands of West Bengal	---	---
(a) Fresh water bheries	9600	10-14

(b) Saline bheries	33000	25500
Mangroves	356500	---

Source: Sinha, 1997

2.1.6.2 State wise estuarine fishery resources in India

S. No.	State	Brackish Water area (Lakh ha)
1.	Andhra Pradesh	0.64
2.	Gujarat	3.70
3.	Karnataka	0.01
4.	Kerala	2.00
5.	Maharashtra	0.10
6.	Orissa	4.17
7.	Tamil Nadu	0.56
8.	West Bengal	2.14
9.	Arunachal Pradesh	2.16
10.	Andaman Nicobar	0.37
11.	Pondicherry	0.01

2.1.7 Floodplain wetlands

The freshwater fishery resources, which have progressively gone into dereliction, comprise the floodplain wetlands / ox-bow lakes, locally known as *mauns* in Bihar, *beels* in West Bengal and Assam. Floodplain wetlands form an important fishery resource in Assam, West Bengal and Bihar, where thousands of poor fishermen are dependent on these water bodies for their livelihood.

2.1.7.1 Distribution of floodplain wetlands in India

State	Distribution Over districts	River basin	Local name	Area (ha)
Arunachal Pradesh	East Kameng, LowerSubansiri, East Stang, Dobang valley, Lohit Changlang and Tirap	Kameng, Subansiri, Libang Lohik, Dihing and	Beel	2500

		Tirap		
Assam	Brahmaputra and Barak valley	Brahmaputra and Barak	Beel	10000
Bihar	Savan, Champaran, Saharsa, Muzaffarpur,Dharbhanga, Monghyr, and Turnea	Gandak and Kosi	Maun, Chaur, Dhar	40000
Manipur	Imphal, Thoubai and Bhishnupur	Iral, Imphal and Thoubal	Pat	16500
Meghalaya	West Khasi hills and West Garo hills	Someswari and Jingiram	Beel	213
Tripura	North, South and West Tripura	Gumti	Beel	500
West Bengal	24-Parganas – North and South, Hoogly Nadia, Murshidabad, Meldah, Cooch Behar, Burdwan, North and South Dinajpore and Midnapore	Hoogly, Ichhamati, Bhagirathi, Churri, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa and Mahananda	Beel, Charha and Baor	42500

Source: Sugunan and Sinha, 2001

2.1.7.1 Distribution of floodplain wetlands in India

State	Distribution Over districts	River basin	Local name	Area (ha)
Arunachal Pradesh	East Kameng, LowerSubansiri, East Stang, Dobang valley, Lohit Changlang and Tirap	Kameng, Subansiri, Libang Lohik, Dihing and Tirap	Beel	2500
Assam	Brahmaputra and Barak	Brahmaputra and Barak	Beel	10000

	valley			
Bihar	Savan, Champaran, Saharsa, Muzaffarpur,Dharbhanga, Monghyr, and Turnea	Gandak and Kosi	Maun, Chaur, Dhar	40000
Manipur	Imphal, Thoubai and Bhishnupur	Iral, Imphal and Thoubal	Pat	16500
Meghalaya	West Khasi hills and West Garo hills	Someswari and Jingiram	Beel	213
Tripura	North, South and West Tripura	Gumti	Beel	500
West Bengal	24-Parganas – North and South, Hoogly Nadia, Murshidabad, Meldah, Cooch Behar, Burdwan, North and South Dinajpore and Midnapore	Hoogly, Ichhamati, Bhagirathi, Churri, Kalindi, Dharub, Dharala, Pagla, Jalangi, Behula, Torsa and Mahananda	Beel, Charha and Baor	42500

Source: Sugunan and Sinha, 2001

Chapter 2: Status of inland capture fisheries production in India

2.2.1 Introduction

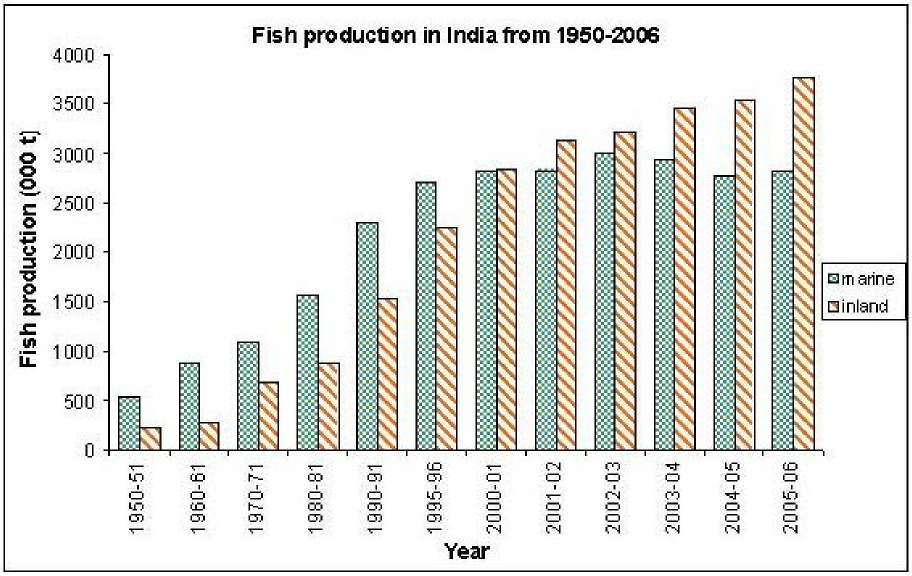
According to estimates of the Central Statistical Organization (CSO), the value of output from livestock and fisheries sectors together at current prices was about Rs.2, 82,779 crore during 2007-08 (Rs.2, 40,601 crore for livestock sector and Rs.42, 178 crore for fisheries) which is about 31.6 per cent of the value of the output of Rs.8, 94,420 crore from Agriculture & allied sector. The contribution of these sectors in the total GDP during 2007-08 was 5.21 %. (DAHD, 2009). India is now holding third position in both freshwater fish production and overall fish production. Fish production has increased from 4.16 million tonnes (2.45 million tonnes for marine and 1.71 million tonnes for inland fisheries) in 1991- 92 to 7.12 million tonnes (2.92 million tonnes for marine and 4.20 million tonnes for inland fisheries) in 2007-08. Fish production during the year 2008-09 was 7.62 million tonnes comprising 2.98 million tonnes of marine fish and 4.64 million tonnes of inland fish. Fisheries sector contributes significantly to the national economy while providing livelihood to approximately 14.49 million people in the country. The overall inland fish production is now highly dependent on aquaculture of Indian major carps. Carps constitute 87% of the inland aquaculture production. Fish seed production during 2007-08 was 24143.57 million fry.

2.2.2 Inland capture fisheries production

India has an estimated overall fish production potential of about 9 million tonnes, with 5 million tonnes expected from inland fisheries. As against the said potential the country is producing around 6.53 million tonnes (2005-06) with a contribution of about 43 % each from marine and 57 % from inland fisheries. Based on the total production, India occupies third position in the world contributing a little over 4 % of the world's total production. In the case of inland fish production, India ranks second in the world. The current per capita availability of fish per annum works out to about 9 kg for the fish eating population of the country which is less than their minimum requirement of 11 kg recommended by the World Health Organization. The structure of fish production in the country has undergone significant changes over the years.

2.2.2.1 Production trend

At the global level, about 85 % of the world fish production comes from the ocean and only 15 % is contributed by fresh water. However, in India, the picture is different. In 1950-51, the share of marine fisheries was 71 % of the total fish production of 7.52 tonnes. During the 1970s and 1980s, the share of inland fisheries was just above one-third of the total fish production. Later, it gradually increased to reach nearly 40 per cent in 1980 – 81 and 71 % in 2005 -06. It is sometimes argued that the increase in the share of inland fisheries was, on the one hand, due to deceleration in growth in marine fish production and on the other because of a policy shift in favour of inland fisheries, especially, aquaculture.



2.2.2.2 Inland Fish Production in India during 1950-51 to 2005-06

Year	Fish Production ('000 tonnes) Inland	Average Annual Growth Rate (percent)	Year	Fish Production ('000 tonnes) Inland	Average Annual Growth Rate (percent)
1950-51	218	-	1989-90	1402	16.66
1955-56	243	2.31	1990-91	1536	4.32
1960-61	280	7.65	1991-92	1710	8.37
1965-66	507	2.95	1992-93	1789	5.00
1970-71	670	6.39	1993-94	1995	6.39
1973-74	748	3.83	1994-95	2097	3.12
1978-79	816	3.55	1995-96	2242	3.34
1979-80	848	1.47	1996-97	2381	8.06
1980-81	887	4.36	1997-98	2438	0.75
1981-82	999	0.08	1998-99	2602	-1.67
1982-83	940	-3.15	1999-00	2823	7.12
1983-84	987	5.87	2000-01	2845	-0.33
1984-85	1103	11.77	2001-02	3126	5.30
1985-86	1160	2.68	2002-03	3210	4.10
1986-87	1229	2.29	2003-04	3458	3.21
1987-88	1301	0.58	2004-05	3526	-1.48
1988-89	1335	6.52	2005-06	3719	3.55

2.2.2.3 Inland Fish Production by States and Union Territories

Inland fish production by States and Union territories for the period 2001-02 to 2005-06 is given below.

Inland fish production in India during 2001-02 to 2005-06 (in 1000 tonnes)

Sl. No.	State / Union Territory	2001-02	2002-03	2003-04	2004-05	2005-06
1.	Andhra Pradesh	471.17	529.40	680.71	642.32	672.25
2.	Arunachal Pradesh	2.60	2.60	2.65	2.20	2.45
3.	Assam	161.45	165.52	181.00	186.31	188.08
4.	Bihar	240.40	261.00	266.49	267.51	279.53
5.	Goa	3.37	4.25	3.60	4.23	3.06
6.	Gujarat	50.77	34.27	45.48	50.43	69.94
7.	Haryana	34.57	35.18	39.13	42.05	48.20
8.	Himachal Pradesh	7.22	7.24	6.53	6.90	7.29
9.	Jammu & Kashmir	18.85	19.25	19.25	19.10	19.15
10.	Karnataka	121.20	86.26	70.00	80.00	120.60
11.	Kerala	78.04	75.04	76.18	76.45	77.98
12.	Madhya Pradesh	47.46	42.17	9.82	62.06	61.08
13.	Maharashtra	122.79	127.24	125.12	130.25	154.66
14.	Manipur	16.45	16.60	17.60	17.80	18.22
15.	Meghalaya	4.97	5.37	5.15	5.64	4.12
16.	Mizoram	3.15	3.25	3.38	3.68	3.75
17.	Nagaland	5.20	5.50	5.56	4.90	5.50
18.	Orissa	168.06	172.53	190.02	193.66	203.23
19.	Punjab	58.00	66.00	83.65	77.70	85.64
20.	Rajasthan	14.27	25.60	14.30	16.39	18.50
21.	Sikkim	0.14	0.14	0.14	0.14	0.15
22.	Tamilnadu	114.00	102.00	101.14	151.73	155.03
23.	Tripura	29.45	29.52	17.98	19.84	23.87
24.	Uttar Pradesh	225.37	249.84	267.00	277.07	289.57
25.	West Bengal	945.80	938.50	988.00	103.55	103.55
26.	A and N Islands	0.06	0.07	0.09	0.08	0.04
27.	Chandigarh	0.04	0.08	0.08	0.08	0.08
28.	Dadra & Nagar Haveli	0.05	0.05	0.05	0.05	0.05
29.	Daman & Diu	0.00	0.00	0.00	0.00	0.07
30.	Delhi	3.20	2.25	2.10	1.41	0.070
31.	Lakshadweep	0.00	0.00	--	---	---

32.	Pondichery	4.90	4.91	5.20	5.25	2.18
33.	Chhattisgarh	95.76	99.80	111.05	120.10	131.25
34.	Uttaranchal	6.42	2.55	2.56	2.57	2.79
35.	Jharkhand	101.00	45.38	75.38	22.00	34.27
Total		**3126.18**	**3209.86**	**34.5789**	**3525.88**	**3719.24**

2.2.2.4 Fisheries sector in national income

According to National Income Statistics, Indian fisheries contributed about 1.07 % of the total Gross Domestic Product (GDP) and 4.69 % of the GDP from agriculture during 2003-04. The vast resources which are capable of yielding 10 million tonnes of fish per year as against the current production of 6.53 million (2005-06) will go a long way in increasing the national income. The contribution of fisheries sector to the Gross Domestic Product (GDP) rose from Rs. 245 crores in 1970-71 to Rs. 26,850 crores during 2002-03. The following table shows the contribution of fisheries sector to GDP.

Year	Total GDP	GDP from		GDP from fisheries as % of	
		Agriculture	Fisheries	Total GDP	GDP from Agri
1970-71	39708	16821	245	0.62	1.46
1980-81	122427	42466	921	0.75	2.17
1990-91	475604	135162	4556	0.96	3.37
1991-92	551552	162317	5300	0.96	3.27
1992-93	627913	184536	6649	1.06	3.60
1993-94	799077	242438	9074	1.14	3.74
1994-95	943408	284042	11099	1.18	3.91
1995-96	1103238	312791	12729	1.15	4.07
1996-97	1285259	376091	15055	1.17	4.00
1997-98	1384446	387445	19555	1.41	5.04
1998-99	1612383	469340	22223	1.14	4.47
1999-00	1761838	422392	20017	1.14	4.47
2000-01	1902998	423522	22535	1.18	5.32
2001-02	2090957	473004	24562	1.17	5.19
2002-03	2249493	456044	56850	1.19	5.89
2003-04			27026	1.07	4.69

(Source: Central Statistical Organisation)

2.2.2.5 Fish availability and consumption

In India, the per capita fish availability is about 9 kg, whereas the per capita requirement is about 11 kg. Unlike Indians, who consume relatively less fish, many Asian neighbours make good use of fish as an important food source. Within India, the Bengalis and Keralites eat much more fish than the national average of 3 kg/person/annum. (The average annual per capita fish consumption in India was 4.5 kg during 1999 – 2001).

Chapter 3: Problems in estimation of inland fish catch statistics

2.3.1 Introduction

Trend analysis by species or species groups of the inland catch data in the FAO database risks being biased for two main reasons: the very poor species breakdown reported by many countries and the recent large fluctuations within the data for major items in the inland catch statistics reported by China, which represents over one quarter of the global production. In 2003 and 2004, global inland catches classified as "freshwater fishes not elsewhere included" again exceeded 50 per cent of the total, and only about 19 consequences as catch information by species is required for management purposes. In countries where inland fisheries are significant for food security and economic development, particularly in Africa and Asia, mismanagement of inland fisheries would as a rule lead to economic losses far greater than the expenditures needed to improve quality and detail of inland catch statistics significantly.

2.3.2 Constraints in fisheries data collection

The major constraints in data collection on fisheries and related aspects are as

Lack of clearly stated management objectives for fishery data collection;

Lack of sufficient funding;

Extreme variability(small scale, part time and seasonal fishing operations);

Inadequate system design and coordination (fragmented and incomplete data system);

Inadequate information processing and analysis systems;

Non-compliance with rules and regulations by the fishermen;

Lack of skilled manpower;

No involvement of local communities in management and data collection ;

Inadequacy of data collection systems

No sampling design

Reported data by fishermen-leads to misreporting

Capture fishery mainly traditional-no fix time and landing centres,

Grouping of data reported- no species data are available

Routine collection of biological data-only project based.

Socio-economic data not collected on a routine basis;

Frame survey-no information about fishing villages, fishers population and their gears and boats, landing centres, water bodies, etc.,

Lack of coordination between different agencies, institutes, states;

No validation of data collected and compiled;

Lack of two way linkage among enumerators, data managers and end users;

Inappropriate data collection methods including insufficient use of sample survey

Non-standard classification and definition of water bodies, gears,boats, species, etc.;

Inaccurate reporting by administration;

Discontinuity in funding disrupting time series data;

Fishermen's unwillingness to give information;

Lack of flexibility for reporting estimates at different levels;

Cross- checking mechanism to validate survey estimate is not followed.

- Deliberate misreporting
- Lack of attention to small-scale fishing activites
- Lack of status, capacity or training of local fishery officers,
- Errors in catch reporting (often field data is collected based on 'recall');
- Difficulty in accessing sources of information (women, children and other fishers far from population centres);
- A reluctance to report catches because this is linked, in most countries, to license fees or other forms of taxation.
- The collection of fish production statistics from inland water is beset with serious difficulties,the main in respect of riverine and estuarine fisheries are,
- Highly dispersed and isolated nature of fishing and landing areas.
- The density of fishing gear and tackly employed and a high percentage of subsistence fishing
- The innumerable landing places
- The migration of fishermen from one area to the other for fishing
- The prevailing system of fish merchants buying off catches from the fishing boats at the fishing spots.
- The multispecies composition of catches and the landing of catches in unsorted condition
- Isolated nature of fishing areas lower estuaries direct observations are very limited.

2.3.3 Needs to collect information

The types of information needed will depend on the intended uses of that information that is it will depend on the objectives of fishery management and the goals of water management policy. There are several possible objectives of inland fishery management that can be generally classified into social, economic, and conservation categories. Priority objectives for collecting information on inland fisheries include:

- To obtain status and trend information on the fisheries and the environment for the formulation and assessment of management interventions concerning the fishery;
- To ensure proper valuation of the fisheries;
- To assess management interventions concerning the fishery
- To justify the request for appropriate allocation of funding and other resources to the sector
- To fulfill international obligations

2.3.4 Approaches to improve information

In general, information collection methods in many areas are based on the application of traditional methods of government fishery officers assessing catch and effot data. However, these methods are best suited for formal, large-scale fisheries and are inadequate or inappropriate for the many informal, small scale fisheries; many inland water bodies support both formal and informal fisheries, i.e. both large scale and small scale. Thus, alternative approaches are being developed and evaluated that attempt to include individual fishers, households, and communities. Additionally, indicators and proxy measures of fishery yield are being developed. Data alone are not always enough to manage a fishery or develop fishery policy. Data must be analysed and transformed into meaningful information and this information delivered in an appropriate form to the people who are actually making decisions that affect fisheries.

2.3.5 Means to obtain information

There are two general means to obtain information on inland fisheries:

Direct measurement of the fishery through frame surveys, catch assessment surveys, census at landing sites, creel census, counting number of fishers, gears, boats, etc, and

Indirect measurements such as yield per type of habitat and extrapolation, GIS and remote sensing, post harvest surveys such as consumption, financial, trade and household surveys.

2.3.5.1 Direct measurement

Direct measurement has not been adequate to represent the entire diversity of many informal or small scale inland fisheries and is best used for large-scale, managed fisheries. For many of the indirect strategies, participatory approaches that involve the stakeholders will be necessary to promote cooperation, information sharing and compliance with fishery management regulations. Information collection systems must be flexible enough to accommodate the diversity of inland fishery data. There are already rigid, inflexible data collection systems in some areas and it would do little good to replace one for another. Practical alternative approaches to information collecting are agricultural surveys, household surveys, consumption surveys, use of geo-referenced data coupled with habitat productivity estimates and fishery co-management. Each approach has strengths and weaknesses. Regardless of the approach used, training in survey techniques, participatory techniques and gender issues will be necessary to improve the quality of data collected.

2.3.5.2 Indirect measurements

Yield is a primary information need. There are direct methods to measure yield but these are difficult to apply to the entire inland water ecosystems that include lakes, temporary water bodies, rivers, swamps and other wetlands. Therefore, alternative approaches will be required to supplement direct measures of fishery yield.

Inland fisheries are extremely diverse and composed of both formal and informal fishery sectors that must be treated differently. Methodologies that work in one area may be inappropriate for others. A certain amount of standardization of terminology, approaches and methods will be essential for basin wide planning and information exchange, however, it is recognized that the diversity of situations will require a diversity of approaches.

Given limited human and financial resources to manage inland fisheries one cannot measure everything that is needed in all areas. Thus, focused studies can provide information on particular fisheries or habitats and these results can then be extrapolated to a wide area. An ongoing and sustainable data collection programme needs to be based on activities that can be done well with a limited amount of financial and human resources inland fisheries and fishing activity often have a strong seasonal component. Data collection and interpretation must take into account how habitats, production, and human activity change in response to the changing environmental conditions. The capacity of local fishery resource officers needs to be increased. Training in standard and new data collection, fish identification and community participation techniques will be required. The status of government fishery officers is often very low and leads to lack of motivation, which results in poor performance of duties. Once the importance of inland fisheries is fully appreciated, the status of the officers responsible for managing the resource should improve.

There are data collection systems in place. Significant progress can be made by working with information that is already available in project reports, government offices, NGO and IGOs. Modification of existing mechanisms to make them more flexible, to ensure they do not bias results in regards to inland fisheries, such the agriculture census, or to ensure that they access all available information, such as information from women and children, can be expected to greatly improve the quality of information needed for fishery management. Inland fisheries do not exist in isolation of other sectors and there are many other users of inland water resources. Inland waters are most strongly impacted by events occurring outside the sector. Therefore, it will be crucial for policy makers and managers of the inland fisheries to form partnerships with stakeholders in other sectors. Often government departments can help form linkages to other sectors where fishers have difficulty in establishing relations. The private sector must also be involved in the partnership, for example access to middlemen and brokers could improve information on commercial (formal) fisheries. Many member countries have limited financial resources and have acknowledged that external assistance will be needed to improve their data collection and fishery management capacities. Training is needed on a variety of subjects and should include local communities and training-of-trainers. Given the productivity of the inland fisheries, the large number of people dependent on them and the wealth of biological and cultural diversity of many inland aquatic ecosystems, donor support in improving information for fishery management is well justified.

Unit 3: Riverine fisheries in India

Chapter 1: Ecology, classification and fish production potential of rivers in India

3.1.1 Introduction

Rivers are linear systems which show a gradient of characters along their length. Ideally the longitudinal profile of a river is concave with a steep upper portion near the source, giving way to reaches of progressively less gradient as the mouth is approached. The steep and torrential upper course is called “rhithron” and the flat, slow-flowing lower course is called “potamon”.

3.1.2 Rhithron zones

Characteristics of rhithron zones

They tend to show an alternation between (i) steep, narrow and shallow riffles or rapids, and (ii) flatter, wider and deeper reaches, termed pools. Riffles have high, turbulent flow, coarse bottoms of boulders, rocks or pebbles and limited attached vegetation. Pools have lower flow, bottoms of somewhat finer material and some rooted vegetation. This zone is characterized by turbulent flow and relatively low temperatures. Generally, the water is highly oxygenated, but at low water the pool and riffle system may break up into a series of pools, whose waters may become completely depleted of oxygen.

3.1.2.1 Adaptations of fishes of rhithron zones

The resident fish species in rhithron zones are entirely rheophilic and fall into two main groups.

· Those species which live on or among the rocks and vegetation of the bottom and are distributed mainly in the riffles. These are of small size and are adapted to grip or cling to the substrate. Such adaptations include mouth suckers, for instance *Chiloglanis*, ventral friction pads as in *Astroblephus* or pectoral fin spines adapted as hooks as in *Glyptothorax*. Other species such as *Mastacembelus* have long sinuous shapes that enable them to twine among the holes in the rocky bottom.

· Those species such as *Barbus* or *Salmo* which are adapted to swim sufficiently fast as to resist the current and even move against it. This they cannot do on a sustained basis, however, and frequently take advantage of cover provided by the slack water of the pools and by snags, overhangs and other features which disrupt the current. Because of the severity of the habitat diversity of resident species tends to be low.

3.1.3 Potamon zones

Characteristics of Potamon zones

Potamon reaches are with wide, flat, meandering channels, mud bottoms and considerable rooted and floating vegetation. Zonation within the potamon is both longitudinal and lateral. Longitudinally, there is a repetition of differing habitats associated with the meanders of the channel. Laterally, there is the distinction between the main channel and its floodplain. The floodplain is normally an area of relatively flat land flanking the main channel. In exceptional cases, larger floodplain areas arise by geographic accident. The plain is usually higher near the river, where raised levees limit the main channel, and slopes downward toward the foot of the terrace confining the plain. Many bodies of water are found on the plain ranging from small temporary pools to large permanent lagoons and swamps.

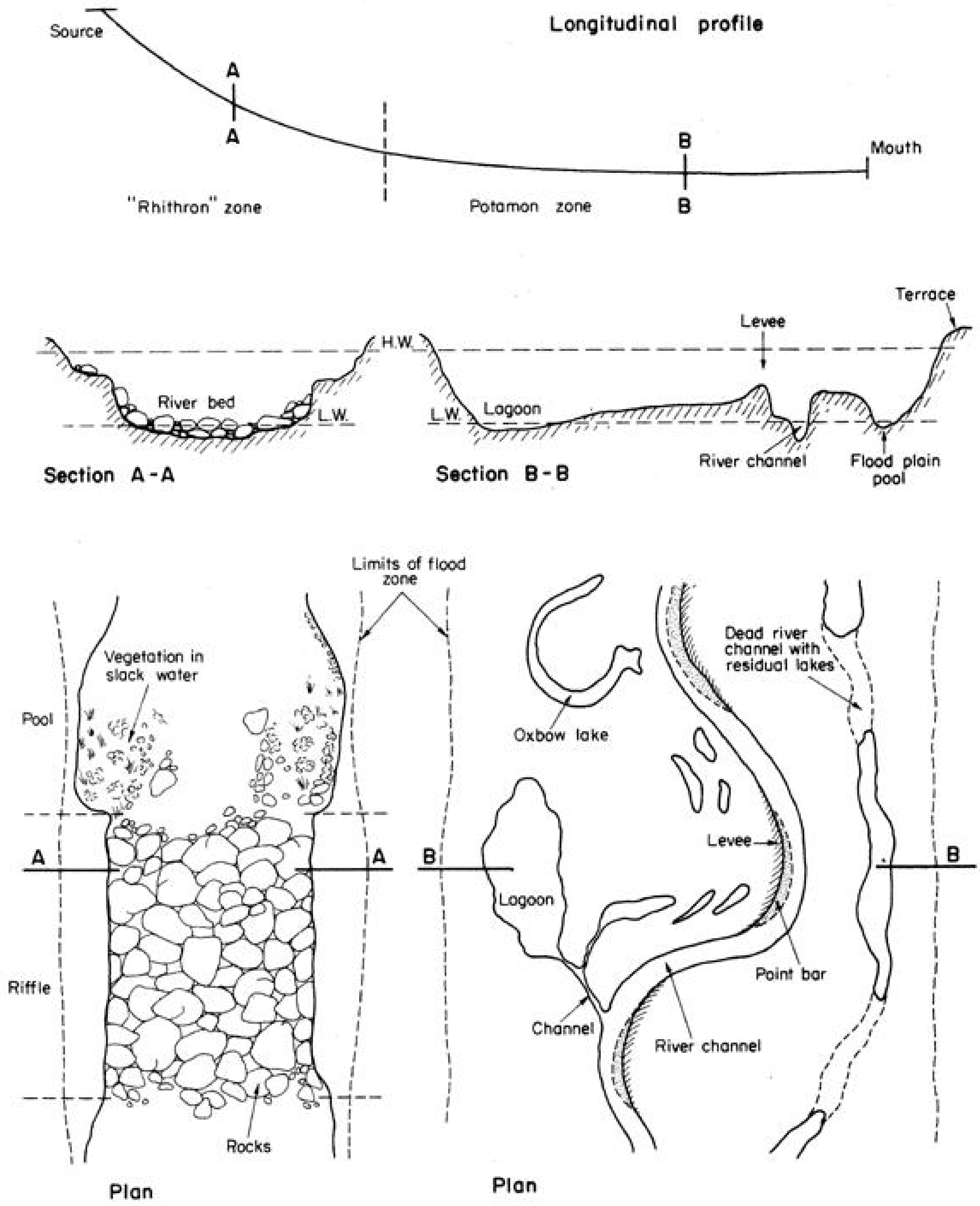
The potamon is environmentally more complex than the rhithron. There is usually a well defined series of river channels flanked by a floodplain. Both running (lotic) and still (lentic) waters may be present. The plain itself contains many types of water body, some of which retain water throughout the inter-flood period. Because of deposition of silt, such features show a succession from open lagoon, through vegetation-lined pools and heavily vegetated swamps to dry land. In the water bodies of the floodplain dissolved oxygen concentrations fall in the dry season, particularly in the smaller pools which may become completely depleted of oxygen.

3.1.3.1 Adaptations of fishes of potamon zones

There are two main adaptations which enable fish to survive the conditions during low waters.

Species which is specifically adapted to resisting low dissolved oxygen concentration. The adaptations may be in the form of auxiliary respiratory organs for using atmospheric oxygen as in the case of such fishes as *Clarias* or *Notopterus*, or may be physiological as with *Carassius* or even behavioural as with many cyprinodonts. The same species often have a capacity to support high temperatures. They generally have complex breeding habits with multiple spawnings, a great degree of parental care, and only migrate laterally between the dry season habitat in the main river channel or the standing waters of the flood plain and the flood season habitat in the inundated area.

Species which uses the rich habitat provided by the flood plain during the flood but escapes the severe dry season conditions by lateral movement off the plain and longitudinal migration within the main river channel to an alternative habitat. This is usually located in the deeper regions of the main river channel, but may also be in the sea or some other large water body adjacent to the river system. A certain proportion of these species move upriver, even as far as the rhithron zone. Such fishes show few adaptations other than a capacity for fast and sustained swimming. Their breeding strategy is generally simple, relying on a single release of a large number of eggs, either on the flood plain or in the headwater streams. To accomplish this they may undertake migrations for very long distances up-and down-river



Longitudinal profile
Source
A
A
B
B
Mouth
"Rhithron" zone
Potamon zone
Terrace
Levee
H.W.
River bed
L.W.
L.W.
Lagoon
River channel
Flood plain pool
Section A-A
Section B-B
Limits of flood zone
Vegetation in slack water
Pool
Riffle
Rocks
A
A
B
B
Oxbow lake
Dead river channel with residual lakes
Levee
Lagoon
Point bar
Channel
River channel
Plan
Plan

3.1.4 Classification of rivers of India

The rivers of India play an important role in the lives of the Indian people. The riverine system of the country comprises four groups of rivers viz. major rivers, medium rivers, minor rivers and desert rivers. Most of the rivers pour their waters into the Bay of Bengal. Some of the rivers whose courses take them through the western part of the country empty into the Arabian Sea. Parts of Ladakh, northern parts of the Aravalli range and the arid parts of the Thar Desert have inland drainage.

3.1.4.1 Major Rivers

The rivers with a catchment area of 20,000 km^2 and above are called major rivers. There are 14 such major rivers in India. The major rivers of India can be classified into Himalayan rivers and Peninsular rivers on the basis of origin. All major rivers of India originate from one of the three main watersheds.

1) The Himalaya and the Karakoram ranges

2) Vindhya and Satpura ranges and Chotanagpur Plateau in central India

3) Sahyadri or Western Ghats in western India

These major rivers are broadly grouped into five systems that include the followings.

1) The Ganga riverine system (Himalayan rivers)

2) The Brahmaputra riverine system (Himalayan rivers)

3) The Indus riverine system (Himalayan rivers)

4) The East coast riverine system (Peninsular rivers)

5) The West coast riverine system (Peninsular rivers)

Major river basins of the country

Major river basins of the country

Sl. No.	Name of the river	Origin	Length (Km.)	Catchment Area (Sq. Km.)
1.	Indus	Mansarovar (Tibet)	1114+	321289+
2.	a) Ganga	Gangotri (Uttar Kashi)	2525+	861452+

	b) Brahmaputra	Kailash Range(Tibet)	916+	194413+
	c) Barak & other rivers flowing into Meghna, like Gomti, Muhari, Fenny etc,			41723+
3.	Sabarmati	Aravalli Hills(Rajasthan)	371	21674
4.	Mahi	Dhar(Madhya Pradesh)	583	34842
5.	Narmada	Amarkantak (Madhya Pradesh)	1312	98796
6.	Tapti	Betul(Madhya Pradesh)	724	65145
7.	Brahmani	Ranchi (Bihar)	799	39033
8.	Mahanadi	Nazri Town (Madhya Pradesh)	851	141589
9.	Godavari	Nasik (Maharashtra)	1465	312812
10.	Krishna	Mahabaleshwar (Maharashtra)	1401	258948
11.	Pennar	Kolar(Karnataka)	597	55213
12.	Cauvery	Coorg(Karnataka)	800	81155

3.1.4.2 Medium rivers

A river with a catchment area between 2,000 and 20,000 km^2 is categorized as Medium River. Forty four such rivers are in India with a total drainage area of 0.24 million km^2. Of these rivers, 9 rivers are interstate rivers as they flow through more than one state. Seventeen rivers flow towards west into the Arabian Sea and 23 towards east into the Bay of Bengal. Four rivers in north eastern states like Mizoram and Manipur flow into Bangladesh. Some of the west flowing rivers include Shetrunji Bhadra, Dhadhar, Vaitama, Kalinadi, Bedti, Sheravathi, Bharathapuzha, Periyar and the Pamba. The total drainage area of these rivers is about 63,500 km^2. Some of the east flowing rivers include Baitarni, Matai, Rushikulya canal, Thotapalli, Kortalaiyar, Palar, Ponnaniyar, Vellar, Vaigai, Tambraparani, Karanphsuli, Kaldan and the Imphal. The total drainage area of these rivers is about 1,793 km^2.

Medium river basins

S.No	Name of the River	Village/Dist. (Origin)	State	Length Catchment (Km.)	Area (Sq.Km)
1.	Ozat	Kathiawar	Gujarat	128	3189
2.	Shetrunji	Dalkania	Gujarat	182	5514
3.	Bhadar	Rajkot	Gujarat	198	7094
4.	Aji	Rajkot	Gujarat	106	2139
5.	Dhadhar	Panchmahal	Gujarat	135	2770
6.	Purna	Dhosa	Maharashtra	142	2431
7.	Ambika	Dangs	Maharashtra	171	3637

8.	Vaitarna	Nasik	Maharashtra	143	2357
10.	Ulhas	Raigarh	Maharashtra	64	2174
11.	Savitri	Pune	Maharashtra	99	2899
12.	Sastri	Ratnagiri	Maharashtra	64	2174
13.	Washishthi	Ratnagiri	Maharashtra	48	2239
14.	Mandvi	Belgaum	Karnataka	87	2032
15.	Kalinadi	Belgaum	Karnataka	153	5179
16.	Gangavati or Bedti (in upper reaches)	Dharwar	Karnataka	152	3902
17.	Sharavati	Shimoga	Karnataka	122	2209
18.	Netravati	Dakshina Kannada	Karnatak	103	3657
19.	Chaliar or Baypore	Elamtalvi Hills	Kerala	169	2788
20.	Bharathapuzha (known as Ponnani)	Annamalai Hills	Tamil Nadu	209	6186
21.	Periyar	Sivajini Hills	Kerala	244	5398
22.	Pamba	Devarmalai	Kerala	176	2235
23.	Burhabalang	Mayurbahanj	Orissa	164	4837
24.	Baitarni	Keonjhar	Orissa	365	12789
25.	Rushikulya	Phullbani	Orissa	146	7753
26.	Bahuda	Ramgirivillage	Orissa	73	1248
27.	Vamsadhara	Kalahandi	Orissa	221	10830
28.	Nagavali	Kalahandi	Orissa	217	9410
29.	Sarda	Vishakhapatnam	Andhra Pradesh	104	2725
30.	Eleru	Vishakhapatnam	Andhra Pradesh	125	3809
31.	Vogarivagu	Guntur	Andhra Pradesh	102	1348
32.	Gundlakamma	Kurnool	Andhra Pradesh	220	8494
33.	Musi	Nellore	Andhra Pradesh	112	2219
34.	Paleru	Nellore	Andhra Pradesh	104	2483
35.	Muneru	Nellore	Andhra Pradesh	122	3734
36.	Swarnamukhi	Koraput	Orissa	130	3225
37.	Kandleru	Vinukonda	Andhra Pradesh	73	3534
38.	Kortalaiyar	Chinglepet	Tamilnadu	131	3521
39.	Palar (including tributary Cheyyar)	Kolar	Karnataka	348	17871
40.	Varahandi	North Arcot	Tamilnadu	94	3044
41.	Ponnaiyar	Kolar	Karnataka	396	14130
42.	Vellar	Chithri Hills	Tamilnadu	193	8558
43.	Vaigai	Madurai	Tamilnadu	258	7031
44.	Pambar	Madurai	Tamilnadu	125	3104

45.	Gundar	Madurai	Tamilnadu	146	5647
46.	Vaippar	Tirunelvelli	TamilNadu	130	5288
47.	Tambraparni	Tirunelvelli	TamilNadu	130	5969
48.	Subarnarekha	Nagri/Ranchi	Bihar	395	19296
				Total	248505

3.1.4.3 Minor rivers

A river with a catchment area of less than 2,000 km^2 is categorized as minor River. These rivers are numerous and are mostly small streams, flowing from Western and Eastern Ghats into the sea. The total drainage area of these rivers is about 0.2 million km^2.

3.1.4.4 Desert rivers

These rivers flow for some distance and disappear in the deserts of Rajasthan. These rivers include Luni, Machai, Rupen, Saraswati, Baner and Ghaggar. The major fishes found in these rivers are *Amblypharyngodon mola, Bari bendelansis, Botia geto, Catla catla, Cirrhina mrigala, C. reba, Labeo* spp, *Danio devario, D. rerio, Tor tor, Nemacheilus botia, Puntius* spp, *Rasbora daniconius, Mastacembelus armatus, Channa* spp., *Trichogaster fasciatus, Clarias batrachus, Mystus* spp, *Heteropneustes fossilis, Wallago attu, Notopterus* spp., etc.

3.1.5 Classification of riverine fishes

Based on the migratory habits, fishes occurring in Indian rivers are classified as:

1. Resident species

The fish species which prefer to remain confined within the local territories are termed resident species. This type includes *Cyprinus carpio, Notopterus spp., Channa* spp., *Mastacembelus* spp., *Garra* spp, *Osteobrama* spp, *Puntius* spp, *Labeo* spp, *Cirrhinus* spp, *Mystus* spp, *Clupisoma* spp etc.

2. Local migrants

The fish species which perform seasonal migrations within short distances for feeding, breeding etc., are called local migrants. This type comprises of mahseer, Indian major carps, large and medium sized catfishes (like B*agarius bagarius*), salmons, trouts etc.

3. Long distant migrants

The fish species which perform regular annual migrations for feeding or spawning or for both are called long distant migrants. This type consists of Indian shad (*Hilsa ilisha*) - an anadromous fish, freshwater eel (*Anguilla* spp.) - a catadromous fish and catfish (*Pangasius pangasius* , migrate from river to estuary).

3.1.6 Production potential of rivers of India

The country as a whole has a river length (including canals) of 1,95,210 km with a resource potential of 29,000 km. Different river systems of the country with a combined length of 29,000 km offer one of the richest fish genetic resources of the world. Their highly diverse natural fish fauna characterizes Indian rivers. All these water bodies have about 930 fish species belonging to 326 genera. Though proper riverine production data are not available, the data collected by CIFRI, Barrackpore on selected stretches of the rivers, Ganga, Brahmaputra, Narmada, Tapti, Godavari and Krishna shows that fish production from these rivers vary from 0.64 to 1.64 tonnes per km, with an average of 1 tonne per km. The riverine fisheries resources contribute significantly to the total inland capture fisheries production. The riverine ecosystem witnessed marked alterations due to water abstraction, dam construction, sedimentation and irrational fishing. These activities affected the natural riverine fish production showing continuous declining trend.

Chapter 2: Fish and fisheries of Himalayan riverine systems in India

3.2.1 Introduction

The main Himalayan river system includes Ganga, Brahmaputra and the Indus river systems. The Himalayan rivers form large basins. Many rivers pass through the Himalayas. In plains, they form large meanders, and a variety of depositional features like floodplains, river cliffs and levees. These rivers are perennial as they get water from the rainfall as well as the melting of ice.

3.2.2 The Ganga river system

The Ganga river system is the largest river system in India. This system alone harbours not less than 265 species of fish. It consists of two rivers namely, the Ganga and Yamuna and their tributaries. The total combined length of the Gangetic river system is 12,500 km. Its total catchment area is 97.6 million ha (9.71 lakh km^2). It is one among the largest river systems in the world. Its water comprises the icy cold Himalayan streams and the warm, biologically more productive waters of the North Indian plains. This system drains the southern slopes of the central Himalayas and covers the states of Haryana, Uttar pradesh, Bihar, West Bengal and parts of Rajasthan and Madhya pradesh. This system harbours the richest freshwater fish fauna of India, ranging from Mahseers and the torrential fishes of hills to the cultivable Gangetic carps, *Hilsa* and other species.

3.2.2.1 The Ganga

Ganga is the longest river of India. The total length of the Ganga river from its source to its mouth (measured along the Hooughli) is 2525 km of which 1450 km is in the Uttar Pradesh, 445 km in Bihar and 520 km in West Bengal. The remaining 110 km stretch of the Ganga forms the boundary between Uttar Pradesh and Bihar. The Ganga originates as Bhagirathi from the Gangotri glacier in Uttar Kashi District in the Himalayas about 3129 m above m.s.l. It is joined by the Alaknanda at Devaprayag and the combined flow of the Bhagirathi and the Alaknanda is known as Ganga. After traveling 280 km from its source, Ganga enters plains at Haridwar. At Allahabad, about 770 km south-east of Haridwar, Ganga is joined by Yamuna, which is its most important tributary. After Farraka in West Bengal, the river ceases to be known as the Ganga. It bifurcates itself into Bhagirathi-Hooughli in West Bengal and Padma-Meghna in Bangladesh. After traversing 220 km further down in Bangladesh, the Brahmaputra joins it at Goalundo and after meeting Meghna 100 km downstream the Ganga joins the Bay of Bengal. Its principal tributaries from the northern drainage are the rivers Ramganga, Gomti and Tons while those from the southern watershed are Chambal, Betwa and Ken (tributaries of the river Yamuna). In Bihar, it receives the very important tributaries like the Ghagra, Gandak, Burhi, Sone, Bagmati and Koshi.

3.2.2.2 The Yamuna

The Yamuna is the largest tributary river of the Ganges in northern India. Originating from the Yamunotri Glacier in Tehri Garwal (Uttar Pradesh) at a height 6,387 m. above m.s.l in the Himalayas, on the south western slopes of Banderpooch peaks, in the Lower Himalayas, it travels a total length of 1,376 kilometers and has a drainage system of 366,223 km^2. It crosses several states, Uttarakhand, Haryana and Uttar Pradesh, passing by Himachal Pradesh and later Delhi, and meets several of its tributaries on the way, including Tons, its largest and longest tributary, Chambal, which has its own large basin, followed by Sindh, the Betwa, and Ken. It flows through Delhi and joins the Ganga at Allahabad.

3.2.2.3 Fish and Fisheries of the Ganga river system

More than 265 species of fishes have been recorded from this river system. The endangered Ganges River Dolphin (*Platanista gangetica gangetica*) is primarily found in the Ganges and Brahmaputra Rivers and their tributaries in Bangladesh, India and Nepal. The head waters of the Ganga system in the upper reaches of the Himalaya have snow trouts, catfishes, mahseers, lesser barils. Upto an elevation of 1067 m, mahseers, *Tor putitora*, *T. tor* and *Acrosscheilus hexagonolepis*, *Bagarius bagarius* and *Labeo dero* form main food fishes. In the plains, carps, catfishes (*Osteobangrus aor* and *O. seenghala,* collectively called tengra), *Wallago attu* , *Hilsa ilisha*, *Pangasius*, *Notopterus* etc. constitute the fishery. The prawns, *Macrobrachium malcolmsoni* and *Palaemon lamarrei* are also found. The catch statistics over the years indicate some disturbing trends in this riverine fisheries system. The biologically and economically desirable species have started giving way to the low value species, exhibiting an alarming swing in the population structure of the Gangetic carps. A survey indicates that contribution of Indian major carps has declined from 44.5% to 8% during the later half of the 20th century. In addition, there is an increasing domination of lower age groups in the commercial catches. The fishery of anadromous *Hilsa* have declined by 96% upstream of Farakka after construction of the Farakka Barrage in1974 due to obstruction of the migration route of the fish.

3.2.2.4 Fishing gears used

Fishing gears used in the Gangetic system include dip net, cast net, purse net, drag net, drift net, trawl net, bag net, long lines, small trap net etc.,

3.2.3 The Brahmaputra river system

The combined length of the Brahmaputra riverine system is 4,023 km. It originates from a great glacier near Mansarovar Lake. It is slightly longer than the Indus, but most of its course lies outside India. It flows eastward, parallel to the Himalayas. It traverses for its first 1,600 km through Tibet, where it is known as ‘Tsangpo‘. There, it receives less volume of water and has less silt. But in India, it passes through a region of heavy rainfall and as such, the river carries a large amount of rainfall and considerable amount of silt.

Afer flowing through Tibet, it flows through Arunachal Pradesh, Assam and Bangladesh. Then, it joins the Ganga at Golaundo. After confluencing with Ganga, the united rivers flow under the name of Padma reaching the Bay of Bengal through the Great Maghna estuary. It has got a large number of tributaries. The Brahmaputra valley is marked for its abandoned river beds, which are subjected to annual inundations. These areas are called, beels. It drains the northern slopes of the Central and Eastern Himalayas, Assam, Bhutan, Sikkim and parts of Northwest Bengal. The total catchment area of this river in India is 1,87,110 km^2 (51 million ha). It has a rich fish fauna of torrential streams in its upper reaches (low economic value) and its middle and lower reaches have several species of carps, catfishes and air breathing fishes, anadromous *Hilsa* (high economic value).

3.2.3.1 Fish and Fisheries of the Brahmaputra river system

A total of 126 species of fishes belonging to 26 families have been recorded from this system. Of these, 41 species are known to have commercial importance. Catfishes (mainly *Wallago attu*) and major (mainly Rohu) and minor carps dominate the commercial catches of upper, middle and lower stretches, while the commercial catch in lower-middle stretch is primarily composed of catfish and miscellaneous catch. The species found in the Himalayas include *To*r spp, *Glyptothora*x spp, *Balitora* spp, *Noemacheilu*s spp, *Schizothorax* spp, *Lepidocephalichthy*s spp, *Gagata* spp etc. The major fishes present in this system include *Labeo gonius*, *Wallago attu*, *Puntius sarana*, *Notopterus notopeterus*, *N. chitala*, *Mystus seenghala*, *Clupisoma gainia* and *Eutropiichthys vacha*. A survey conducted by CIFRI, Barrackpore indicates that there is significant decline in the fishery in many stretches of the river. Mahseers, once plentiful in the upstream stretches of rivers, are already under the threat of extinction.

3.2.3.2 Fishing gears used

Dip net, cast net, gill net, purse net, drag net, trawl net, bag net, long lines etc., are the fishing gears commonly employed in the Brahmaputra system.

3.2.4 The Indus river system

Though massive as a whole, it has only a small segment left in the present-day India. The rivers of the North West Himalayas are Indus, Jhelum, Chenab, Ravi, the Beas and Sutlej. This system harbours exotic rainbow and brown trouts in their upper reaches and a variety of indigenous carps and catfishes in their lower sections. Trout streams of Kashmir constitute one of the world's richest sport fishing waters attracting tourists from all over the world.

3.2.4.1 River Indus

The Indus originates in the northern slopes of the Kailash range in Tibet. It enters Indian Territory in Jammu and Kashmir. The fish fauna of the upper reaches of Indus rivers has not been fully explored because of its inaccessibility. The major fishes in Indus are *Schizopygopsis stoliczkee, L. gontius, Rita buchanani, Sisor rhabdophorm, Exostoma stolicizkae, Trichogaster* sp and *Nemacheilus* spp.

3.2.4.2 River Jhelum

The Jhelum originates in the south-eastern part of Kashmir, in a spring at Verinag. It flows into the Wular Lake, which lies to the north, and then into Baramula. Only a small part of the river Jhelum flows through Jammu and Kashmir. Its catchment area upto Indo-Pakistan border is 34,775 km^2. The common fishes found in the river Jhelum include *Schizothoraichthys spp,* six species of *Schizothorax*, *Diptynchus maculatus*, *Cyprinus carpio, Labeo dero, Crosscheilus diplochilus, Salmo trutta fario, Glyptosternum reticulatum, Botia birdi* and *Nemacheilus gracilis* and *Nemacheilus kashmirensis*.

3.2.4.3 River Chenab

The Chenab originates from the confluence of two rivers, the Chandra and the Bhaga, which themselves originate from either side of the Bara Lacha Pass in Lahul. It is also known as the Chandrabhaga in Himachal Pradesh. It enters the plains of Punjab near Akhnur and is later joined by the Jhelum. It is further joined by the Ravi and the Sutlej in Pakistan. Its catchment area upto Indo-Pakistan border is 26,155 km^2. The fishes that are common in the river Chenab are *Dipthychus maculates* and *Glyptothorax kashmirensis.*

3.2.4.4 River Ravi

The Ravi originates near the Rohtang Pass in the Kangra Himalayas and follows a north-westerly course. It flows as a part of the Indo-Pakistan border for some distance before entering Pakistan and joining the Chenab river. The total length of the river, Ravi is about 720 km. Its catchment area is 14,442 km^2. The major fishes present in the river are *Amblypharyngodon mola, Barilius bendelisis, Carassius carassius, Catla catla, Cirrhina mrigala, C. reba, Cyprinus carpio, Labeo* spp, *Tor tor, Mastacembelus armatus, Channa* spp., *Trichogaster fasciatus, Clarias batrachus, Heteropneustes fossilis, Mystus spp., Ompok bimaculatus, O. padba, Rita rita* and *Wallago attu*.

3.2.4.5 River Beas

The river, Beas originates in Beas Kund, lying near the Rohtang Pass. It runs past Manali and Kulu, where its beautiful valley is known as the Kulu valley. It joins the Sutlej river near Harika, after being joined by a few tributaries. The total length of the river is 615 km. Its catchment area is 20,303 km^2. The most common fishes are *Xenetodon cansi, Gadusia chapra, Amblypharyngodon mola, Barbus* spp, *Carassius carassius* spp, *Catla catla, Chela* spp, *Cirrhinus mrigala, C. reba, Cyprinus carpio, Labeo* spp, *Danio devario, Tor tor, Nemacheilus botia, Oxygaster gora, Puntius* spp, *Rasbora daniconius, Mastacembelus armatus, Channa* spp., *Trichogaster fasciatus, Clarias batrachus, Heteropneustes fossilis and Notopterus* spp.

3.2.4.6 River Sutlej

The river, Sutlej originates from the Rakas Lake, which is connected to the Manasarovar Lake by a stream, in Tibet. It flows in a north-westerly direction and enters Himachal Pradesh at the Shipki Pass, where it is joined by the Spiti river. It cuts deep gorges in the ranges of the Himalayas, and finally enters the Punjab plain after cutting a gorge in a hill range, the Naina Devi Dhar, where the Bhakra Dam having a large reservoir of water, called the Gobind Sagar, has been constructed. It turns west below Rupar and is later joined by the Beas. It enters Pakistan near Sulemanki, and is later joined by the Chenab. It has a total length of almost 1500 km. A total of 70 species have been recorded from the river Sutlej. The most common among them include *Wallago attu, Clarias batrachus, Heteropneustes fossilis, Mystus* spp, *Rita rita, Eutropiichthys vacha, Notopterus notopeterus, N. chitala, Puntius* spp, *Colisa fasciatus, Esomus danricus* and *Chela laubuca*.

Chapter 3: Fish and fisheries of peninsular riverine systems in India

3.3.1 Introduction

The main peninsular river system includes the rivers like Mahanadi, Godavari, Krishna and Cauveri on the east coast and Narmada and the Tapti on the west coast. The peninsular rivers flow through shallow valleys. A large number of them are seasonal as their flow is dependent on rainfall.

3.3.2 The East coast river system

It is a composite system of rivers, the main constituents of which are the Mahanadi, the Godavari, the Krishna and the Cauvery, having a combined length of about 6,437 km. The total catchment area is 121 million ha. This system drains the entire peninsular India, east of Western Ghats in the west and southern parts of central India including Chotta Nagpur hill ranges. These rivers drain into the Bay of Bengal. Mahanadi has all the Indian Major Carps common with the Ganga system. The other rivers of the East coast system, besides their own indigenous fish fauna of several carp species harbour Gangetic carp, catfishes, murrels and prawns. Tributaries of the Cauvery from the Nilgiris have cold water fish like trout and tench.

3.3.2.1 The river Mahanadi

It is a river of eastern India. The Mahanadi rises in the Satpura Range of central India, and flows east to the Bay of Bengal. The Mahanadi drains most of the state of Chhattisgarh and much of Orissa and also Jharkhand and Maharashtra. It has a length of about 860 km. Near the city of Sambalpur, a large dam, the Hirakud Dam is on the river.

Fish and Fisheries of Mahanadi

The river mainly harbours the hill stream fishes. The most common fishes are *Chela untrahi, Erethistes conta* and *Arius gagora.*

3.3.2.2 The river Godavari

The river with second longest course within India, Godavari is often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. It is about 1440 km long. It originates from Deolali hills near Nasik and Mumbai in Maharashtra around 380 km distance from the Arabian Sea, but flows southeast across south-central India through the states of Chhattisgarh, Karnataka, Orissa and Andhra Pradesh, and empties into the Bay of Bengal in the Northern Western Ghats. Its catchment area is 315,980 km^2. It is a seasonal river, widened during the monsoons and dried during the summers. Its main tributaries are Manjira, Wainganga (secondary tributaries – Penuganga and Wardha) and Indravati. Its minor tributaries are Purna, Maner, Sabari etc. There is no major dam. However, several small dams have been built across the tributaries of Godavari and long irrigation canals form a network of water bodies.

Fish and Fisheries of Godavari

The most common fishes in this river include fishes such as carps (*Labeo fimbriatus, Cirrhinus mrigala, Labeo calbasu, Catla catla*), catfishes (*Mystus seenghala, Mystus aor, Silonia childreni, Wallago attu, Pangasius pangasius, Bagarius bagarius)* and *Hilsa ilisha.* Of the several carp species, *L. fimbriatus* is found to dominate and this is followed by *C. mrigala*. *Macrobrachium malcolmsonii* (Godavari prawn) is the prawn common in this river. Fishing gears that are commonly employed are gillnets (set gillnet, drift gillnet, drag gillnet, barrier gillnet), seines (shore seine, large seine and drag net) and cast net.

3.3.2.3 The river Krishna

The Krishna is one of the longest rivers of India (1120 km in length). Its c atchment area is 233,229 km^2. It originates at Mahabaleswar in Maharashtra, passes through Sangli and meets the sea in the Bay of Bengal at Hamasaladeevi in Andhra Pradesh. The Krishna river flows through the states of Maharashtra, Karnataka and Andhra Pradesh. Its most important tributary is the Tungabhadra River, which itself is formed by the Tunga and Bhadra rivers that originate in the Western Ghats. Other tributaries include the Koyna, Bhima, Mallaprabha, Ghataprabha, Yerla, Warna, Dindi, Musi and Dudhganga rivers. There are dams (anaicuts) or weirs and barrages. Several reservoirs have been built on the rivulets, and some major dams as the Lakkavali, Tungabhadra, Koina and Vanivilas Sagar have been constructed. The conditions of flow, nature of river bed and other features of the Krishna river system are quite similar to Godavari system.

Fish and Fisheries of Krishna

The fish species composition is similar to the Godavrai system. The major fishes of the river include carps (*Labeo fimbriatus*, *Cirrhinus mrigala*, *Labeo calbasu*, *Catla catla*), c atfishes (*Mystus seenghala, Mystus aor, Silonia childreni, Wallago attu, Pangasius pangasius, Bagarius bagarius)* and *Hilsa ilisha.* Fishing gears employed are similar to the Godavrai system.

3.3.2.4 The river Cauvery

It is one of the great rivers of India. This river is also called Dakshin Ganga. It originates in the Brahamagiri hills in the Western Ghats range of Karnataka state, and from Karnataka through Tamil Nadu, it empties into the Bay of Bengal. The source of the river is Talakaveri located in the Western Ghats about 5,000 feet (1,500 m) above sea level. It flows generally south and east for around 765 km, emptying into the Bay of Bengal through two principal mouths. Its basin is estimated to be 27,700 square miles (71,700 km^2), and it has many tributaries including Shimsha, Hemavati, Arkavathy, Kapila, Honnuhole, Lakshmana Tirtha, Kabini, Lokapavani, Bhavani, Noyyal and Amaravati. The large Mettur dam has been constructed across Cauvery in Tamilnadu. In Tamilnadu, in the Thanjavur delta, the river divides into a northern branch, the Coleroon and a southern branch, the Cauvery proper. The Lower anaicut is across the river, Coleroon and the Upper anaicut and Grand anaicut are across Cauvery proper.

Fish and Fisheries of Cauvery

Eighty three species of fishes belonging to 23 families have been reported from the Cauvery river. The most common fish species are as below:

Carps: *Catla catla*, *Labeo rohit*a, *Cirrhinus mrigala*, *Cyprinus carpio*, *Tor putit*ora, *Barbus carnaticus* , *B. dubius*, *Labeo kontius*, *Cirrhinus cirrhosa*, *Acrossocheilus hexagonolepis*, *Osteochilus hexagonolepis, Osteochilus brevidorsalis etc*

Catfishes: *Mystus seengala*, *M. aor*, *Wallago attu*, *Pangasius pangasius*, *Silonia silondia*, *Glyptothorax madraspatanum* etc.

Miscellaneous : *Notopterus notopterus, Channa marulius, Osphronemus goramy etc*

Fishing gears employed

They are similar to the Godavrai system. They include gillnets (set gillnet, drift gillnet, drag gillnet, barrier gillnet), seines (shore seine, large seine and drag net) and cast net.

3.3.3 The West coast river system

The combined length of this system is 3,380 km. Its total catchment area is 69.6 million ha. It drains the west of Western Ghats. It includes the basins of the Narmada, Tapti and the drainage of Gujarat. The Narmada and the Tapti are the longest rivers of this system and have rich fish fauna. The fish fauna of this system mainly consists of carps, catfishes, mahseers, murrels, perches, prawns etc.

3.3.3.1 The river Narmada

The Narmada is a river in central India. It forms the traditional boundary between North India and South India, and is a total of 1,289 km (801 mi) long. Of the major rivers of peninsular India, only the Narmada, the Tapti and the Mahi run from east to west. It rises on the summit of Amarkantak Hill in Bilaspur district of Madhya Pradesh state, and for the first 320 km (200 miles) of its course winds among the Mandla Hills, which form the head of the Satpura Range; then at Jabalpur, passing through the 'Marble Rocks', it enters the Narmada Valley between the Vindhya and Satpura ranges, and pursues a direct westerly course to the Gulf of Cambay. Its total length through the states of Madhya Pradesh, Maharashtra, and Gujarat amounts to 1312 km (815 miles), and it empties into the Arabian Sea in the Bharuch district of Gujarat. Its total catchment area is 94,235 km^2 lying in Madhya Pradesh and Gujarat with 18 tributaries with catchment area ranging from 1,350 to 6,330 km^2. Of these, 16 are in Madhya pradesh and two are in Gujarat.

Fish and Fisheries of Narmada

The fisheries of the river Narmada consists of the following species.

Carps: *Tor tor*, *Labeo fimbriatus*, *L. calbasu*, *L. bata*, *Labeo kontius*, *Cirrhinus mrigala*, *C. reba*, *Catla catla*, *Puntius sarana* etc.

Catfishes: *Mystus se*en*gala*, *M. aor*, *M. cavasius*, *Wallago attu*, *Rita pavimentata*, *Ompok bimaculatus* etc

Miscellaneous : *Notopterus notopterus*, *Channa* spp., *Mastacembelus* spp, minnows *etc*

Fishing gears employed

They include cast net, gill net, long lines etc.

3.3.3.2 The river Tapti

The Tapti is a river of central India. It is one of the major rivers of peninsular India with the length of 724 km. It rises in the eastern Satpura Range of southern Madhya Pradesh state and flows westward, draining Madhya Pradesh, Maharashtra and South Gujarat before emptying into the Gulf of Cambay of the Arabian Sea, in the State of Gujarat. The Western Ghats or Sahyadri range starts south of the Tapti River near the border of Gujarat and Maharashtra. The Tapti River basin lies mostly in northern and eastern districts of Maharashtra but also covers Betul, Burhanpur districts of Madhya Pradesh and Surat district in Gujarat as well. The principal tributaries of Tapti River are Purna River, Girna River, Panzara River, Waghur River, Bori River and Aner River.

Fish and Fisheries of Tapti

Fishing season commences from September to October and continues till the onset of monsoon. Fishing operations are extensive after Jan - Feb. Cheer fishing also takes place during Nov – Jan with scare line and a composite net made by towing two cast nets. Fishing gears employed are similar to the Narmada rivers sytem.

The fisheries of the river Narmada consists of the following species.

Carps: *Tor tor*, *Labeo fimbriatus*, *L. calbasu*, *L. bata*, *L. kontius*, *L. boggut*, *Cirrhinus mrigala*, *Puntius sarana.*

Catfishes: *Mystus se*eng*ala*, *M. aor*

Miscellaneous : *Channa* spp., *Mastacembelus armatus, Clupisoma garua*

Chapter 4: Impacts of dams on riverine fisheries

3.4.1 Introduction

Dams interrupt stream flow, and generate hydrological changes along the integrated continuum of river ecosystems that ultimately can be reflected in their associated fisheries. The extent to which fisheries can be developed, sustained or protected along these modified riverine ecosystems reflects basin topography, geological features, watershed hydrology, and climate, as well as engineering features of the dam itself, and operational programmes for retention and release of water from the reservoir, through the dam and into the tail waters. Fundamental considerations must include establishment and maintenance of habitat for spawning, recruitment and maturation of the fish stocks, and provisions for passage by fishes that during certain phases of their life cycles, depend on longitudinal movements along the stream continuum.

Compensation for loss in yield from river fisheries can be difficult to achieve through development of reservoir fisheries. The larger the river, and the more downstream the location of the dam, the less the potential there is for a reservoir fishery to compensate in terms of yield for losses sustained by the river fishery. Compensation potentials apparently are higher in shallower reservoirs in tropical regions than they are in deeper reservoirs and in more northern latitudes. Even if compensation is achieved from a fishery perspective, specific needs of fish species not included in the fishery, and/or that may be threatened or endangered, must be considered to avoid negative impacts to these fishes.

River fishery production is dependent on length of river, catchment area and, for specific sections of rivers, the position of the segment along the river continuum. If altered hydrology resulting from dams curtails or eliminates normal, historical downstream flooding, overall fisheries production throughout the system can be negatively impacted. The effects of the interference may be variously harmful, beneficial or indifferent depending on the particular situation and fish fauna inhabiting the rivers concerned.

3.4.2 Harmful effects

Harmful effects of dams and other structures on the fish populations can be categorized into (1) Obstructional (2) Ecological

3.4.2.1 Obstructional effects of dams on fisheries

If the riverine fishery is sustained by stocks of migrating fishes that become blocked by a dam, the riverine fishery can be severely impacted. If the migrating fishes are anadromous or catadromous species, linked to ocean fisheries, or those of inland seas or large lakes, the negative impacts to these stocks and their associated fisheries can be catastrophic. Major concern throughout Asia is that movements of migratory fishes along river courses will be blocked by dams. Additionally, dewatering of stream channels immediately downstream from dams can be a serious problem. Dams also can block the flow of nutrients from ocean environments upstream into riverine environments by preventing anadromous fishes that die after spawning (eg, Pacific Salmon) from depositing these nutrients via carcass decay in upstream reaches.

3.4.2.2 Ecological effects of dams on fisheries

- Ecological changes affect both migratory and non-migratory species of fishes
- The most obvious effects from placing dams on rivers result from formation of new lentic or semi-lentic environments upstream from the dam, and tailwater environments downstream from the dam. Both environments can be conducive to the establishment and maintenance of fish stocks appropriate for exploitation by fisheries.
- Cumulative effects of dams in catchment basins and tributary streams can significantly block nutrient flow throughout the ecosystem, affecting fisheries production in downstream reservoirs, river channels and estuary and marine environments.
- Development of reservoir plankton reflects nutrients captured by the reservoir. This plankton generally relates directly to fisheries production of the respective reservoir. However, when several dams are constructed on upstream tributaries of a river ecosystem, the cumulative effects of these dams can be that of blocking the flow of nutrients originating from the catchment basin from the lower reaches of the ecosystem,

thereby negatively affecting fisheries production in downstream portions of the ecosystem (including estuary and marine environments).

- Some species shift to new spawning and migration range
- Anadromous fishes tend to settle down
- Local stocks of fish form
- Intra-specific biological differentiation of fish occurs
- Egg-laying substrata change
- Spawning grounds inundate
- Water levels fluctuate
- Physico-chemical conditions of spawning areas in the upper reaches, marshlands, constituting the spawning and feeding grounds of some important food fishes may disappear.
- Turbidity and silting pattern change. It may result in the failure of spawning or ineffective spawning of many important fishes
- Considerable reduction of water flows in the residual rivers result in the formation of shallow areas, which impede or obstruct fish movements.
- When dams, weirs etc., are constructed in estuaries due to reduction in discharge of water, changes occur in temperature and salinity regimes of brackishwaters and of current velocities and directions at the mouth of rivers. This may affect the migration of fishes particularly the anadromous varieties resulting in successful migration or total failure of runs.

3.4.3 Beneficial effects of dams on fisheries

- Beneficial reservoir fisheries also exist in drier regions where dams are constructed for agricultural irrigation, and fisheries are secondary considerations. Benefits seem more pronounced for smaller, shallower reservoirs that have reasonably high concentrations of dissolved solids and that are located in the upper reaches of their respective river ecosystem. Stocking of exotic species (both in reservoirs and in tailwaters) can enhance yields, as long as the exotic fishes are environmentally sound and culturally acceptable to the surrounding human population. In this regard, caution is warranted in cultures where fishing and fish consumption are non-traditional activities. Building reservoirs in the context of such cultures may not achieve projected fishery benefits even though exploitable fish stocks may exist. Dams also can enhance some riverine fisheries, and particularly with respect to tail water fisheries immediately below dams. Fishes can become concentrated below dams as a result of the attractive foraging opportunities there as well as from seasonal congregations of migratory fishes. On a per unit area basis, tailwater fisheries can be better than those of the reservoirs themselves.

3.4.4 Impacts of dams on fisheries in India

- Dams have had negative impact on river fisheries in various systems throughout the region. Sharp declines in catches of *Hilsa ilisha* were noticed as a result of dams, barrages, weirs and anaicuts on the Hooghly, Godavari, Krishna and Cauvery rivers, and that mahseer *Tor putitora* and *T. tor* no longer are found above Nangal and Talwara dams. Fish ways constructed in conjunction with dams are used as fish traps by local fishers.

- In addition to impacts on hilsa and mahseer stocks and their associated fisheries, formation of reservoirs in India has had negative impact on snow trout (*Schizothorax*), and rohu (*Labeo)* in Himalayan streams, and catadromous eels and freshwater prawns in all major river systems. One of the earliest known impacts to river fisheries in India occurred as a result of construction of Mettur Dam (1935) on the Cauvery River, which formed Stanley Reservoir and completely stopped runs of the Indian shad *Tenualosa ilisha*. Within the reservoir itself, water level changes, recruitment failures and predation resulted in reduced stocks of Indian major carps.
- Reservoirs in Punjab region have resulted in good fisheries, with more than 1,800 t/year landed annually at Bhakra Dam and Pong Dam, collectively. In the reservoirs formed by these dams high yield fisheries have evolved, primarily through development of stocks of exotic fishes (eg, the fishery for the exotic silver carp, *Hypophthalmichthys molitrix* contributes more than 30% to the catch from Gobindsagar Lake).
- However, river fisheries have been negatively impacted, particularly with regard to migratory fishes. Construction of barrages at Ropar, Harike and Ferozepur has restricted migration of Indian major carps, in spite of fishways. During most of the year, little water is released into the river below the dams from the reservoirs, and fish are concentrated in pools where they are more easily captured by fishers. Fishways designed to promote fish passage past dams are used by fishers to capture fish. Dams in India's Punjab region have reduced flooding, but in so doing they have also negatively impacted production of Indian major carps, resulting in reduced total fish production for the region.
- Persons linked to river fisheries through culture, tradition and economics incorporate these fisheries as dominant components of their human identities. Reorientation of their values and activities after impacts to or loss of the foundation for their identities can generate considerable socio-economic stress to these people, their communities and their cultures.

3.4.5 Measures to overcome the negative impacts of dams

- Bernacsek (1984) provided an excellent summery of design and operational features for dams to address fisheries concerns. He suggested:
- (i) maximum possible crest elevation
- (ii) discharge structure intakes positioned at highest possible elevation
- (iii) discharge water into tail waters be sufficiently oxygenated to support aquatic fauna
- (iv) annual water level fluctuation in the reservoir to be within the range of 2.5-4.0 m
- (v) drawdown rate not to exceed 0.6 m/month
- (vi) downstream discharge to include an annual artificial flood event. Along the stream continuum, dams and their associated upstream reservoirs have downstream effects on riverine environments and, subsequently, diverse influences on downstream fisheries, even beyond the lotic ecosystem. Further, to facilitate the migration of fish during breeding period, fish passes or fish ways are found necessary and successful.

3.4.6 Fish passes / Fish ways

- A fish pass is an inbuilt arrangement in a headwork or barrage or a dam facilitating the upstream migration of fishes to reach their spawning grounds. Normally there is a provision of more than one pass in a structure. The barrages or head works constructed after 1950's a provision of 'fish passes' or 'fish ladders' has been made. A fish pass must be attractive, accessible and must afford an easy passage for the fish. In a typical fish pass the water flow is usually fast, invariably shallow and turbulent and the fish find sanctuary behind the projections, ultimately move their head out and will come out the move upstream.

3.4.6.1 Types of Fish passes / Fish ways

- The following types of fish passes have been used for the migration of fishes in freshwaters in foreign countries.
- **1) Natural:** In this type of fish passes the approach routes of fish may be strengthened with concrete to the natural rock with the natural rock with the object of concentrating flows previously diffuse, reducing turbulence and deepening pools.
- **2) The Pool design (Fish ladder)** : It consists of a series of pools arranged in a ladder-like manner from downstream to upstream. The flow of water from pool to pool may be over solid obstacles or through passages between obstacles or a combination of two types. Each pool is designed in such a way that it provides adequate resting grounds for the ascending fishes.
- **3) Deep baffled channel:** This is a modified Deniel type of fish way designed for low gradient and is suitable for extreme variations in inflow and water level. Actually, it is a single slot vertical baffle fish way.
- **4) Simple sluice or inclined chute:** The chute is an inclined channel or a sort of waterfall with deep descent. The effective width of the channel is actually much less than the width of sluice and many sharp turns cause cross currents that are very difficult to be counteracted by large fishes.
- **5) The Deniel design:** It is a narrow channel with closely spaced baffles set at an angle with the axis of the channel. In this kind of fish way, the force of fast flowing water is minimized and fishes can negotiate them easily.
- **6) The Fish lock:** It is an arrangement for the regulation of flow of water with the help of mechanical gates. The inflow and outflow can be regulated thus providing fishes with the passage to move either way.
- **7)** Other types include fish lifts, dished channel, submerged orifice and roughened channel

3.4.7 Conclusion

- Because dams tend to be constructed to enhance socio-economic development activities, they tend to attract people and industry. Subsequently, river ecosystems containing dams must contend with secondary environmental pressures such as increases in pollution as well as increased exploitation and extraction of their resources (primarily water, fish, and substrates), that are independent from and in addition to the direct influences of dams and reservoirs on the physical and biological dimensions of the system. Determining the impact of dams on river ecosystems and their associated fisheries depends on spatial and temporal scales of interest. If spatial scales are sufficiently large (planetary, continental, perhaps regional and biome), and temporal scales are sufficiently long (decades, centuries, millennia), placing a dam on a river does little more than increase atmospheric water vapour (through evaporation from the reservoir), reduce long term stream flows downstream, desiccate terrestrial environments, salinate surrounding areas, and shift bio-energetic processes (some of which can lead to floral and faunal extinction at various scales of resolution). We cannot assign the terms “good” or “bad” to any of these phenomena. They simply reflect anthropogenic activity on this planet. However, if we look at smaller spatial and shorter temporal scales, (which we obviously cannot neglect since we have to make decisions that have bearings on the present and future human generations and also on present and future living aquatic resources) we have to keep in mind that dams and their reservoirs (which can under certain circumstances help to better nourish people and make their livelihoods more sustainable) can - if wrongly placed - also lead to significant declines of fisheries and to extinction of aquatic species.

- Given sufficient time, geophysical and climatic forces will override and erode the physical influences of dams, and evolutionary forces will alter how life forms interact with the resulting environments. Caution is warranted to avert potential negative impacts from dams with respect to fisheries and associated human interactions with these and other river resources. Such caution underscores the reality that people are depending on us, the scientists, the resource managers, the decision makers, to be right.

Chapter 5: Impact of inter-river basin linkages on fisheries

3.5.1 Introduction

In the 19th century, Sir Arthur Cotton had thought of a plan to link rivers in southern India for inland navigation. Though partially implemented, the idea was later abandoned because inland navigation lost ground to the railways. In more recent times, the 'Ganga - Cauvery Link' proposal mooted by former Irrigation Minister , Dr. K.L. Rao was examined and found impracticable because of the very large financial and energy costs involved, and the 'Garland Canal' idea put forward by airline pilot Captain D. Dastur, was termed as technically unsound .

The recent revival of the idea of interlinking of 'surplus' basins with 'deficit' basins has been the result of work done by the National Water Development Agency (NWDA) and bears a conceptual continuity with Dr. Rao's proposal.

3.5.2 Components of river – linking project

The Himalayan rivers component and the peninsular rivers component constitute the two parts of the river - linking project.

3.5.2.1 Himalayan component

The Himalayan segment envisages 14 links, viz. , Manas-Sankosh-Tista-Ganga, Kosi-Ghagra, Gandak-Ganga, Ghagra- Yamuna, Sarda-Yamuna, Yamuna-Rajasthan, Rajasthan-Sabarmati, Chunar-Sone Barrage, Sone Dam-Southern tributaries of Ganga, Ganga-Damodar-Subernarekha, Subernarekha-Mahanadi, Kosi-Mechi, Farakka-Sunderbans and Jogi-Gopa-Tista-Farakka. The general idea is to transfer waters from 'surplus' eastern rivers to 'deficit' central, western and southern regions.

3.5.3 International Scenario

International experience in linking of rivers has shown both beneficial and harmful aspects. Diversion of water in upper reaches in the case of the Aral Sea in Central Asia (in former USSR) resulted in loss of over 60 per cent of its surface area and two-thirds of volume. The cause is attributed to a vast expansion of irrigation in the Central Asian Republics beginning in the 1950s, which greatly reduced inflows to the Sea. China has officially launched the world's largest water diversion project, which will divert water from the Yangtze River in the south to the country's dry north, including Beijing. The project, valued at US $ 59 billion, may cost twice as much as the ongoing Three Gorges Hydroelectric Project. The project will be the biggest of its kind in the world and the largest engineering programme in China. It consists of three canals running about 1,300 km through the country's eastern, middle and western parts.

The Spanish National Hydrological Plan (SNHP) has proposed a massive transfer of water from the Erbo river in the north of the country to the Valencia and Murcia rivers in the south, which suffers severe water shortage difficulties due to such things as intensive agriculture and tourism. There, however, have been reactions regarding the loss of Europe's most ecologically important wetlands and the proposal is being reviewed.

3.5.4 Impact on fisheries

3.5.4.1 Positive impacts

Canals and reservoirs: The proposed interlinking of rivers would comprise more than 36 major dams and 30 canal links. In addition, there will be many more irrigation canals and barrages. These major reservoirs, canals and other water harvesting structures will add to the potential fishery resources of the country.

Rejuvenation of lakes and rivers: The rivers and lakes in the water recipient zone will bring benefit with increased water perennially, congenial habitat and consequently, higher fish production.

3.5.4.2 Negative impacts

Loss of habitat: River interlinking might affect fish feeding and breeding habitats in the rivers and lakes in the water donor zones due to lowering of water volume and enhanced siltation load. The flood plains and wetlands connected with donor rivers would also be affected. River run-offs provide energy for a number of vital processes in downstream estuaries, delta and coastal areas. Reduced river discharge could result in loss of coastal habitats such as mangroves, coral reefs, sea grasses, estuarine and delta regions.

Water quality changes: Significant changes in water quality of rivers, lakes, estuaries and coastal waters could occur due to changes in sediment load, nutrients and contaminant levels. The levels of toxicants and contaminants in donor rivers may go up owing to reduction in self-purifying functions subject to changes in flow regimes.

Loss of biodiversity: Each river system has distinct groups of biota different from other water bodies. When environment is altered, they are affected, with particular threat to endangered and endemic species. The linkage of rivers could also lead to loss and homogenisation of genetic diversity of fishes.

Changes in land-ocean interactions: River is a critical component of the deltaestuary-coastal sea ecosystem. Un-impounded rivers provide energy for a number of vital processes in downstream estuaries, delta and coastal areas, upon which healthy fisheries are dependent. The linkage of rivers could alter the timing and quantity of river discharge into the sea, which may alter the river-mediated landocean interactions and coastal fisheries. A recent study conducted by Central Marine Fisheries Research Institute, Kochi, on 'Impact of Dams on River into Sea and Changes in the Coastal Waters' has shown that reduction in river discharge into the sea will adversely affect the water chemistry and productivity profile of coastal waters and the estuarine fisheries.

3.5.5 Strategies to be followed before taking up river linkage project

The following strategies are the recommendations emerged from the deliberations took place in the National Academy of Agricultural Sciences organized Round Table of “Impact of interlinking of river basins” held during 21-22, May 2004.

Data mining: Large volume of raw data on water quality, productivity, aquatic ecology and fish biodiversity are available for river systems from various parts of the country. Most of these data are not properly analysed and interpreted. Hence, there is an urgent need for data mining and analysis to gather base line information on water quality, aquatic ecology, productivity and fish biodiversity for various river systems.

Modelling studies and scenario analysis: Software-aided modelling studies are required to assess the impact of changes in river runoff on water chemistry, productivity, aquatic ecology, biodiversity and fish production. The impact of interlinking of river basins on fisheries will vary from one river system to another and from region to region. Hence, detailed scenario analysis and simulation studies have to be carried out for each of the river systems to assess the impact under varying flow conditions.

Scaled-down approach: Before initiating large-scale river basin linking at national, level, it will be appropriate to conduct studies on linking adjacent river systems with 10 similar ecosystems. Such scaled-down approach will be very useful to assess and understand the environmental impacts of river linking on aquatic ecosystem.

Environmental flow: Environmental flows may be broadly defined as the 'provision of water for freshwater-dependent ecosystems to maintain their integrity, productivity, services and benefits in cases when such ecosystems are subject to flow regulation and competition from multiple water users. There is an urgent need to assess the minimum environmental flow in donor rivers. It is anticipated that the knowledge base created through this process will strengthen the level of understanding of methodologies available for use, their relative strengths and deficiencies, and their potential for application under various circumstances.

Loss-gain statement: There is an urgent need to work out a loss gain statement on the possible impact of interlinking of river basins on fisheries, using the available data.

River ranching: River ranching of fishes is being carried out in various parts of the country by different agencies. It is necessary to evaluate the usefulness of river ranching for enhancing the fish production in our river systems. River ranching with fish seed in altered scenario needs to be addressed in a proper perspective.

River siltation and dredging: The siltation pattern in donor and receipt rivers could change due to interlinking. Heavy siltation of rivers, canals and lakes is already an acute problem in the Himalayan region. There is urgent need to assess the usefulness of river bed dredging for improving the river ecology and fish production.

Impact on estuarine and coastal waters: River run-offs provide energy for a number of vital processes in downstream estuaries, delta and coastal areas. These processes include transport of nutrients, organic matter and nutrient-rich silt, oxygen enrichment, entrainment of nutrients in bottom sediments, dilution and flushing of pollutants, etc. The most widely discussed and well-documented impacts of large scale hydrological alterations (river damming and river diversion, for example) on marine systems are reductions in water and sediment discharge. Immediate attention should be given to study the impact of altered river flow due to river interlinking on biodiversity pattern of estuarine and coastal fauna.

Biodiversity studies: **It** is necessary to study and identify the endangered species which could become extinct due to interlinking. Based on existing biodiversity lists of exotic and native species, it is necessary to identify the prevalent differences between the rivers likely to be linked and project the post-linking scenario.

Taxonomic studies: Taxonomists and taxonomy related studies are required to assess and document the aquatic biodiversity patterns. Hence, there is an urgent need to give stress to taxonomic studies and developing human resources in the field of taxonomy.

Unit 4: Reservoir fisheries in India

Chapter 1: Ecology, classification and fish production potential of reservoirs in India

4.1.1 Introduction

A reservoir is a large expanse of impounded water artificially created by putting across a stream an earthern, stone masonry or concrete bundh or dam. Reservoirs are formed mainly for irrigation, flood control, recreation, fishery development, etc. The ecology of the reservoir differs from that of a river or lake, and the reservoirs form an important source of fisheries, but this potential has not been fully exploited in India. The reservoirs have to play major role in order to make significant improvement in inland fish production of the country. The reservoirs constitute the single largest inland fisheries resource in terms of resource size and production potential. Reservoirs are located in hilly regions as well as in plains.

4.1.2 Ecology of reservoirs of India

The reservoirs are man-made ecosystems. Besides adding substantially to fish production, they offer employment opportunities. While aquaculture in small water bodies such as ponds is capital intensive, development of fisheries in reservoirs a culture based capture activity is labour intensive. In other words, the reservoir is an ecosystem where fluviatile and lentic conditions co-exist. In reservoirs, the quality of impounded water varies from watershed to watershed and even with the same watershed depending on the soil climate and human activities. It also varies with shape of the reservoir basin, photoperiod, wind action and quality of water change. Owing to these variables evaluation of water quality and productivity of the reservoir have to be made separately for different sets of ecological families of reservoirs sharing similar eco-climate.

India has 19,370 small reservoirs with a total water surface area of 14,85,557 ha. At least 100 of them have been subjected to scientific studies. Habitat variables responsible for a reservoir's productivity can be summed up into climatic, morphometric and hydro-edaphic factors. The peninsular reservoirs are characterized by a narrow range of fluctuations in water and air temperature across seasons, a phenomenon which prevents the formation of thermal stratification. Many reservoirs in the Upper Peninsula show thermal stratification during summer. Wind-induced turbulence facilitates the return of nutrients to the trophogenic zone. Most reservoirs on the mountain slopes of Western Ghats, Himalayas and the other highlands are deeper, with steeper basin walls, compared to irrigation impoundments. Mean depth does not show any direct correlation with productivity, either at primary or fish level. A high shoreline development index gives a better indication of productivity. Plankton, benthos and periphyton pulses of Indian reservoirs coincide with the months of least level fluctuations. Oligotrophic tendencies shown by some reservoirs are mainly due to poor nutrient status and other chemical deficiencies. In most cases, poor water quality is accountable to poor catchment soil. Low levels of phosphate and nitrate are not indicative of low productivity due to quick recycling of these nutrients. Specific conductivity reflects the production propensities of reservoirs satisfactorily. Almost all productive reservoirs have a clinograde oxygen curve and a vertical stratification of chemical variables such as pH, carbon dioxide, total alkalinity and specific conductivity. High seasonal rainfall and discharge of water during monsoon result in high flushing rates, which do not favour colonization by macrophytic communities. Similarly, inadequate availability of suitable substrata retards the growth of periphyton. Plankton constitutes the major link in the trophic structure. A rich plankton community with well-marked succession is the hallmark of Indian reservoirs with blue-green algae as the major component. The main factors that retard the growth of benthos are a rocky bottom, frequent water level fluctuation and rapid deposition of silt and other suspended particles. Large reservoirs, on average, harbour 60 species of fishes, of which at least 40 contribute to the commercial fisheries. Fast-growing Indian major carps are the prominent commercial fishes. Dam construction has adversely affected populations of many other species such as *Tenualosa ilisha*, *Tor* spp. and *Cirrhinus* spp. While culture-based fisheries have been successfully practiced in many small reservoirs, the management norm followed in medium and large reservoirs is primarily on capture fishery. In large and medium reservoirs, stocking was successful only when stocked fishes bred. Two exotic fishes viz., *Oreochromis mossambicus* and *Cyprinus carpio* have been introduced into Indian reservoir with discouraging results.

4.1.3 Reservoirs of India

Sl. No.	State	Major Reservoir	River on which
1	Tamilnadu	Stanley (Mettur)	Cauvery
		Bhavani Sagar	Bhavani
		Amaravathy	Amaravathy (tributary of Cauvery)
		Sathanur	ponniar
		Aliyar	Aliyar
		Poondi	
2	Kerala	Idukki	Periyar
		Parappar	Kallada
		Neyyar	Neyyar
		Kuttiadi	Kuttiadi
		Periyar barrage	Periyar
3	Karnataka	Tungabhadra	Tungabhadra
		Markonahalli	Shimsha
		Hemavathi	Hemavathi
		Vanivilas Sagar	Vedavathi
		Supa	Kalinadi
		Kabini	Kabini (major tributary of cauvery)
		Krishnaraja Sagar	Cauvery
4	Andhra Pradesh	Nagarjuna Sagar	Krishana
		Hussain Sagar	
		Yerrakalava	
		Osmansagar	Musi
		Himayatsagar	Issi
		Nizamsagar	Mowgina
5	Maharashtra	Dhom	Krishna

		Bhatghar	Yelwandi
6	Madhya Pradesh	Gandhisagar	Chambal (Largest tributary of Yamuna)
		Ravishankarasagar	Mahanadi
		Govindgarh	Bichia (tributary of Ganga)
		Mansarovar	
		Kulgarhi	Durga nalla (stream of Ganga)
7	Orissa	Hirakud	Mahanadi
		Rangoli	Brahmani
8	Gujarat	Ukai (Vallabhsagar)	Tapti
		Sayajisarovar	
9	Rajasthan	Ramgarh	Banganga (tributary of Yamuna)
		Chhaparwara	Mavshi
		Jaisamand	
		Ranaprathapsagar	
		Bajajsagar	
10	Himachal Pradesh	Gobindsagar	Sutlej
		Pong	Beas
		Pandoh	Beas
11	Uttar Pradesh	Rihand (Gobind Ballah Pant Sagar)	Rihand (a tributary of Sone river)
		Gulariya	Gulariya
		Baigul	Baigul (Sukhi) (tributary of Ganga)
		Baghla	Barica
		Keetham	
12	Jharkhand	Getalsud	Subarnarekha
		Konar	Konar
		Tilaiya	Barakar
		Maithon	Barakar
		Panchet	Damodar
	Bihar	Nalkari	Nalkari (tributary of Damodar)
		Badua	

4.1.4 Classification of reservoirs

The Ministry of Agriculture, Government of India classified reservoirs as small (<1000 ha), medium (1000 to 5000 ha) and large (>500 ha) for the purpose of fishery management. There are 19,134 small reservoirs in India with a total water surface area of 14,85,557 ha, 180 medium reservoirs with 5,27,541 ha, and 56 large reservoirs with 11,40,268 ha.

4.1.5 Fish production from reservoirs

The number and total area of small reservoirs is very large as compared to large reservoirs. Based on estimated annual average fish yields from Indian reservoirs as 50 kg/ha for small, 12 kg/ha for medium and 11 kg/ha for large ones as at present and applying the national fish production rate (20.0 kg/ha) of reservoirs to 1.49 million ha of small, 0.52 million ha of medium and 1.14 million ha of large ones, the current production can be estimated at 74.129 t for small, 6.488 t for medium and 13.033 t for large reservoirs. On an average with stocking of large size fingerling and providing formulated feed, India can achieve an average production of 500 kg per ha. Thus 3.15 million ha of Indian reservoirs can produce 1.5 million t of fish and generate an income of Rs.600 crores. It has also been observed that the overall fish productivity of India reservoirs is more or less stagnant during the past few years. This is because of a series of management problems of water bodies located in different eco climatic conditions and hence behaving variably because of hazards. As the stored water is mainly used for power generation, irrigation and other purpose, its level in the reservoir is subject to great fluctuations, season to season and year to year, influencing the fish fauna.

4.1.6 Fish production potential of reservoirs

Assuming an increased yield of 100, 75 and 50 kg/ha for small, medium and large reservoirs respectively, the annual production can be expected to be 148,556 t for small, 39,565 t for medium and 57,013 t for large reservoirs. On this basis, the present production of all reservoirs can go up from the present 0.93 lakh t to 2.45 lakh t. per annum. This modest prediction indicates that reservoirs should receive adequate attention in future plans with necessary infrastructure and conducive socio-economic environment.

Present and potential production from reservoirs of India

Category	Total Number	Area (ha)	Yield (kg/ha)	Present production (tonnes)	Potential production (tonnes)
(1) Small	19134	1485557	49.90	74129	148556
(2) Medium	180	527541	12.30	6488	39565
(3) Large	56	1140268	11.43	13033	57013
Total	19370	3153366		93650	245134

(Source: Sugunan, V.V., 1995)

4.1.7 Ichthyofauna

The ichthyofauna of a reservoir basically represents the faunal diversity of the parent river system. Large reservoirs on an average harbour 60 species of fishes, of which at least 40 contribute to the commercial fisheries. The fast growing Indo- Gangetic carps, popularly known as Indian Major Carps, occupy a prominent place among the commercially important fishes. More recently, a number of exotic species have contributed substantially to commercial fisheries.

Broad catagorisation of the species is as follows:

The Indian major carps: *Labeo rohita, L. calbasu, L. fimbriatus, Cirrhinus mrigala, Catla catla*

The mahseers: *Tor tor, T. putitora, T.khudree, Acrossocheilus hexagonolepis*

The minor carps including snowtrout and peninsular carps: *Cirrhinus cirrhosa, C. reba, Labeo kontius, L. bata, Puntius sarana, P. dubius, P. carnaticus, P. kolus, P. dobsoni, P. chagunio, Schizothorax plagiostomus, Thynnichthyes sandkhol, Osteobrama vigorsii*

Large catfishes: *Mystus aor, M. seenghala, Wallago attu, Pangasius pangasius, Silonia silondia, S. childrenii*

Featherbacks: *Notopterus notopterus, N. chitala*

Airbreathing catfishes: *Heteropneustes fossilis, Clarias batrachus*

Murrels: *Channa marulius, C. striatus, C. punctatus, C. gachua*

Weed fishes: *Ambassis nama, Esomus danrica, Aspidoparia morar, Amblypharyngodon mola, Puntius sophore, P. ticto, Oxygaster bacaila, Laubuca laubuca, Barillus barila, B. bola, Osteobrama cotio, Gambusia chapra*

Exotic fishes: *Oreochromis mossambicus, hypophthalmichthys molitrix, Cyprinus carpio specularis, C. carpio communis, Gambusia affinis, Ctenopharyngodon idella*

Chapter 2: Fish and fisheries of major reservoirs in India

4.2.1 Reservoirs of the Ganga river system

The main reservoirs on the Ganga river system are Rihand, Matatila, Nanaksagar and Sardasagar in Uttar Pradesh; Tilaiya, Maithon, Konar, Panchet and Mayurakshi in Jharkhand, Gandhisagar in Madhya Pradesh and Kangsabati in West Bengal. The reservoirs on the Ganga river system, especially Rihand and Gandhisagar harbour indigenous Indian major carps.

Fishes in the reservoirs located in the upper reaches of the rivers are three species of mahseers, namely, *Tor putitora*, *T. mosal* and *T. tor;* the katli, *Acrossocheilus hexagonolepis*; the snow trout, *Schizothorax plagiostomus*; medium carps, *Labeo dero* and *L. pangusia* and the goonch, *Bagarius bagarius*. The reservoirs located in the middle and lower reaches of the rivers harbour the Indian major carps, catla, rohu, mrigal and kalbasu; other carps viz. *Labeo gonius* , *L. bata, L. boga, L. boggot, Puntius sarana, Chagunius chagunio*, etc. Important catfishes in this region are *Wallago attu, Silonia silondia, Pangasius pangasius, Rita rita, Mystus aor, M. seenghala*, etc. Smaller catfishes are *Clupisoma garua, Eutropiichthys vacha, Mystus cavasius, Ompok bimaculatus*, etc.

4.2.2 Reservoirs of the Brahmaputra River System

At present, there is no important reservoir in this system

4.2.3 Reservoirs of the Indus River System

Govindsagar on River Sutlej is the most important reservoir in the Punjab with somewhat developed fisheries. Fish species of this reservoir are those found in the upper reaches of the Gangetic system. *Tor putitora* and *Labeo dero* are dominant throughout the reservoir, fishes such as *Schizothorax plagiostomus, Crossocheilus latius latius, Garra gotyla, Clupisoma montana, Mastacembelus armatus* and *Mystus bleekeri* occur largely in upper sections and *Cyprinus* var. *specularis, Mystus seenghala* and *Labeo bata* are in the middle and lower parts of the reservoir.

4.2.4 Reservoirs of the Mahanadi River System

Hirakud dam on river Mahanadi is the longest dam in the world. Fish fauna resembles reservoirs of Ganga river system. Some of the commercially important species besides the Gangetic carps and catfishes found in the Hirakud are *Tor mosal* var. *mahanadicus, Labeo fimbriatus, Rita chrysea*, etc.

4.2.5 Reservoirs of the Godavari River System

There is no major dam on the river Godavari. The commercially important species of the impounded area of river Godavari are: *Cirrhinus mrigala, Labeo fimbriatus, L. calbasu, L. rohita, Cirrhinus horai, Catla catla, Mystus seenghala, M. aor, Bagarius bagarius, Pangasius pangasius* and *Silonia childreni.* The prawn *Macrobrachium malcolmsonii*, forms a major fishery.

4.2.6 Reservoirs of the Krishna River System

Tungabhadra, Nagarjunasagar and Nizamsagar are the important reservoirs of the Krishna river system. The important endemic species are: *Labeo fimbriatus, L. calbasu, L. porcellus, L. potail, L. bata, L. boga, L. boggut, Puntius kolus, P. pulchellus, P. dobsoni, P. curmuca, P. sarana, Tor khdree, T. mussulah, Cirrhinus reba, C. fulungee, Osteobrama vigorsii, O. belangeri, Thynnichthys sandkhol, Wallago attu, Mystus aor, M. seenghala, M. punctatus, M. cavasius, Silonia childreni, Eutropichthys goongwaree, Pseudeutropius taakree, Rita pavimentata, Ompok bimaculatus, Bagarius bagarius* etc. *Puntius kolus, P. pulchellus* and *Thynnichthys sandkhol* dominate in Tungabhadra resrvoir, Anjanapur reservoir and Nizamsagar, respectively. Indian major carps introduced in many reservoirs of the Krishna river system have established themselves. *Labeo gonius* and *L. panguisa* also occur, having been introduced along with the Indian major carps, *Tor neilli*, a sp. of mahseer, is endemic to Tungabhadra and Krishna rivers.

4.2.7 Reservoirs of the Cauvery River System

Krishnarajasagar in Mysore and Bhavanisagar, Mettur dam (Stanley reservoir) and Poondi Reservoir in Tamil Nadu are the more important reservoirs in the Cauvery river system. The dominant species of this system are: *Puntius dubius, P. carnaticus, P. sarana, P. micropogon, Cirrhinus cirrhosa, C. reba, Labeo kontius, L. calbasu, L. fimbriatus, L. potail, L. porcellus, tor khudree, T. mussulah, Acrossocheilus hexagonolepis, bagarius bagarius, Wallago attu, Mystus punctatus, Silonia childreni, Pangasius pangasius.* In addition to the above *Catla catla, Labeo rohita, Cirrhinus mrigala, Cyprinus carpio, Osphronemus gorami and Etroplus suratensis* have been stocked in many reservoirs of this river system where they have established themselves.

4.2.8 Reservoirs of the West Coast River System

Rivers Narmada and Tapti have no large reservoirs at present. Ukai in Gujarat; Koyna, Shivajisagar and Powai lake in Maharashtra and Malampuzha, Neyyar and Periyar dams in Kerala on different rivers of the West Coast of India are the major reservoirs.

Both Gangetic and peninsular fish fauna are intermingled in the Narmada-Tapti system. The species commonly found are: *Tor tor, T. khudree, T. mussullah, Labeo fimbriatus, L. calbasu, L. dyocheilus, L. gonius, L. rohita, L. bata, Cirrhinus mrigala, Catla catla, Puntius sarana, Mystus seenghala; M. aor, Wallago attu, Bagarius bagarius, Clupisoma garua, Rita pavimentata,* etc. In reservoirs situated on the rivers, originating from the Western Ghat and flowing into the Arabian sea, the important peninsular endemic species are: *Labeo nigrescens, Puntius thomassi, P. jerdoni, P. filamentosus, P. curmuca, P. pulchellus, Ompok malabaricus,* etc. In Malampuzha reservoir, *Catla caltla, Labeo fimbriatus, Cirrhinus cirrhosa, Tilapia mossambica* and the mirror carp, *C. carpio* var. *specularis* have been transplanted.

In addition to the species mentioned under different reservoirs, some species occur occasionally in different reservoirs. They are *Channa* spp., *Mastacembelus* spp., *Notopterus* spp., *Aspidoparia, Oxygaster, Rasbora, Amblypharyngodon, Osteobrama and* small scalled barbels, *Puntius* spp.

4.2.9 Fisheries of important reservoirs

Stanley Reservoir (Mettur dam, Tamilnadu)

Mettur dam is situated across the river Cauvery. It is one of the largest reservoirs with a water spread area of 15,346 ha and capacity of 2,646 million m^3.

Fish and fisheries

Indigenous ichthyofauna of the river comprises *Acrossocheilus hexagonolepis, Puntius carnaticus, P. dubius, Tor putitora, Labeo kontius, L. fimbriatus, Cirrhinus cirrhosa, C. reba, Aorichthys aor, A. seenghala, Pangasius pangasius, Silonia silundia* and *Wallago attu.* This is the first reservoir (15,346 ha) to be developed scientifically for fishery development. The reservoir came into existence in 1934. The fish catch was 660 t/yr, with dominance of major carps, recorded in 1951-52. But this yield was not sustained later and the catch decreased from 400 t/yr (1984-85) to 110 yr/ha (1991-92). Three downstream barrages on Cauvery, viz. the Lower anaicut, the Great anaicut and the Upper anaicut restrict the upstream migration of the anadromous fish, *Tenualosa ilisha* and hence after the construction of Mettur dam this species disappeared. Apart from this species, *Puntius* spp, *Labeo kuntius* and *C. cirrhosa* also disappeared.Thus Mettur lost its glory due to lapses in management.

Fishing gears

The gear commonly used is the gill net. The floating gillnets are called Rangoon nets.

4.2.9.1 Bhavanisagar Reservoir (Tamilnadu)

It was constructed across the river Bhavani in Taminadu. Its ichthyofauna comprises 51 species belonging to 11 families. Among them, 18 species contribute to the commercial fisheries. The important species in order of abundance are *Labeo calbasu, Cirrhinus mrigala, C. catla, Labeo rohita, Puntius dubius* and *Labeo fimbriatus* among the carps and *Mystus aor* and *Wallago attu* among the catfishes. The fish yield is about 250 tonnes. As per a recent report, stocks of *L. calbasu* and catfishes like *W. attu* and *M. ao*r were also found to decline, attributed to the dominance of weedfishes. Intensive stocking of *L. fimbriatus*, though a native fish of Cauvery system, also did not pay any dividends.

4.2.9.2 Sathanur Reservoir (Tamilnadu)

It is a well developed reservoir, also known as 'catla reservoir' due to predominance of catla after its introduction in 1957. This reservoir is also known as 'crown jewel' due to its high yield and giving good revenue to Tamil Nadu state. Despite unintentional introduction of tilapia and *Rhinomugil corsu*la in this reservoir, the catla fishery was not affected.

4.2.9.3 Amaravathy Reservoir (Tamilnadu)

This is also a productive small reservoir (850 ha). It gave a high fish yield earlier (500 kg/ha) with accidental introduction of tilapia (1957-58). Subsequently, when the reservoir was regularly stocked with major carps, the tilapia fishery declined (60 to10%). There was establishment of major carps and dominance of catla followed by rohu and mrigal.

4.2.9.4 Fish production in Tamilnadu reservoirs

Reservoir fisheries production inTamilnadu in 2003-2004 was 869.6 t, which contributed only 1.12 % to the total inland fish production of the state (77303.5 tonnes) .

4.2.9.5 Nagarjunasagar (Andhra Pradesh)

The prominent species are *Labeo fimbriatus L. calbasu, L. bata,Cirrhinus reba, Puntius sarana, Wallago attu, Mystus seenghala, M. aor, M. cavassius, Bagarius bagarius* and *Ompok bimaculatus.* Stocking of this reservoir (28,475 ha) was regular with a low rate of stocking due to which major carp fishery could not come up and it has become a catfish dominated water body.

4.2.9.6 Tungabhadra Reservoir (Karnataka)

It was constructed on the main river Krishna in Karnataka. Its ichthyofauna resource is similar to Nagarjunasagar. In productive reservoirs likeTungabhadra and Krishnarajsagar of Cauvery basin in Karnataka, the major carp fishery could not establish. Over 95% of the catch was of weed-fish (*Salmostoma* spp and *Chanda* spp.)

4.2.9.7 Gandhisagar Reservoir (Madhya Pradesh)

After Mettur reservoir, Gandhisagar reservoir is another example and the role-model of fisheries development in India to register a high yield of 3,424 t. The reservoir (66,000 ha) was devoid of catla during pre-impoundment but after stocking of this fish and its breeding in the reservoir catla accounted for 60-70% in the total catch.

4.2.9.8 Tawa Reservoir (Madhya Pradesh)

This reservoir of Narmada basin (20,055 ha) was constructed in 1975. Earlier its fish yield was very low (0.019 to 0.325 t from 1974-75 to 1978-79) but later the yield increased to 344 t (28 kg/ha) in 1988-89 due to stocking with catla, contributing to 67% in the total catch.

4.2.9.9 Vallabhsagar Reservoir (Ukai, Gujarat)

It is a productive reservoir (52,000ha) across Tapti river which yielded 8,000 t (160 kg/ha) of fish in 1997-98 and it is still capable of yielding 220 kg/ha. The catches of major carps continue to decline but those of catfishes are increasing. The reservoir is unique in having an endemic *Hilsa* population contributed 199 t (2.3%) in 1998-99. The reservoir is a good example of socio-economic reform.

4.2.9.10 Damodar Valley Corporation Reservoirs (Tilaiya, Konar, Maithon and Panchet)

The river, Damodar is one of the tributaries of the Ganga. The Tilaiya and Konar were constructed across the rivers, Barakar and Konar. Maithon and Panchet are the other two reservoirs constructed across the river Damodar and its tributaries. These are seasonal rivers. Dominant fish species in these reservoirs are *Cirrhinus mrigala*, *Labeo calbasu,Puntius* spp. *Wallago attu, Notopterus* spp*, Barilius bola.* Trash fishes found are *Ambassis nama, A. ranga* and *Puntius* spp.

4.2.9.11 Rana Pratapsagar (Rajasthan)

It is the largest reservoir of Rajasthan built on the river Chambal constructed under the Integrated Chambal Valley Scheme. The other reservoirs constructed under the scheme are Gandhisagar, Jawahar Sagar and Kota Barrage. It covers an area of 20,000 ha. The major fish species are *Catla catla*, *Cirrhinus mrigala*, *Labeo rohita*, *Wallago attu* and *Mystus* spp. The trash fishes are *Puntius sophone, P. ticto, Osteobrama cotio, Amblypharyngodon mola*, *Esomus danricus*, *Ambassis nama* and *A. ranga.*

4.2.9.12 Getalsud Reservoir (Jharkhand)

This is located across the river Subarnarekha in Bihar. Its total area is 3459 ha.The fish fauna includes Indian Major Carps, medium and small sized carps, catfishes, murrels, air breathing fishes, mullets and featherbacks.

4.2.9.13 Govind Ballabh Pant Sagar / Rihand reservoir (Uttar Pradesh)

The reservoir situated in the Mirzapur district of Uttar Pradesh was constructed across river Rihand, a tributary to Sone, which in turn joins Ganga in Uttar Pradesh. Its total water spread area is 46,620 ha.

Fish and Fisheries

The commercial catches are dominated by major carps, and among the carps, catla is the predominant species. Like Sathanur reservoir, this reservoir (45,538 ha) also had dominance of catla (73 to 99%) from 1971-72 to 1980-81. So much so, it was popularly known as “catla mine”. Catla fish got adjusted to the ecosystem so well that it was reflected as the most outstanding monospecies fishery of the reservoir. Unfortunately, the catala fishery declined later with the establishment of five thermal plants along the bank of the reservoir and also on account of lapses on management. The desert State of Rajasthan yielded appreciable quantities of catla from reservoirs like Ramgarh,Guda and Jaisamand.

The breeding population of fish can be built up in a reservoir when stocking with viable seed is done during the early phase of reservoir formation. Among the three Indian major carps, *C. catla* is the best suited for stocking reservoirs followed by *C. mrigala*. In the case of *L. rohita*, it has certain limitations to adjust. This apart, there are some other endemic fish species available in India like *Pangasius pangasius*, *Puntius pulcheilus, Barbodes carnaticus,Thynnichthys sandkhol.* The other species are *Cirrhinus mrigala*, *Labeo calbasu*, *L. rohita*, *L. bata*, *Puntius sarana,Wallago attu*, *Silonia silondia*, *Mystus spp.*, *Bagarius bagarius*, *Notopterus chitala*, *N. notopterus and Channa marulius*. Gears commonly used are surface gill net and giant dragnet.These nets are operated from the flat bottomed country craft.

4.2.9.14 Gobindsagar / Bhakra Nangal (Himachal Pradesh)

It was constructed under Bhakra-Nangal project at Bhakra across the river Sutlej.It is an important reservoir in Himachal Pradesh. The maximumwater spread areaof the reservoir is

16,870 ha and minimum is 5,670 ha with a shoreline of 564km. The reservoir is clearly demarcated into three zones depending on thenature of run off i.e. warm lacustrine, mixed lacustrine and cool lacustrine.

Fish and fisheries

The fish species present in this reservoir arecommonly those found in the upper reaches of the river. Its ichthyofunacomprises 51 species belonging to 9 families, including the brown trout *Salmo trutta*, snow trouts, *Schizothorax*spp. and several species of hillstream fishes. In addition to two exoticspecies viz. *Hypophthalmicthys molitrix*and C*yprinus carpio* var. *specularis*, *Catla catla*, *T. putitora*, *L. rohita*, *L. dero*, *L. calbasu*, *L.bata*, *L. dyocheilus*, *Cirrhinus mrigala*, *Wallago attu* and *A. Seenghala* constitute the commercialfisheries in order of their abundance. *Channa*spp and *A. seenghala* are the twopredators known. Its fish yield was commendable. The yield (113.5 kg/ha) being the highest inIndia, coming as it was from a large reservoir, was mainly due to silver carp (*H. molitrix*), which accidentally enteredinto the reservoir in 1971. Beforedominance of silver carp, the reservoir had a good fishery of major carps andmahseer but this has later more or less disappeared. Howerver, Gobindsagar is known to be a well managed reservoir.

4.2.9.15 Pong Reservoir (Himachal Pradesh)

With increase in population of *W. attu* and *M. seeng*hala, the major carp population declined to such an extent that the reservoir emerged as a cat-fish reservoir (58%), yielding 244 t/year by 1997-98.

4.2.9.16 Sardasagar and Nanaksagar Reservoirs of Kumaun

The reservoirs such as Nanaksagar, Baigul, Dhaura, Haripura and Tumaria are situated in the Nainital district of Uttar Pradesh in the Terai region of Kumaun hills. The reservoir, Sardasagar is located on the border of Nainitaland Pilibhit.

Name of the reservoirs of Kumaun	**River**
Sardasagar (7303 ha)	Chukasand
Nanaksagar (4662 ha)	Deoha and Kamin
Baigul	Baigul
Dhaura (1200 ha)	Dhaura and Katna
Haripura	Bhakra
Baur (1320 ha)	Baur
Tumaria (2681 ha)	Phika and Dhela

Of these reservoirs, the first two are large reservoirs and others are of small size varying from 1200 to 2600 ha. There are 49 species in these reservoirs. The dominant species are *Labeo* *gonius, L. calbasu, Gadusia chapra, Wallago attu, Mystus* spp., *Channa* spp.,*Oxygaster* spp., *Puntius* spp*., Chela* spp*., Nandus nandus,Mastacembelus.* However, *Catla catla, Tor tor* and *Barulius* spp disappeared completely from the reservoirs. All the reservoirs have a large number of weed fishes such as *Gadusia chapra, Puntius spp., Chela laubuca,Chela bacaila, Amblypharyngodon mola, Esomus danricus, Chanda nama, C. ranga* and *Xenetodon cancila.* These weed fishes constitute 75-80% of the total fishyield. Due to the abundance of these trash fishes, a number of carnivorousspecies, *Wallago attu, Mystus* spp.,*Channa* spp., *Mastacembelus* spp., thrive in the reservoirs and form more than 10% of the total yield. Some major carps have been introduced into these reservoirs. These are *Labeo rohita, Catla catla,Cyprinus carpio* and *Cirrhinus mrigala* to augment the fish production. The annual yield form Sardasagar reservoir is about 15 kg/ha. The average yield from all the reservoirs of Terai region is about 35 kg/ha/yr which is much higher than the average yield of 10-15 kg/ha of reservoir all over the country. However, economically important fishes like carps and catfishes constitute less than 10% of the total yield form the reservoirs of Terai region of Kumaun.

4.2.10 Mahseer fishery in reservoirs

Migratory fish like mahseer, which visit clear water streams for breeding, often fail to reach breeding groundsafter impoundment. Consequently, with increasing number of reservoirs that have come up across different streams and rivers, breeding grounds of mahseer are lost. In addition to this, indiscriminate fishing of its brood stock and juveniles, mahseer production shows declining trend.

4.2.11 Reservoir fisheries management in India

The present low level of fish production in Indian reservoirs can be attributed to inadequate management. In many of the reservoirs, the high rate of primary and secondary productivity is not channeled to fish production.

4.2.11.1 Management of medium and large reservoirs

Medium and large reservoirs are predominantly capture fisheries system and the management norms are based on the principle of stock manipulation, adjustment in fishing effort, observance of conservation measure and gear selectivity. In broad terms, management of medium and large reservoirs in India can be considered more akin to enhanced capture fisheries. Although many of them are stocked, their fisheries continue to depend to a large extent on the wild or naturalized fish stock.

i. Stock enhancement

Stocking attempts in medium and large reservoirs are successful only when the stocked fishes breed and propagate themselves.

ii. Species enhancement

It aims at augmenting the species range by adding fish species from outside with a view to colonize all the diverse niches of the biotope for harvesting sustainable crop.

4.2.11.2 Management of small reservoirs

The small reservoirs are generally managed as culture- based capture fisheries, akin to extensive aquaculture; where the main accent is on stocking, fattening and harvesting. The key management parameters of culture based fishery are species selection, stocking and environmental enhancement.

Statewise fish yield from reservoirs of India (in kg per ha)

States	Small	Medium	Large	Average
Tamil nadu	48.50	13.74	12.66	22.63
Uttar Pradesh	14.60	7.17	1.07	4.68
Andhra Pradesh	188.00	22.00	16.80	36.48
Maharashtra	21.09	11.83	9.28	10.21
Rajasthan	46.43	24.47	5.30	24.89
Kerala	53.50	4.80	-	23.37
Bihar	3.91	1.90	0.11	0.05
Madhya Pradesh	47.26	12.02	1.53	13.68
Himachal Pradesh	-	-	35.55	35.55
Orissa	25.85	12.76	7.62	9.72
Average	49.50	12.30	11.43	20.13

4.2.12 Reasons for low yield from reservoirs

- Arbitrary stocking and no sound stock management norms lead to low productivity
- The management of small reservoirs is on the basis of culture-based fisheries.However, proper attention is not paid for stocking density, size at stocking,size at harvesting, levels of fishing mortality and natural mortality andharvesting schedule which hold the key for obtaining the optimum yield.
- Congregation of Indian major carps above the spill ways for breeding, which results in heavy escapement of brood and fingerlings. This poses a serious problem for building up stocks of desirable fishes in such reservoirs. Development of fisheries insuch reservoirs require suitable screening of the spill way and the canal mouth. In addition, there should be an annual cropping policy of stocking in September – October and harvesting by June end.

4.2.13 Well managed reservoirs

- Several small reservoirs across the country were stocked with Indian major carps with the effort of CIFRI, Barrackpore. It resulted in the improvement of fish yield from these reservoirs.

Reservoir	**Yield (kg per ha)**
Aliyar (Tamil Nadu)	194
Tirumoorthy (Tamil Nadu)	182
Meenkara (Kerala)	108
Chulliar (Kerala)	316
Markonahalli (Karnataka)	63
Gularia (Uttar Pradesh)	150
Bachhra (Uttar Pradesh)	140
Baghla (Uttar Pradesh)	102
Bundh Beratha (Rajasthan)	94

4.2.14 Crafts and gears employed in reservoirs

The presence of underwater obstacles restricts the use of active year in reservoirs. Hence, mostly passive gears are used. Simple gill nets, entangling type of gill net (Rangoon net) shore seines are the major gears. Long lines, hand lines, pole and line, cast nets and dipnets are also used. Two-boat mid-water trawling has been recommended for commercial species and single two-boatbottom trawling for eradication of uneconomic species of fishes in large reservoirs like Gandhinagar and Hirakud. Coracle, Plank–built flat bottomed canoe, dinghy, dugout canoes, rafts made of discarded old tyres, logs, used canetc., are the commonly used crafts in Indian reservoirs.

4.2.15 Development of the fisheries of Indian reservoirs

The low fish yield from various large reservoirs in India is mainly due to unscientific management and over exploitation. Hence, attention needs to be paid on the following steps to improve the yield from reservoirs.

1. Survey of fish fauna of the river before impoundment of the reservoir.
2. Clearance of submerged obstructions like tree trunks, buildings, etc., preferably at the pre-impoundment stage and weeds, to permit easy exploitation.
3. Establishment of a fish farm. Production of fish seed in pens and cages would be able to play vital role in procuring seed for stocking the reservoirs as required.
4. Stocking of the reservoir.
5. Survey of fish seed resources to decide the necessity and intensity of stocking from extraneous sources.
6. Rehabilitation of fishermen communities on the periphery of the reservoir.

7. Organisation of co-operative societies for proper marketing.
8. Topographical survey of the reservoir substrata.
9. Experimental fishing before throwing open the reservoir for commercial exploitation.
10. Transport and marketing.
11. Conservation and management

Chapter 3: Natural vs Man-Made Lakes

4.3.1 Natural Lake

Natural lakes are naturally formed, usually "bowl-shaped" depressions in the land surface that became filled with water over time. These depressions (also called basins) were typically produced as a result of the catastrophic events of glaciers, volcanic activity, or tectonic movements. The age of most permanent lakes usually is of a geological time frame, but with most not much older than 10,000 years. A few are much older, and some ancient lakes may be millions of years old.

Other natural processes that produced lake basins include (i) seepage of water down through layers of soluble rock, (ii) erosion of the land surface by wind action, and (iii) plant growth or animal activity that resulted in damming of the outlet channels from shallow depressions in the land surface. There are literally millions of small lakes around the world, concentrated largely in the temperate and sub-arctic regions. These regions are also characterized by a relative abundance of fresh water. Many more millions of temporary lakes occur in semi-arid and arid regions.

4.3.2 Man-Made Lakes

Man-made lakes are water impoundments—or water accumulated in reservoirs—that do not occur naturally in the landscape. These lakes are most commonly created by constructing dams in river or stream valleys. Water released downstream from large man-made lakes, or reservoirs, is regulated according to water use. Reservoirs are typically constructed for purposes of power generation, flood control, navigation, water supply, and recreation. Smaller man-made lakes may be constructed for agricultural irrigation, recreation, or aesthetic purposes. Since the reservoirs have both river-like and lake-like characteristics, reservoirs constitute an intermediate type of water-body between rivers and natural lakes. Their flushing rate and the degree of river influence ultimately determines the specific characteristics and potential uses of reservoirs.

A man-made lake can be designed and constructed to incorporate the desired features including, size, depth, shoreline slope, vegetation, nutrient levels, water residency time, water elevation, and water levels. A man-made lake goes through a period of equilibrium establishment (accelerated ageing) over the first few years. After that time the differences are minimal.

4.3.3 Difference between Man-made and Natural lakes

Man-made lakes differ from natural lakes in several significant ways. The drainage basins of reservoirs are typically much larger in relation to the lake surface area than the drainage basins of natural lakes. Reservoir basins tend to be narrow, elongated, and dendritic (branching) because they are most commonly formed in river valleys. Reservoirs receive runoff from large streams and rivers, and are not typically intercepted by wetlands or shallow interface regions. The result is that runoff inputs are larger, are more closely linked to rainfall, and affect a larger portion of the lake than is the case in most natural lakes. These characteristics lead to high inputs of nutrients and sediments in rainy weather.

Natural lakes tend to be located at the headwaters of rivers or streams, whereas man-made lakes tend to be closer to the mouth of the river or stream. Natural lakes therefore tend to have lower nutrient and sediment concentrations than those in man-made systems. The water levels in natural lakes are fairly constant, while those in reservoirs are typically managed for flood control, hydropower production, and/or navigation. Reservoirs frequently release water from the bottom of the dam pool, which contains little dissolved oxygen; this may cause problems with water quality downstream. Natural lakes, in contrast, typically release well-aerated surface waters.

Management of reservoir water levels result in large areas of sediments that are alternately flooded and exposed; frequent manipulation of water levels prevents the establishment of stabilizing wetlands and shoreline vegetation, and increases shoreline erosion and sediment loading. The frequent alternation between flooding and exposure may encourage sediments to release more nutrients than are found in natural lakes. The higher nutrient load encourages the growth of algae and other organisms that sink to the sediments upon death. The sediments gradually fill in the reservoir, so that the life span of the reservoir is shorter than that of natural lake systems.

Man-made lakes formed by river impoundment typically have hydrodynamic characteristics that are very different from natural lakes, consisting of riverine (riverlike), transitional, and lacustrine (lakelike) zones in the reservoir. Lakes created for hydropower generation may have additional variations in hydrodynamic characteristics caused by the flow created by the power-generating turbines, or by the pumping system for hydropower generation.

Smaller man-made lakes and ponds also have characteristics different from natural lakes. The creation of these impoundments can alter the shape of the basin to inhibit the establishment of emergent and shoreline vegetation necessary to prevent bank erosion. Small man-made lakes frequently have no outflow point, and hence accumulate sediments and nutrients at a faster rate than natural lakes. The result is that small man-made lakes support different flora and fauna than natural lakes.

The biota (animal and plant life) of man-made lakes may be very different from natural systems. Reservoirs are stocked with fish to develop sport fisheries for recreation. Small man-made lakes and ponds are also frequently stocked with fish for recreation, and to control the growth of submerged vegetation. The stocking of fish develops a different food web from what would naturally occur. The impoundment of rivers also may inhibit the growth of native fish species by preventing movement of the fishes at critical times, and by removing native habitat (flowing water) necessary for reproduction. In addition, the reduced flow velocity and increased sediment loading can suffocate native mussels and other bottom-dwelling species. The differences in flow and sediment also alter the base of the food web to one of suspended algae (phytoplankton), rather than the attached algae (periphyton) and detrital material that form the food base in rivers and streams.

4.3.4 Differences between lakes and reservoirs on a global scale

Lakes	Reservoirs
• Especially abundant in glaciated areas; orogenic areas are characterized by deep, ancient lakes; riverine and coastal plains are characterized by shallow lakes and lagoons	• Located worldwide in most landscapes, including tropical forests, tundra and arid plains; often abundant in areas with a scarcity of natural lakes
• Generally circular water basin	• Elongated and dendritic water basin
• Drainage: surface area ratio usually <10:1	• Drainage: surface area ratio usually >10:1
• Stable shoreline (except for shallow, lakes in semi-arid zones)	• Shoreline can change because of ability to artificially regulate water level
• Water level fluctuation generally small (except for shallow lakes in semi-arid zones)	• Water level fluctuation can be great
• Long water flushing time in deeper lakes	• Water flushing time often short for their depth
• Rate of sediment deposition in water basin is usually slow under natural conditions	• Rate of sediment deposition often rapid
• Variable nutrient loading	• Usually large nutrient loading their depth
• Slow ecosystem succession	• Ecosystem succession often rapid
• Stable flora and fauna (often includes endemic species under undisturbed	• Variable flora and fauna

conditions)	
• Water outlet is at surface	• Water outlet is variable, but often at some depth in water column
• Water inflow typically from multiple, small tributaries	• Water inflow typically from one or more large rivers

Unit 5: Estuarine fisheries in India

Chapter 1: Ecology, classification and fish production potential of estuaries in India

5.1.1 Introduction

Majority of the flowing waters on the earth finally reach the sea. Near to the coast even small brooks, channels and streams join the sea after traversing small distances. At and near the juncture, where the river joins sea, a unique aquatic environment is created having the characteristics of both the marine and freshwaters virtually an admixture of these two environments. This water mass is usually called as a buffer zone or ecotone. Estuaries thus come into existence at an area of the sea coast where the river joins the sea. An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage (Pritchard, 1967). Estuaries are the transitional zones between the rivers and sea and have specific ecological properties and biological composition.

5.1.2 Ecology of estuaries

Several unique features are seen in most estuaries with regards to the physics, chemistry, geology and biological features.

- The fast flowing rivers of upland regions lose their velocity and turbulence and become nearly still except for the changes brought about by tides.
- The depth and width generally increases.
- Waters tend to become clear due to settling of suspend matter caused by great reduction in velocity.
- The bottom of the estuary gets built up due to deposition of materials brought by the flood waters.
- Physical environmental characteristics like penetration of light and temperature change compared to shallow upland river stretches.
- Salinity, dissolved gasses and chemical nutrients again show variations from that in the upper stretches.

- The estuary shows distinct seasonal variations in several of the physic-chemical and biological characters, particularly those waters, which come under monsoonal regime. The estuary can show marine, freshwater and intermediary characters nearly freshwater during monsoon season and flooding periods, marine characteristics in pre-monsoon or summer and between monsoons an admixture feature of seawater and freshwaters.
- Tidal regimes also influence the estuarine characters with high tide bringing more seawater into the region and on withdrawal of same during low tide with more freshwater entering the area.
- Biologically an estuary is more unique in allowing the development of a set plants and animals that only can thrive in a buffer media of estuary. Euryhaline organisms capable of tolerating some degree of variation in salinity of the waters develop and thrive here.
- Estuaries thus support freshwater life forms, marine forms and finally the brackish water forms, capable of inhabiting waters with changing salinity features. Also, this environment will support pure freshwater forms in the upper reaches, euryhaline forms in the middle regions and stenohaline forms in areas near to the mouth. During flooding and monsoon conditions, only freshwater forms are present and during dry period or summer with no or less freshwater inflow more marine forms inhabit the region and the euryhaline brackish water forms exist during rest of the period.
- The estuaries are considered as the highly productive aquatic ecosystems for all forms of aquatic life including benthic forms.
- They are ideal and favourable nursery areas for a wide variety of commercially important marine finfishes and shellfishes, as the waters are more sheltered with favourable conditions for breeding and feeding. An assortment of food components, i.e. phytoplankton and zooplankton, thrive here to help for the growth and development of different fishes and shellfishes.
- Many estuaries support a thriving commercial fishery of brackish water finfishes and shellfishes.
- Owing to their sheltered nature, estuaries offer safe navigation and anchoring of boats and ships

5.1.3 Geo-morphological classification of estuaries

- Estuaries are divided into five types as below:
- **1. Saltwedge estuary**
- It is formed when a river flows into a tideless sea. As the freshwater is less dense than salt water, it tends to flow over the surface of the salt water. The seawater rests on the bottom as motionless saltwedge. Hence, this is called saltwedge estuary.
- **2. Partially mixed estuary**
- It is formed when a river flows into the sea with appreciable tidal movements. The turbulence caused at the meeting place, not only mixes the saltwater upwards into the freshwater, but also mixes the freshwater downwards. This dilutes the salt water near the bed and produces a salinity gradient towards the head of the estuary.
- **3. Well mixed estuary**
- It is shallow with a high tidal range, and probably with intertidal mudflats or banks. The mixing is more intense. As it is shallow, there is no vertical circulation. There is a lateral variation in salinity. The freshwater tends to flow down on one side of the estuary and the

saltier water enters the other side. Consequently, a horizontal residual circulation is established.

- **4. Fjord**
- It is the deepest estuary. It can be considered as saltwedge estuary with an infinite layer. The salinity of the bottom layer does not vary significantly. The effect of tidal flow in the mixing is negligible. They often have a shallow bar of rock or silt near their mouths. The tidal flow over this can cause turbulent mixing within a limited area. There is no fjord in India.
- **5. Bar-built estuary**
- It is found when offshore barrier, sand islands and sand spits are deposited about sea level. Such islands or spits extend between headlands in a chain broken by one or more inlets. The area enclosed by the barrier beach is generally elongate and parallel to the coastline. Although these estuaries have a small drainage area, they generally receive more than one river. They are shallow and wind provides the important mixing mechanism. These estuaries remain open during monsoon seasons. They remain land locked when there is no water flow in the river. Hence, they are also called temporary estuaries.

5.1.4 Categories of estuaries

- **1. Open estuary**
- It is always connected with the sea. It is located at the mouth of the river or lake. It may be perennial, filled with the water of the river throughout the year or seasonal in which the river dries up during summer, isolating the estuary from the sea. Chilka lake is an open estuary.
- **2. Embanked estuary**
- It is a confined area of brackish water, exposed to sea only during low tides or else it may remain surrounded by continuous chain of barrier islands. Examples: Adyar estuary and Cauvery estuary in Tamil Nadu. They are also situated in West Bengal, where it is called ‘Bhasabadha’ fisheries or ‘Bheris’.
- Based on mixing and patterns of salinity distribution caused by various factors, there are two types of estuaries.

- **1. Positive estuary**
- It is the one in which the influx of fresh water is sufficient to undergo mixing and there occurs a pattern of increasing salinity usually towards the mouth of the estuary. This type of estuary has low oxygen concentration in the deeper waters and considerable organic material in the bottom sediments. Vertical distribution of salinity may range from top to bottom uniformly.

- **2. Negative estuary**
- In arid regions, where the rate of evaporation in estuaries exceeds the inflow of fresh water, salinity increases in the upper part of the basin, especially if the mouth of the estuary is restricted by shoreline features that check the tidal flow. The salinity

distribution in this type of estuary is the reverse of the positive estuary. Negative estuaries and lagoons are hypersaline but possess a moderate oxygen concentration at depths. Bottom mud is generally poor in organic content.

5.1.5 Classification of estuarine animals

- Estuarine animals are classified into five main groups as below:

1. Oligohaline organisms

- This group includes most of the freshwater forms inhabiting rivers which cannot tolerate variations in salinity of more than 1 ‰ and which are not found at the head of the estuary.

2. True estuarine organisms

- True estuarine organisms are such that they are geographically restricted to estuaries only and are best represented in their upper and middle reaches in low salinities. Although these organisms have marine affinities, they have adapted themselves to tolerate a wide range of salinity.

3. Euryhaline marine organisms

- These organisms extend in their distribution from the sea to the upper reaches of the estuary and can tolerate salinity as low as 15 ‰. A few, however, can tolerate salinities of even 5%o. These organisms form the majority of total estuarine biota.

4. Stenohaline marine organisms

- These organisms live on open seashore and at mouths of estuaries. They do not enter estuaries below salinities of 25 ‰ in the lower reaches.

5. Migrants

- Certain euryhaline marine migrants spend only a part of their lives in estuaries. Many are predators subsisting on resident estuarine benthic organisms.

5.1.6 Fisheries production potential of estuaries of India

- Various estuarine systems spreading over 14.22 lakh hectare form an important component of the fisheries resources of the country. The fisheries of estuaries are above subsistence level and contribute significantly to the production. The average fish yield varies from 45 to 75 kg per ha. Estuarine fishery is the mainstay during the monsoon season when fishing in the sea, because of turbulent conditions and stormy weather, gets suspended. Food chains in the estuaries differ from the open sea in several aspects. A greater part of the organic production in estuaries is controlled by larger plants (macroalgae, mangroves, etc.) rather than phytoplankton. As consumers of the organic matter, zooplankton become less important than the suspension and deposit feeders. Organic detritus forms a major source of food for the estuarine communities. Nearly 49% of Indian marine fish catch originate from estuaries which provide indication of the dependence of marine species on estuaries in early life history.

- The National Commission on Agriculture stated that “under the term estuarine fisheries is included the fishery output from the mouth of rivers, the large brackish water lakes, the innumerable tidal creeks and backwaters along the coast and the coastal canal system. Fishes of brackish water are usually marine which can tolerate wide salinity changes and are called euryhaline. These are clupeids, mullets, catfishes, perches and prawns. *Mugil cephalus* forms a large part of the estuarine fishery. In addition, species that are not of commercial value also contribute to the fishery of brackish water. They include gar fishes, halfbeaks, eels, flatfishes, sharks, rays and oysters. Some migratory fishes that migrate to freshwater from sea or vice versa are also included. They include Tenualose (*Hilsa) ilisha*, *Polynemus* spp, *Pama pama*, *Tachysurus* spp, *Pangasius* spp and the prawn, *Macrobrachium* spp.

Chapter 2: Fish and fisheries of estuaries of the east coast of India

5.2.1 Introduction

The major estuarine systems in India are the Hooghly-Matlah estuarine system in West Bengal; the Mahanadi and Rushikulya estuary in Orissa; the Godavari and the Krishna in Andhra Pradesh; the Adyar,the Cauvery, Vellar and Vaigai estuaries in Tamil Nadu, the Narmada and the Tapti in Gujarat, Asthamudi in Kerala, Kalinadi in Karnataka and Mandovi – Zuari system of Goa. The important brackishwater lakes of the country are the Chilka lake in Orissa, the Pulicut lake and Killai backwaters in Tamil Nadu and Cochin and Vembanad backwaters in Kerala. Though the fisheries of various estuarine systems have been studied in the last two decades, a continuous monitoring of the fisheries is done only in the Hooghly-Matlah estuarine system, the largest estuarine complex in India. The following estuaries are the important estuaries situated along the east of India.

5.2.2 The Hooghly-Matlah estuary

The Hooghly-Matlah estuary, which is located within the State of West Bengal, occupies the marshy deltaic area called the Sunderbans. Sunderbans at the Ganga-Brahmaputra delta are regarded as the largest single mangrove jungle of the world transcending the political boundaries of India and Bangladesh and occupying a total of 10,000 km^2. The portion falling in India occupies over 4,170 km^2 (23,400 ha). The total approximate area of Sunderbans estuarine waters is 2,340 km^2. The main Hooghly estuary is a positive estuary. It has an approximately triangular wide mouth and, probably, due to the strong scouring action of the stream as well as tidal currents, a greater overall circulation is maintained. The tidal influence can be realised up to a distance of 290 km from the sea.

5.2.2.1 Fish and Fisheries

Among the estuaries of India, Hooghly-Matlah estuarine system provides one of the richest grounds for fishery in India. About 130 species of fishes and 30 species of prawns and crabs are found in the commercial catches obtained from the Sunderbans area. Nearly 16,000 fishermen live in different zones of the estuary, and fishing activity goes on intensively throughout the year and the total annual catch amounts to 20,000 – 26,0000 tonnes.The fish fauna of the Hooghly-Matlah is classified into residents and transients or migrants.

5.2.2.2 Resident species

Mullets: *Liza parsia* and *L. tade*: Threadfins: *Polynemus tetradactylus* and *P. indicus*, Croakers: *Sciaena miles* and *Sciaenoides barites*; Perches: *Lates calcarifer*; Ribbon fish; *Trichiurus savala*; Clupeids: *Setipinna taty* and *Ilisha elongate* , *Setipinna phasa* , *Hilsa sinensis* and *Coilia borneensis*, *Coilia ramcarati*; Catfish: *Tachysurus jella* and *Plotosus canius*. Other species include *Harpadon nethereus, Polynemus paradieus, Pama pama* and *Sillaginopsis panijus.*

5.2.2.3 Migrants

The Hooghly-Matlah estuary serves as a nursery for migrant species providing spawning grounds for many, which show anadromous or catadromous types of migrations. These species can be broadly divided into four categories.

1. Marine forms that migrate upstream and spawn in freshwater areas of the estuary are: *Tenualosa ilisha*, *Polynemus paradiseus, Sillaginopsis panijus* and *Pama pama*.

2. Freshwater forms that migrate downstream and spawn in the sea (catadromous fishes) are *Anguilla* spp (Freshwater eel)

3. Freshwater species which spawn in saline areas of the estuary are: *Pangasius pangasiu*s and the prawn, *Macrobrachium rosenbergii.*

4. Marine fishes that spawn in the saline areas of the estuary are: *Tachysurus jella*, *Osteogeneiosus militaris, Polynemus indicus* and *P. tetradactylus*. These species spawn in areas where salinity ranges between 1.00 and 26.0‰. The young, after a brief sojourn, lasting a few months, return to the sea with the onset of monsoon.

The young ones of many marine species of prawns and fishes such as *Penaeus indicus, P. carinatus*, *Leander stylifera*, various sciaenids, ribbon fishes, etc. migrate for feeding into the lower zone of the estuary during the winter and summer months and return to the sea when the salinity of the estuary goes down with the onset of monsoon.

Hilsa (*Hilsa ilisha*) , Gangetic whiting (*Sillago panijus* - tool maach), mullets (*Mugil* spp.) and penaeid prawns form commercially important fishery in this estuary. Of the 30 species of prawns, six species constitute commercial fishery. They are, in order of dominance, as follows: *Metapenaeus brevicornis, Parapenaeopsis sculptilis, Palaemon styliferus, P. tenuipes and Macrobrachium malcolmsonii* and *M. rosenbergii*. The large sized penaeids like *Penaeus monodon* and F. *indicus* are represented poorly. In this estuary, prawn fishery dominates the fish catches, contributing as high as 30 to 40% to the total landings. The commercially important species of the Hooghly-Matlah estuary are *Tenualose ilisha*, *Lates calcarifer*, *Polynemus paradiseus, Liza parsia, L. tade, Polynemus indicus, Pama pama, Sillaginopsis panijus* and prawns.

5.2.2.4 Status of *Hilsa* fishing in Hooghly – Matlah estuary

Hilsa fish, *Tenualosa lisha*, a remarkable fish of Hooghly estuary. It deserves importance because of its unique taste, popular preference and high market price. It ranks as the prime fish and commercially it constitutes the most important fishery of the ecosystem. During monsoon (July to October) period hilsa catch contributes to the bulk (about two third) of the total annual landing of the species from this estuary. The hilsa fishery in winter, however, is of a smaller magnitude. Wide fluctuations in *hilsa* catch in Hooghly estuary has an interesting characteristic. Available information depicts that the harvested yield of the upper portion of the estuary is in a declining trend. Hilsa, the most important anadromous specific attention in studies as the fish migrates during monsoon from sea to the riverine water bodies. Human use of river systems has intensified considerably in the last century due to increasing population and the associated higher demand for water through industrial and agricultural technologies. The upper stretch of Hooghly estuary is greatly involved with earnings of the fishermen residing nearby river side. Fall in hilsa catch has deprived the fishermen from availing of hilsa catches at least from the upper stretch of the estuary due to indiscriminate killing of juveniles. *Hilsa* juveniles (fry and fingerlings) constitute a substantial part of hilsa catch from the upper freshwater stretch. Young hilsa, which start their downward migration, are trapped by small meshed nets.

5.2.2.5 Fishing gears used

Among the various types of gears used, bagnets are the most common and these are particularly designed for their operation in tidal areas. Nearly 4000 bagnets of different mesh sizes are operated in the estuary. Other gears employed are trawl net, large seine, small seine, purse seine, drift net, lift net, cast net, set-gill net, set-barrier, traps and hooks and lines. Winter season yields the best results. Prawns and Bombayduck form more than half of the bagnet catches. Of the total landings, the bagnet fishery contributes about 70% from the estuarine areas.

5.2.2.6 Conservation and management

The overall decline in the salinity of Hooghly-Matlah estuarine system after commissioning of the Farakka Barrage with gradient and marine zones being pushed down towards the sea. This has brought about drastic changes in the species composition of fishes caught with freshwater species making their appearance in tidal zones at the cost of some neretic species. This major estuarine resource of the country has also been subjected to stresses like urbanization, pollution, land development, dams, degradation and over exploitation in some areas. Further, exploitation by very small meshed nets may affect the concerned stocks. This situation may lead to depletion of stocks and hence it is necessary to take appropriate regulatory measures.

5.2.3 Mahanadi Estuary

Mahanadi estuary is situated in Cuttack and Puri district of Orissa. It is formed by the river Mahanadi which meets the Bay of Bengal. Its total area is 30,000 ha. The annual fish production is about 550 tonnes. The major fishes found in this estuary include mullets, seabass, sciaenids and prawns. This estuary is characterized by poor tidal oscillations and flood discharge due to sand bar formation in the sea mouth. This has affected fish yield from the estuary.

5.2.4 Rushikulya Estuary

This estuary is located in Orissa. This estuary is largely being used for the collection of prawn seeds and fries of milkfish for aquaculture. The milkfish, *Chanos chanos* is one of the fin fishery resources of this area. Three peak occurrence of the *Chanos* sp. fry is recorded during the month of August, September and April (17.52%, 14.96% and 10.1% respectively). The lowest catch of the fry is observed during December (5.66%). The variation in the distribution is related with the physical parameters. In addition to these species, there is a regular fishery of other species and many estuarine fishes are caught throughout the year.

5.2.5 Godavari Estuary

The Godavari estuary is situated at the place where the 1330 km long Godavari meets the Bay of Bengal on the east coast of India in the state of Andhra Pradesh. River Godavari divides at Dowlaiswaram into two prinicipal distributaries viz., the Vasishta and the Gautami which enclose a wide delta between them. The tidal effect is relised up to 45 km from the river mouth. The total area of this estuary is about 18000 ha. There are about 185 species of fishes excluding clupeids. The annual fish production is about 5000 tonnes. Prawns form an important fishery in the Gautami-Godavari estuary. Whitebait, *Anchoviella commersonii* is abundant from Feb – June when the salinity is high and these are absent during the flood period when the salinity is low. *Setipnna godavariensis* and the sciaenid, *Pseudosciaena axillaries* form notable fishery. Mullets form one third of the total fish catch. Other species of commercial importance are *Pristipoma hasta*, *Leiognathus* sp., *Gerres filamentosus*, *Caranx* sp., *Sillago sihama, Gobius* sp., *Sciaena* sp., *Platycephalus* and *Lates calcarifer* , etc. Other prominent fishes include elasmobranchs, pomfrets, mackerels, perches and ribbonfish.

It is well known for its rich prawn fishery. *Metapenaeus monoceros, M. brevicornis, M. dobsoni, M. affinis, Fenero penaeus indicus, P. monodon, P. semisulcatus, P. merguiensis* and *P. japonicus* are the common prawns occurring here. Of the several species of prawns, *M. monoceros* which is the most abundant prawn, is available in the lower reaches of the estuary, particularly in the mangrove swamps and backwaters. The fisheries of odavari estuary is being affected severly by the sand bar formation. Shore seines, dragnet, bagnet, gill net and stake nets are the gears commonly used in this estuary.

5.2.6 Krishna Estuary

The Krishna divides into 3 branches, viz. a western branch, Krishna proper; an eastern branch, Gollumutta paya and a central branch, Nadimeru, before it falls into Bay of Bengal. Freshwater discharge into the estuary dries up completely from March to June.

5.2.7 Cauvery Estuary

The estuary is formed by the river Cauvery which meets the Bay of Bengal in Tamil Nadu. The river Cauvery in its deltaic region lying in Tamilnadu divides into a northern branch, the Coleroon and a southern branch, the Cauvery proper. Little is known about the fishing potential of the Cauvery estuary. The following fauna have been recorded from Cauvery estuary (ZSI, 2011)

· 117 species of fishes which belongs to 87 genera and 52 families

· 21 species of crabs which belongs to 13 genera and 8 families

· 19 species of prawns which belongs to 9 genera and 4 families

· 31 species of molluscs which belongs to 22 genera and 16 families

Common species in this estuary include mullets, clupeids, perches, *Lates*, *Polynemus*, eels, prawns, crabs and others.

5.2.8 Adyar Estuary

The estuary is formed by the 40 km long Adyar river whch meets the Bay of Bengal within the southern limits of Chennai city in Tamilnadu. The estuary is connected to the sea only during monsoon and post monsoon months when freshwater discharge ensues. By the end of January, a sand bar is formed at the river mouth and the estuary gets totally cut off from the sea. The common species are mullets, prawns, *Sillago sihama*, Oreochromis *mossambicus*, catfishes, *Etroplus* spp, *Panchax parvas*, *Aplocheilus melastiga* and the mudskipper, *Periophthalmus koelreuteri* etc.,

5.2.9 Vellar Estuary

The estuary is formed by the river Vellar which drains into the Bay of Bengal at Portonova in Tamilnadu. The total course of the river is 480 km, of which the estuary covers only 262 ha. The catches of this estuary include mullets, sciaenids, catfishes, polynemids, leiognathids, prawns, crabs, clams. It serves as a good nursery ground for many of the fishes in Portonova waters. Mullets constitute 23.5%, prawns 13% and crabs 8% of the total landings. Contribution of molluscan (mainly clams) fishery is substantial (65%). These are sold at a cheap rate and their shells are utilized for the production of lime. Main gears employed for fishing are different types of cast nets with varying mesh sizes. Fishing by a hollow cone-shaped basket is also employed. Peak fishing seasons are summer and premonsoon months, although intensive fishing starts soon after the rains.

5.2.10 Vaigai and its adjacent estuaries

There are seven estuaries in Ramanathapuram district (Tamilnadu), covering an average area of about 93.77 ha. Of the seven estuaries, the estuaries, Vaigai, Kottakudi, Kottakarai, Pamban - Chinnapalam and the Pambar remain open throughout the year. The other two estuaries, Malalta and the Palaiyar remain closed for 7 – 9 months. Among them, Vaigai estuary is the most important one. This estuary lands the highest catches. Commercial fisheries in Vaigai estuary assume importance from aquaculture viewpoint as it is rich in seed resources of commercially important species of fishes and prawns. Important fishes are milkfish, mullets and prawns.

Chapter 3: Fish and fisheries of estuaries of the west coast of India

5.3.1 Narmada Estuary

This estuary is formed by the river Narmada which drains into the Gulf of Cambay in the west coast. *Tenualose ilisha* forms an important fishery in the Narmada estuary and some distance upstream. Catches at the estuary mouth comprise a mixture of *H. ilisha* and *T . sinensis.* Mullets and prawns are also common in ths estuary. The annual fish production is about 4000 tonnes.

5.3.2 Tapti Estuary

Tapti estuary is situated in Gulf of Cambay near Surat in Gujarat state.It is formed by the river Tapti which meets the Arabian sea through Gulf of Cambay. Fisheries potential of the Tapti estuary has drastically declined after the commissioning of the Ukai dam.

5.3.3 Asthamudi Estuary

It is situated in the Kollam district of the state, Kerala. Ninety-seven species belonging to 39 families of fishes, prawns, crabs and clams, etc., are available here. Of the 39 families, 12 contribute to the fishery substantially. Mullets and the pearl spot are the most abundant forms having a good market value. Anchovies form a seasonal fishery from July – October. It is rich in prawn resources and the peak prawn fishery season lasts from Aug – Oct. Traditional dug-out canoes are the common fishing crafts. Four types of gears, namely seine nets, cast nets, Chinese dipnets and drag nets are commonly used. In addition to these gears, Lure fishing and Scare-line fishing are also employed. Besides the capture fishery, it provides a good scope for fish and prawn culture.

5.3.4 Mandovi-Zuari Estuarine System

These estuaries are situated in the state, Goa. They discharge into the Arabian sea through the Marmugoa and Aguda Bay respectively. In the Zuari estuary, almost marine conditions prevail with a little freshwater drainage. In the Mandovi estuary, the freshwater drainage continues throughout the year. The annual fish catch from the estuarine system varies from 150 to 350 tonnes with an average value of about 200 tonnes. Demersal fishes, mainly prawns and finfishes contribute from 50 to 70 % of the total catch. The dominant group of the demersal finfishes includes catfishes, flatfishes, rock cod and sand whiting. There are extensive beds of the estuarine clam, *Meretrix casta*, the average yield of this clam from different beds is about 80 tonnes. In Goa, there is a considerable scope for cultivation of bivalves on ropes suspended from floating rafts in the estuaries.

5.3.5 Nethravathi and other adjacent estuaries

A large number of estuaries are found in the South Kanara district in Karnataka, of which the Nethravathi-Gurupur estuary and the estuaries at Choodapur are the most important. The fish catches in the estuaries consist of *Sillago* spp. *Thrissocles* spp. *Anadontostoma chacunda*, *Ambassis* sp., *Ilisha indica*, *Kowala coval*, *Platycephalus* sp., *Lutjanus* spp., *Gerrus* spp., *Leiognathus* spp., *Sphyraena* spp., *Mugil* spp., *Hemiramphus* spp., *Tenthis* spp., *Stolephorus indica*, *Caranx* spp., *Chironemus* spp., *Belone* spp., *Epinephelus* spp., *Tachysurus* spp., *Pseudosciaena* spp., *Therapon jarbua*, *Mystus gulio* sp. etc. Fish population in the estuaries is mainly composed of the juveniles and immature individuals. Estuaries are a potential source of brackishwater fish seed especially milk fish and mullet. Crustacean resources are limited. Prawns are more abundant than crabs. *Metapenaeus dobsoni*, *M. monoceros* and *F. indicus* are the dominant prawns and *Scylla serrata*, the crab. Clams form a regular fishery of local importance. Important gears are shore seines, gill nets, cast nets, hook and line and mini-otter trawls. Crabs are caught in bottom set gill nets used for the capture of other fishes.

5.3.6 Kalinadi, Aghnashini and Sharavati Estuaries

These estuaries are situated in the North Kanara district of Karnataka. Fauna mainly comprises bivalves, gastropods and crabs. Bivalves dominated in areas with sandy bottom. Several diversified methods of traditional fishing are used in this estuary almost throughout the year. These include gill nets, cast nets, hook & line, pole & line, drag nets, scoop nets, light fishing, scare line, crab fishing with traps and clam fishing by hand-picking at low tide or by dragging bagnets of wire meshes. Little is known about the fisheries of these estuaries.

5.3.7 Manakuddy Estuary

This estuary of river Puzhayar is situated about 8 km North of Cape Comorin (Tamilnadu). Total area is about 145 ha. It is bordered all along with vast stretches of salt pans on either side. *Tilapia, Mugil, Etroplus, Gerrus, Chanos, Therapon, Ambassis, Lates, Anguilla* and *Mystus* are the common fish species. A few species of caridean prawns, *Macrobrachium* spp., and the penaeid prawns viz. *F. indicus, P. monodon, M. dobsoni* and *M. monoceres* are also common. About 10 tonnes of fishes are caught annually, prawns constituting about 4 tonnes. More than 90% of the prawns are caught by cast net.

Chapter 4: Fish and fisheries of major brackish water lakes and backwaters in India

5.4.1 Introduction

A lagoon has freshwater streams flowing into it from the hinterland or the catchment areas, on one side, and on the other side, the lagoon opens into the sea through a comparatively narrow mouth. Lagoons associated with estuaries constitute an important inland fishery resource. India has two important lagoons / brackish water lakes viz. the Chilka Lake and the Pulicat Lake in the east coast. These two major brackish water lakes are not only identical with each other, broadly in their hydrological and biological features. They are also identical with similar major lagoons in South and Southeast Asia. The backwaters comprise a system of interconnected lagoons, bays and swamps penetrating the mainland. The important backwaters in India are Cochin backwaters, Vembanad backwaters and Kakinada backwaters. Some scientists consider the two brackish water lakes such as Chilka Lake and Pulicat Lake also as backwaters. Similarly, some scientists categorise the above mentioned three backwaters as brackish water lakes or lagoons.

5.4.2. Brackish water lake fisheries

The major brackish water lake in India include,

1. Chilka lake

2. Pulicat lake

5.4.2.1 Chilka Lake

Chilka Lake (also Chilika Lake) is the largest brackishwater lagoon or lake in India. It is situated along the east coast of India khurda in Puri and Ganjam districts of the State of Orissa and encloses a number of small islands. The rivers Daya, Nun and Bhargovi, the distributaries of the Mahanadi, are the Principal perennial sources of freshwater to this brackishwater lagoon but the volume of their discharges is directly dependent on the intensity of rainfall over their catchment areas. The lake is connected to the Bay of Bengal by a long channel, 135 km wide. The area of the lake varies from 1165 km² in the monsoon season to 906 km² in the dry season, and is studded with numerous small islands. It is about 65 km long. The lagoon is having more than 20000 ha of fringe area or littoral zone. The entire area has been allotted for prawn culture. The length of the outer channel is 29 km and width is 365 m. On its south-west, the outer channel divides into two branches at Satpara, one continuing its original course, ends into a network of swamps and waterways while the broader one, taking a turn at right angles, finally reaches the main lagoon at a point called 'Mugger-Mukh'. The lake has an artificial man-made channel connecting Palur Bay (at southern extremity of the lake) with Rushikulya estuary. The depth of the lake varies from 25 m in the summer to 3.6 m in flood reasons.

The lake is divided into three sectors viz. Northern, Central and Southern.

5.4.2.1.1 Fish and Fishery

The lake maintains an ideal ecological condition to harbour and nurture catadromous, anadromous and endemic species of fish and prawn and the Irrawaddy Dolphin *(Orcaella brevirostris)*. There are 225 species of fishes belonging to 147 genera, 71 families and 15 orders. At present 35 species of fishes are commonly available in the lake of which 16 species are commercially important. They include *Mugil cephalus, Liza troshelli, Lates calcarifer, Eleutheronema tetradactylum, Pseudosciaena coibor, Nematalosa nasus, Mystus gulio, Tenualosa ilisha, Tachysurus arius, Osteogeniosus militaris, Plotosus canius, Grenidens crenidens, Gerres setifer, Etroplus suratensis, Sparus sarba* and *Strongylura strongylura.* Stomatopoda (2), Prawns and shrimps (24), Brachyuran crabs (28),Hermit crabs (6), Mollusca

(136) have also been recorded from Chilka lake., The four commercially important prawn species, available in this lake are *F. indicus, Penaeus monodon, Metapenaeus monoceros* and *Metapenaeus dobsoni.* The important crabs available in this lake are *Scylla serrata* and *Portunus* sp.

For better monitoring practices, these 16 economic fish species can be classified as under based on their breeding and migration habits. Mullets (*M. cephalus, L. macrolepis*), *S. sarba, L. calcarifer* and *C. crenidens* are catadromus by nature. *T. ilisha, N. nasus, P. coibor, T. arius, E. tetradactylum* and *G. setifer* are having anadromous habit. *M. gulio, O. militaris, P. canius, E. suretensis, G. setifer,* Beloniformes and *Tricanthus* sp. are endemic to the lake.

It is evident from the catch composition that the catadromus and anadromus species occupy more than 80% of the total stock in the lagoon. Most of the catadromus species breed near the lake mouth or inshore water in the sea while the anadromus species breed in the lake areas where the rivers Daya, Nun and Bhargovi discharge their monsoon runoff. The endemic species enjoy the entire northern and central sectors of the lake and Satpara area for breeding purposes. Moreover, the lake has been found to be enriched with variety of natural fish and prawn feed viz., detritus, algae, zooplankton, insect larvae, fish and prawn larvae, periphytic organisms etc. to suit the aquatics in all stages of their life cycle and in all niches.

The very high percentage of prawn seed in the tow net collection is not reflected in the total yield of prawn, the most commercially important species whose food chain is mainly comprised crustacean, detritus and zooplankton. Mullets, in spite of dominating the larval population in the lake, contribute only 12.5% to 14.7% in the total output. The species mainly thrives on bottom biota, mud and algae. Though there is overwhelming abundance of food of prawn and mullets, the predators might be primarily responsible for the comparatively low yield. The Chilka is not a self contained lake. About 70 to 80% of its fish load depends on migration to sea. Abundance of migratory species in the lake mainly depends on the condition of the outer channel and unobstructed ingress and egress of water over the area from Satpara to Mugger Mukh. The low output in the extreme southern sector indicates inactive role of the Palur canal in the migration. Accordingly, low migration rate might be another cause of low output. Some species of freshwater (carps and murrels) enter the lake during the monsoon and are caught, forming about 1% of total catch which is estimated to be 4000 tonnes/yr.

5.4.2.1.2 Crafts and Gears

The types of nets most commonly used are fixed gill net, fixed net, gill net, drag net, cast net, seine net and scoop net. Local *Bahini fishing* has been replaced by gill-cum-drag netting system. In the rivers mainly nylon gill nets and cast nets are operated. In deeper areas in the lake having less macro vegetation gill-cum-drag net/gill net and drag net with or without pockets are in use. Mostly country boats are used for fishing and mechanised boats though mainly used for transportation are slowly creeping in fishing activities.

5.4.2.1.3 Conservation and management

Regulated discharge through incoming rivers, siltation and anthropogenic pressure has made considerable negative impact on the fishery of Chilka Lake. On account of siltation, the lake has shrunken from 906 km^2 in 1965 to 620 km^2 in 1995. Siltation at the lagoon bed and the connecting channel has resulted in profuse weed infestation at 60 – 950 kg/m^2. In addition, the recently made man-made breakthrough between the lake and the ocean probably for promoting tourism caused changes to the lake's ecology. Hence, there has been a qualitative and quantitative decline in fisheries. Total fish landing has decreased from 4,243 tonnes in 1990 to 1270 tonnes in 1995. Prawn catch decreased from 28% to 14%. Overfishing and wanton destruction of stocks, barricading the outer channel with fixed small meshed gill nets, construction of pens with fine mesh nylon mosquito netting, increased number of operators atc are the factors attributed to the low fish production. The population of Irrawaddy Dolphins is also dwindling and has come down to as few as 50 in numbers due to entanglement in gill nets and drags nets. Cumulative effect of all these factors has caused a sharp decline of the once lucrative commercial fishery of the Chilka Lake. Therefore, it is neceassry to take stringent conservation measures to overcome all these problems for the improvement of the Chilka lake fishery. Chilka Lake is designated a wetland of international importance under the Ramsar Convention.

5.4.2.2 Pulicat Lake

It is the second largest brackishwater lagoon in India. It is located along the south-east coast of India between Andhra Pradesh and Tamil Nadu. Earlier, it had a water spread area of 461 km^2 with an average depth of about 1.5 m, but now it has shrunk to 350 km^2 with a depth of less than about one metre, chiefly due to siltation of the lagoon. Major portion of the lake is situated in the Nellore district of Andhra Pradesh and the rest in Thiruvallur district of Tamilnadu, where it is connected to the Bay of Bengal by a narrow mouth near the Pulicat village. The drainage area of the lake is 4,400 km^2 (more than 77,700 ha) and is highly productive giving an annual yield of about 1100 tonnes. There are three monsoonal rivulets that flow into the lagoon viz. Swarnamukhi, Kalangi and Arni. The Buckingham canal (East Coast Canal) flows through the Pulicat Lake at its southern end, near the Pulicat town. In addition to several mud-flats (some in the form of uninhabited islands), there are large islands viz. Sriharikota, Venaadu and Irukkam.

5.4.2.2.1 Fish and Fishery

Penaeid prawns constitute a major fishery in Pulicat Lake. Since prawns are highly priced and exported, the whole fishing pressure is on prawns in this lake. There are 12 species of penaeid prawns which include F. *indicus* (white prawn), *P. monodon* (tiger prawn), *P. semisulcatus* (green prawn), *P. canaliculatus* (striped prawn), *P. japonicus* (kuruma prawn), *P. latisulcatus*, *P. merguiensis* (banana prawn), *Metapenaeus monoceros* (speckled prawn), *M. dobsoni, M. affinis, M. brevicornis* (yellow prawn) *and M. burkenroadi*. Of the two exportable prawn species, *Penaeus indicus* is plenty in this lake which serves as an ideal nursery for this species. However, *P. monodon* is declining in numbers. It has a rich diversity of 29 species of crabs from marine, brackishwater, freshwater and terrestrial. Of these, the crabs, *Scylla serrata*, *S. tranquebarica* and *Portunus pelagicus* are highly abundant occurring all over the lake throughout the year. Indeed, Pulicat Lake is the largest producer of mud crabs among the various brackishwater bodies in India. Usually, non-padu fishermen are engaged in crab fishing in this lake.

The edible oyster (C*rassostrea madrasensis*) which is a keystone species here, is the most extensively distributed bivalve in this lake. In addition to this oyster, mud clam, *Meretrix casta* and blood clam, *Anadora granosa* are also common in this lake. The pearl oyster, *Pinctada vulgaris* occurs sparingly. A total of 168 species of finfishes have been recorded from this lake which include 1 shark species, 3 ray species, 164 species of teleosts (15 - Clupeiformes, 9 - Cypriniformes, 4 - Anguilliformes, 5 - Beloniformes, 1 - Syngnathiformes, 3 - Cyprinodontiformes, 8 - Mugiliformes, 1 - Polynemiformes, 95 - Perciformes, 1 - Mastacembeliformes and 15 - Tetraodontiformes). In fact, Pulicat lake is ideally suited for this edible oyster. The Pulicat lake fishery mainly consists of mullets, perches, clupeids, catfishes, prawns and crabs. Prawns and crabs constitute more than 50% of the catch, mullets (18-22%), perches (7.5 – 13%) and clupeids (6-10%). Perches form the valuable component of the fishery due to good taste and flavour. Most common species of perches are *Sillago sihama*, *Gerrus* spp. *Chrysophys* spp. *Lates calcarifer, Siganus* spp., *Etroplus* spp., *Therapon jarbua*, *Lutjanus* spp. and *Leiognathus* spp. The southern sector of this lake is more productive than the northern part.

5.4.2.2.3 Padu fishing system

System of fishing followed in Pulicat Lake is called ‘Padu system’ in which fishermen from one village operate nets in anyone of the ‘Padus’ (fishing grounds) or in all the padus simultaneously during the day allotted to them. The days are so arranged that each village gets the opportunity to fish in the areas specified for at least 2 days in a week by rotation. ‘Padus’ are fishing areas varying in depth from 1 to 3 m.

5.4.2.2.3 Fishing gears used

In addition to hand picking, encircling stake net and cast net are used for prawn fishing. Long lines and scoop nets are used for crab fishing. The fishing gears like bag net, drag net, shore seine, hook and line are commonly employed for fishing.

5.4.3.4 Killai Backwaters

It is a shallow body of brackishwater situated in Tamil Nau state between the Vellar and Coleroon (Kollidam) estuaries and extends to about 16 km in the north-south and 5 km in the east-west. It has a permanent connection with the Bay of Bengal. About 100 tonnes of prawns are landed annually. The prawn species in the order of abundance include *F. indicus*, *Penaeus monodon* and *Metapenaeus dobsoni*. *Macrobrachium rosenbergi* is found from October to December indicating that they migrate to estuary for breeding. Prawns are caught by stake nets, cast nets and drag nets.

Chapter 5: Shellfish fisheries of brackish waters / estuaries and pond fisheries

5.5.1 Introduction

Some species of gastropods and bivalves are found distributed in the brackish waters, estuaries, bays, lagoons etc. They are the collected by the poor fishermen and fisherwomen along both the east and west coasts.

5.5.2 Gastropods

Gastropods are mostly distributed in the shallow waters, lagoons and reef areas of the coastal sea. They are mainly reported from Gulf of Mannar, and Coramandal coast along the east coast, Lakshadweep and Andaman Islands. In the past, these shells were thrown out into the sea as discards. Nowadays, though they have less edible value, they find a prominent place in the commercial shell-craft industry. Many of these gastropods are exploited for food as well as for ornamental purposes. The shells are used in making ornaments and curios. They are used whole or cut into pieces of desirable shapes during processing. A few gastropod species are utilized as food by man. Demand for consumption of gastropods is not high in India, the same being limited for occasional use by poor class people including fishermen of coastal areas. The important species of edible gastropods of Indian coasts are *Cellana radiata, Trochus niloticus, T. radiatus, Umbonium vestiarium, Turbo marmoratus, T. intercostalis, Strombus canarium, Lambis lambis, Thais rudolphi, T. bufo, Oliva gibbosa.* Most prevalent practice is that the fishermen scoop out the soft body with a hooked iron rod, boil the soft body in a little brine, slice it and sun dry for future use as a fried curry. The gastropod shells with attractive shapes and colours are used as ornamental items.

5.5.3 Bivalves

Bivalves that include clams, mussels, edible oysters and window pane oyster are the shellfishes collected from the brackish waters and estuaries in India. The clams and mussels are not only limited to the sea coast; they often extend into muddy bottom of bays, estuaries and brackish water zones including the marshy lagoons along both the east and west coasts of India. Edible oysters are found in aggregated form on hard rocky or even on semi-hard sandy substrate in the bays and creeks near coastal waters. They are also available in the estuaries and other brackish water areas. Mostly, bivalves are collected for their meat and shell. Edible bivalves and ornamental shells gained popularity and their fishery improved after banning pearl fishing in 1961. During 1995-99, the average quantity of edible bivalve products exported per annum have been estimated as 580 tonnes, worth Rs.26 million and 567 t of oyster shell powder valued at Rs.1.5 million. The bivalve resources are mostly underexploitated along the northwest and northeast coasts whereas overexploited along the southeast and southwest coasts.

5.5.3.1 Production trends of bivalves

The average annual production of edible bivalves during 1996 to 2000 was estimated as 1.52 lakh tonnes, about 2.5 times more than the average landings during the period prior to 1996. A variety of clams, oysters, mussels and windowpane oysters are distributed along the Indian coastline. They are mostly collected by the local people. Clams and cockles form 73.8%, followed by oysters (12.5%), mussels (7.5%) and windowpane oysters (6.2%). The west coast accounts for 52.3% of the landing where the catch is utilized for both the meat and the shell.

Among the maritime states, Andhra Pradesh is the top producer (70,705 t) followed by Kerala (58,763 t). The production levels in other states are negligible.

Commercially important bivalves in the brackish waters and estuaries of India

Bivalves resources	**Common name**
Clams and Cockles	
Villorita cyprinoides	Black clam
Paphia malabarica, Paphia spp.	Short neck clam, Textile clam
Meretrix casta, M. meretrix	Yellow clam
Marcia opima	Baby clam
Mesodesma glabaratum	
Sunetta scripta	Marine clam
Donax spp.	Wedge clam
Geloina bengalensis	Big black clam
Anadora granosa	Cockle
Placenta placenta	Windowpane oyster
Tridacna maxima, T. squamosa and *T. crocea, Hippopus hippopus*	Giant clam
Mussels	
Perna viridis	Green mussel
Perna indica	Brown mussel
Edible oysters	
Crassostrea madrasensis	Indian backwater oyster
Saccostrea cuculata	Rock oyster

5.5.3.2 Mode of exploitation

Bivalve fishing

Both fishermen and fisherwomen are engaged in the bivalve collection in the estuaries, bays and brackish water lakes. Fishing methods for bivalves are simple, using non-mechanized gear ranging from manual picking to hand operated dredges. Clams are handpicked by men and women usually during low tide. In the shallow estuaries and sandy beaches, fishers usually remove the sand by their feet or by wooden or metal plates and pick out the buried clams. About 50 kg of clams are fished within 3 to 4 hours daily. A scoop net made of semicircular iron frame and nylon net of 30 mm mesh size is used for fishing clams. In deeper areas, fishermen go out in pairs, dive in turns and collect clams. In Kakinada Bay, Shoe Dhoni is used for clam collection with a fishing trip extending from 3 to 4 consecutive days. Oysters are gathered by separating them from the rocky substratum with knife. Mussels are also collected in the similar way. For the purpose of harvesting mussels, the fishermen walk through the shallow waters and reach the beds. They also dive in the deep waters and locate the encrusted mussels. Generally knives or iron chisels, fixed to wooden handles, are used to detach them from the encrustations. They are collected into baskets or net bags, tied to their waist.

5.5.3.3 Fishing season

The fishing season is usually during the post and premonsoon period. In certain estuaries of Goa, the clam fishery is mainly during the monsoon period when there is no marine fishing activity.

5.5.3.4 West coast

The estimated landing of bivalves along the west coast is 52,537 tonnes. Kerala state accounts for 47% of the total landing of clams and cockles. Organized clam fishery takes place in Vembanad and Ashtamudi lakes in Kerala. Vembanad is known for the black clam, *Villorita cyprinoides* while Asthamudi is known for the shortneck clam *Paphia malabarica.* Their fishery depends on the export demand. Mussels are the second dominant group, which are gathered all along the coast. Of the several species of clams, *Meretrix meretrix*, known as bay clam or great clam is the most popular. They are abundant along the coast of Karnataka, Goa and Maharashtra. Another clam, *Meretrix casta*, is very abundant in all the estuaries and the backwaters along both the coasts. Oyster fishery is limited to certain estuaries like Dharmadam, Vembanad Lake, Kayamkulam and Ashtamudi Lake. Clams and oysters are very popular in Karnataka where the fishery is conducted in the major estuaries like Udayavara, Mulky and Gurupur. Recently, the demand for green mussel has increased and about 2,000 tonnes of *Perna viridis* were landed during 2000. Information on the bivalve fishery and exploitation along the northwestern states is scanty. Nauxim Bay is famous for the fishery of windowpane oyster where about 8,000 to 10,000 oysters are gathered every day. In Maharashtra, bivalves are collected only in certain regions like Ratnagiri coast. Windowpane oysters and edible oysters are the main bivalve resource of Gujarat. However, there is no well organized bivalve fishery in these regions.

5.5.3.5 East coast

Tamil Nadu, Pondicherry and Andhra Pradesh are rich in bivalve resources. However, their utilization for human consumption is very negligible. Information on bivalve fishery in the northeastern states like Orissa and West Bengal are not available. Very extensive beds of clams are found in various sites of Tamil Nadu coast including Adayar and Athankarai estuaries, Andhra Pradesh coast. The clam, *Meretrix casta* is common along the east coast also. Some other species such as *Katelysia opima, Paphia* and *Gafrarium* are also found in good numbers in coastal areas. The Andaman and Nicobar Islands have several bivalve resources among which the black lip pearl oyster, *Pinctada margaritifera*, the giant clams *Tridacna maxima*, *T. squamosa*, *T. crocea* and *Hippopus hippopus* are gathered for the tourism based ornamental shell industry. *Perna viridis* and economically important clams like *Paphia* spp. are used occasionally. In the Lakshadweep Islands, local people collect the giant clams.

5.5.3.6 Utilization

The bivalves are utilized in various forms such as frozen, dried, pickled and canned clam and mussel meat, oyster shell powder and other ornamental shells. Bivalve meat is consumed along the west coast. Smoked and canned oysters are found in big cities. In Kerala and Andhra Pradesh, clams are also used for preparation of artificial shrimp feed or directly as shrimp feed. Shells of bivalves are used for the production of cement, calcium carbide, sand-lime bricks and lime. The lime shell is used as manure, as mortar in building construction, as a pesticide by mixing with copper sulphate, in the effluent treatment and in glass, rayon, polyfibre, paper and sugar industries. Attractive bivalve shells are used and traded for ornamental purpose.

5.5.3.7 Conservation and management

Bivalves are one of the least managed fishery resources along the Indian coast. There is no proper regulation for effective utilization and conservation of bivalve resources. Sexually mature bivalves with high reproductive potential constitute bivalve fishery. Indiscriminate exploitation of young clams and mussels take place in some states, especially in Kerala and Andhra Pradesh. Efforts for fishing bivalves can be enhanced in majority of the states.

Unit 6: Floodplain wetland (Beel) fisheries in India

Chapter 1: Ecology and classification of food plain wetlands (Beels) of India

6.1.1 Introduction

The floodplain wetlands are either permanent or temporary water bodies associated with rivers that constantly shift their beds especially in the potamon regimes. The frequency with which river changes its course depends on a number of variables like flow velocity, sediment transportation rate, slope, channel pattern, water and sediment yield, amount and duration of precipitation over the catchment area, texture and lithology of soil, tectonic status.

National Commission on Agriculture stated that the freshwater fishery resources, which have progressively gone into dereliction, comprise the floodplain wetlands. The floodplain wetlands usually represent the lentic component of floodplains viz., ox-bow lakes, sloughs, meander scroll depressions, residual channels and the back swamps and excludes the lotic component (the main river channels, the levee region and the flats). In addition, all the wetland tectonic depressions located in river basins are also included under floodplain wetlands. Thus, all the wetland formations located at the floodplains can be termed as flood plain wetlands. These are also called ox-bow lakes, locally known as *Beels* in Assam, Arunachal Pradesh, Meghalaya and Tripura, *Maun, Chaur and Dhar* in Bihar, *Pat* in Manipur, *Beel Charha* and *Baor* in Northern and Southeastern West Bengal and *Jheels* / *Tal* in Uttar Pradesh.

Wetlands are among the world’s most productive environments. They provide tremendous economic benefits to mankind through fishery production (over 2/3 of world’s inland fish harvest is linked to the health of wetland areas, the maintenance of water tables for agriculture, water storage and flood control, shoreline stabilization, timber production, waste disposal, water purification and recreational opportunities. They provide critical habitats for birds (especially water fowl), mammals, reptile, amphibian, fish and invertebrate species, some of which are threatened with extinction.

The wetlands associated with floodplains of rivers cover an estimated area of 0.2 million ha. They are a common feature of Indian landscape, especially along the Ganga and Brahmaputra river systems. There are 1,392 beels in Assam, of which 423 are registered with the Government and the remaining 960 are unregistered. Altogether derelict and semi-derelict wetlands are estimated to cover an area of 1,00,000 hectares. Referring to the flood plain wetlands of the country, Sugunan and Sinha observed “Floodplain wetlands form an important fishery resource in Assam, West Bengal and Bihar, where thousands of poor fishermen are dependent on these water bodies for their livelihood”

6.1.2 Geomorphology

The floodplain wetlands are an integral component of the Ganga and the Brahmaputra basins. The Indo-Gangetic plains are situated between the southern peninsula i.e. oldest mass in the Indian sub-continent and the extra peninsular Himalayas in the north. The Himalayan mountains are comparatively of recent origin and are distributed by earth movement, as evident from rock being folded, faucets, over thrust and even carried over some distance as thrust sheets. The plains occupy the depression in the earth's crust between these two elevated regions. Here the sediments are of recent origin and largely consist of silt which can be easily eroded. The Indo-Gangetic alluvial tracts, especially in the northeast, are also geologically unstable and experience earthquakes of varying intensities from time to time. Two devastating earthquakes occurred in northeast during 1897 and 1950.

Table 12.1. Floodplains and oxbow lakes of Ganga, Brahmaputra and Barak basins

Basin	Eco-region	Drainage area of basin (million ha)	Total geographical area of the country (%)	Average population density (per sq. km)	Tributaries on which oxbow lakes are situated	State of oxbow lakes	Area of oxbow lakes (ha)
Ganga	Hot, sub-humid, moderate rainfall	86.15	26.2	414	Ghaghra, Tons, Yamuna, Gomati, Chhoti Sarju, Sarda, Ramganga, Chambal, Burhi Rapti, Gandak, Burhi Gandak, Lakhandei, Beghamti, Adhwara, Kamla, Kosi, Bhagirathi, Hooghly, Icchamati, Mayurakshi, Dharub, Dharakla, Jalangi, Churni, Kalindi, Dharub, Dharala, Pagla, Behula, Torsa and Mahananda	Uttar Pradesh Bihar West Bengal	NA 40,000 42,500
Brahmaputra	Hot humid to warmer humid,	19.44	5.9	149	Dibru, Burhidihing, Dishang, Dikhow, Jhanji,	Assam Meghalaya Arunachal Pradesh	92,000 213

	high rainfall zone				Kakodonga, Dhansiri, Sonai, Kapili, Kulsi on south bank and Dihang, Aai Pontemeri, Mora, Jiadhal, Subansiri, Manas, Dhansiri, Dhansiri, Kameng, Pagladia, Champabati, Sarabhanga on north bank		2,500
Barak	Hot humid to warm perhumid, high rainfall zone	4.17	1.4	24	Baral, Sonai, Sushma, Dhaleswari, Longai	Meghalaya Manipur Assam Tripura	213 16,500 8,000 500

(Source: ICAR Handbook on Fisheries and Aquaculture)

Table: 12.2. Distribution of oxbow lakes in the Ganga, Brahmaputra and Barak basins

State	River basin	Lake district	Area (ha)
Uttar Pradesh	Ghaghra, Tons, Yamuna, Gomti, Choti Sarju, Sarda, Ramganga, Chambai, Burhi Rapti	Ballia, Azamgarh, Mau, Basti, Deoria, Gorakhpur, Jaunpur, Rae, Bareilly, Pratapgarh, Allahabad, Barabanki, Sitapur, Unnao	10,000
Bihar	Gandak, Burhi Gandak, Lakhandei Baghmati Adhwara, Kamla, Kosi	West Champaran, East Champaran, Muzaffarpur, Darbhanga, Sitamarhi, Madubani, Samastipur, Purnia, Saharsa, Begusarai, Khagaria, Monghyr	40,000
West Bengal	Bhagirithi, Hooghly, Lcchamati, Mayurakshi, Dharub, Dharakla, Jalangi, Churni, Kalindi, Dharub, Dharala, Pagla, Behula, Torsa and Mahjananda	Nadia, Murshidabad, Burdwan, Maldah, 24 Parganas, Hooghly, Birbhum, Cppch Behar, Midnapur, Dinajpur	42,500
Foothills of Arunachal Pradesh	Kameng, Siang, Dibang, Dihang, Tirap, Lohit	East Kameng, Lower Subansiri, East Siang, Dibang valley, Lohit, Tirap	2,500

Brahmaputra basin of Assam	Lohit, Buhri dihing, Dibru, Jhanji, Dikhow, Dimow, Manas, Kapili, Sonai, Pagladia, Dhansiri, Kakodanga, Kollong, Subansiri, Aai, Jhanji, Champabati, Kakodanga, Dibru, Dishang, Pontemeri	Tinsukia, Dibrugarh, Sibasagar, Jorhat, Lakimpur, Golaghat, Dhemaji, Sonitpur, Darang, Nagaon, Morigaon, Nalbari, Kamrup Barpeta, Goalpara, Dhubri, Kokrajhar	92,000
Barak basin of Assam	Barak, Sonai, Sushma, Katakhal, Dholeswari and Longai, Rukni	Karimgani, Hailakandi, Cachar	8,000
Valley district of Manipur	Iral, Imphal Thoubal	Imphal, Thoubal and Bishunipur	16,500
Foothills of Meghalaya	Someshwari and Jinjiram	Khasi and Garro hills	213
Valley district of Tripura	Gomti, Manu and Khowai	North South and West Tripura districts	500

(Source: ICAR Handbook on Fisheries and Aquaculture, 2006)

6.1.3 Origin of floodplain wetlands

The lithology, geological structure, tectonic status, seasonal variation in river discharge and flow characteristics largely determine the formation of floodplain wetlands. The beels of country owe their origin either to the often changing course of river in the potamic stretches or tectonic adjustment.

In the northern part of Bihar and West Bengal as also in Assam, the river emerging from the central and eastern Himalayas suddenly debouch into plains and ultimately flow down as the river Ganga, Brahmaputra and Barak. These river carry heavy loads of silt and detritus from the Himalayas and overflow during southwest monsoon season submerging huge tracts of land every year. These river change their course every often creating numerous floodplain lakes and braided channels, mainly in the form of oxbow lakes. In deltaic West Bengal, due to low gradient and high riverine discharge during monsoon season, rechannelisation of rivers occurs at the slightest obstruction to flow, resulting in creation of beels of varied types. In the northeast i.e. Assam, foothills of Arunachal Pradesh, Meghalaya, frequent earthquakes coupled with heavy rainfall and cutting action of river meanders have resulted in the formation of typical ox-bow lakes, lake like beels or true tectonic depressions. The pats of Manipur owe their origin mainly to the cutting action of stream meanders.

6.1.4 Physico-chemical features of soil and water

Important physico-chemcial features of soil is, bottom very rich with organic carbon, available nitrogen and phosphorus. Bottom soil of these lakes is enriched by organic matter, inorganic minerals through deposits of decaying weeds, incurring of river water and surface run-off, therefore all the aforesaid parameter change from year to year.

Floodplains of Ganga system are more or less alkaline whereas the lakes of Brahmaputra basin are acidic to neutral in nature. Among the dissolved gases, the concentration of dissolved oxygen and free carbon dioxide always remains at optimum level. The total alkalinity and specific conductivity range of water is indicative of moderate to high production. The dissolved organic matter of water which determines the chemical oxygen demand (COD) is quite high. The high values may be attributed to constant loading of organic detritus and sedimentation due to death and decay of macrophytes. In contract to rich nutrient status of soil phase, the nutrient status of water has low nitrate and phosphate. It appears thus both the major nutrients are locked either in soil phase or macrophytes. Judging from ecological yardstick, it is evident that nutrient status of soil and of water of these lakes is extremely high. The shallow nature of the basin, presence of euphotic zone and rich nutrient status are attributed to fish production.

6.1.5 Components of a typical flood plain

According to Leopold *et al.*, (1964), a typical floodplain will include the following

i. T**he river channel**

ii. **Ox bow lakes** : cut off portion of meander bends of river.

iii. **Point bars** : these are loci of deposition on the convex side of curves in the channel.

iv. **Meander scrolls** : Depressions and rises on the convex sides of bends formed as channel migrates laterally down valley by the corrosion of the concave bend.

v. **Sloughs** : area of dead water formed both in the meander scroll depression and along the valley walls as flood flow more directly down valley scouring adjacent to the valley walls.

vi. **Natural levees** : Raised barns or crests above the floodplain surface adjacent to the channel, usually containing coarsest materials deposited as flood flow over the top of the channel banks. These are most frequently found at the concave bank and are submerged annually. They may be absent or imperceptible where most of silt load in transit is fine grained.

vii. **Back swamp deposits** : over bank deposits of finer sediment deposited in slack water ponded between the natural levees and the wall or terrace riser. These are submerged for long period of the year.

viii. **Sand splays** : deposits of flood debris usually coarse sand particles in the form of splays or scattered debris.

6.1.6 Classification of floodplain wetlands

The floodplain wetlands include low lying water bodies of diverse origin, size, shape, depth, inundation pattern, ecological characteristics etc. They can be classified as below

6.1.6.1 Classification based on morphology

i. Ox-bow lakes : These are cut off portion of river meanders. The basins are relatively narrow, long, deep and have either bend or straight shapes. They derive the name from their shape, which is usually horse-shoe shaped, crescent shaped or serpentine. They receive water from the parent river through the old channel or neighbouring catchment areas.

ii. Lake like wet : These are wide and shallow with irregular contours. They may be connected to the river through channels or receive water from it during floods. During the monsoon season, the entire neighbouring areas gets flooded turning the beels into vast sheet of water whereas during non-monsoon season the water spread area shrinks to the basin proper.

iii. True tectonic depressions : These are created by tectonic activities like earthquakes and usually resembles natural lakes with regular contours. Normally they are not connected to river through connecting channels but may receive water from latter during floods. Such tectonic wetlands are common in the northeastern region.

iv. Meteorite lake : These are created by the impact of full of a meteorite on earth. Such beels have regular, nearly oval shape and abnormally high banks on all sides, which, according to geologists, can be created when the left over portion of a large meteorite hits the earth. The morphometric features of the beels are similar to those of volcanic lakes, except for the fact that they are located in the plain and are very shallow.

6.1.6.2 Classification based on water retentivity

i. Seasonal *beels* : These are shallow floodplain wetlands, which periodically get inundated by monsoon rains and floods but completely dry up during summer months.

ii. Perennial *beels* : Deeper and permanent beels, which retain water round the year.

6.1.6.3 Classification based on depth

i. **Shallow *beels*** : having max. depth up to 5 meters

ii. **Medium *beels*** : having max. water depth ranging from 5 – 10 m.

iii. **Deep *beels*** : having max. depth of over 10 metres.

6.1.6.4 Classification based on size

i. **Small *beels*** : Effective area less than 100 hectares.

ii. **Medium *beels*** : Effective area 100 – 500 hectares.

iii. **Large *beels*** : Effective area more than 500 hectares.

6.1.6.5 Classification based on riverine connection

i. Open *beel*s : These *beel* retain continuity with parent river either for the whole year or at least during the rainy season. Such *beels* have continuous exchange of water as well as fish fauna with parent river.

ii. Closed *beels* : These *beels* are completely cut off from the nearby river and receive water mostly from their catchment area following monsoon rains or during high flood.

6.1.6.6 Classification based on the extent of macrophyte infestation

i. **Weed chocked *beels*:** A *beel* can be considered a weed chocked when more than 50% of the total water spread area is covered by aquatic macrophytes.

ii. **Moderately weed infested *beels*** : A *beel* can be considered as moderately weed infested when less than 50% of total water spear area is covered by aquatic macrophytes.

Chapter 2: Fish and fisheries of floodplain wetlands (Beels) in India

6.2.1 Ichthyofauna diversity

The faunistic composition of these lakes generally reflects the diversity of the parent river as well as the state of entrophication of that particular lake. In open-lakes, the catch is dominated by the riverine fauna during flood season. The principle indigenious fishes inhabiting these lakes are 58 spp. belonging to 34 genera from these lake indicates that the resources supports rich and varied indigenous stocks of carps, catfishes, feather backs, snake heads, herring, gobies, perches, needle fish, mud eel, spiny eel, loaches etc. Because of the ecological changes of these lakes from oligotrophic to eutrophic, the fish spp. goes on changing. The members of Notopteridae, Siluridae, Bagridae, Sisoridae and Schilbeidae are encountered mostly in the open type lake. The ecosystem is an important source of food, forage, larvicidal and therapeutically important fishes. Presence of various species may be attributed to nature of basin, type of lake, impact of embankment, intensity of eutrophication and introduction to exotic.

Table: 12.6. Estimated fish yield of some oxbow lakes of Ganga, Brahmaputra and Barak basins

Basin	State	District	River basin	Name of lake	Area (ha)	Estimated fish yield (kg/ha/ year)
Ganga	Uttar Pradesh	Ballia	Ghaghra	Surhatal	2,000.00	240.00
		Mau	Ghaghra	Ratoital	800.00	142.0
		Azamgarh	Tons	Salontal	200.00	245.00
		Basti	Ghaghra	Chandutal	230.00	150.0
		Allahabad	Yamuna	Alwar Jheel	250.00	150.0
	Bihar	Muzaffarpur	Burhi Gandak	Sikenderpur	45.5	230.00
		Muzaffarpur	Burhi Gandak	Manika	105.8	190.00
		Samastipur	Burhi Gandak	Muktapur	60.00	120.00
		Champaran	Burhi Gandak	Motijheel	100.0	147.00
		Samastipur	Burhi Gandak	Muktapur	60.0	240.00
	West Bengal	Hooghly	Hooghly	Kol	81.6	150.0
		Nadia	Bhagirathi	Boror	9.2	204.0
		Murshidabad	Bhagirathi	Bhandardaha	437.0	150.0
		Cooch Behar	Dharub	Khoardo	50.0	204.0
		Barddhaman	Bhagirathi	Bansdaha	26.00	1,100.0
		24 Pargana	Lchhmati	Garapota	122.00	330.0
		Malda	Ghurnamani	Pagla	40.00	137.0
Brahmaputra	Assam	Kamrup	Brahmaputra	Dora	160.0	116.00
		Sonitpur	Brahmaputra	Dighali	40.0	36.00
		Barpeta	Brahmaputra	Kapla	75.0	126.0

		Dibrugarh	Brahmaputra	Mer	30.0	71.0
		Naogaon	Brahmaputra	Samaguri	60.00	96.00
Barak	Assam	Cachar	Barak	Ramnagar	15	215.00
		Karimganji	Longai	Sone	3,458	97.00

(Source: ICAR Handbook on Fisheries and Aquaculture, 2006)

6.2.2 Fisheries of the open *beels*

Some beels retain their riverine connection for a reasonably longtime which are relatively free from weed infestation. These beels are typical continuum of rivers where the management strategy is essentially akin to riverine fisheries. Thus, basic approach is to allow recruitment of conserving and protecting the brooder and juveniles. These measures have the dual advantage of conserving the natural habitat of the beels along with extending the benefits of conservation to the lotic ecosystem of the parent stream. In capture fishery management, the natural fish stock as managed, therefore a thorough insight of population dynamics including recruitment, growth and mortality is very much essential. Identification and protection of breeding grounds, allowing free migratory of Brooders and Juveniles and conservation measures to protect brood stock and juveniles are important.

6.2.3 Culture based fisheries of closed *beels*

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

The right species stocked in right number, in right size and their recapture at right size are determining factors. These have to be decided as a part of ecosystem oriented management. The management parameters are size at stocking, stocking density, fishing efforts, size at capture, species management, species selection and selection of fishing gear.

6.2.4 Culture and capture fishery of *beels*

There are systems, which combine the norms or capture and culture fisheries. The marginal areas of beels are cordoned off for culture systems either as ponds or as pens and the central portion is left for capture fisheries. This has been tried in many places of the country.

In order to increase production from beels, some culture practices can be easily incorporated without disturbing the existing practice of capture fisheries. A system of combining capture fishery and aquaculture has been developed by CIFRI, which has been practised widely in the eastern and northeastern states of India.

Under this system, a series of small enclosures are created along the periphery of the lake to be leased out to entrepreneurs for aquaculture. These enclosure can be made of earthen dykes or bamboo mat barricades. Some of the enclosure can act as nurseries to rear fish seed both for aquaculture and stocking. When culture based fishery is practised the connecting channel should be protected with wire mesh to prevent stocked fish from escaping.

Integrated system of development of floodplain wetlands and beels in which integrate the many uses of floodplain wetlands and minimize conflicts. Floodplain wetlands and areas along their margins already tend to become swamps converting these marginal areas into paddy fields is comman practice among relatively resource rich farmer. The beels area consequently shrinks. Fisheries get marginalized in the process. This is a very common cause of conflicts among the various water users. As some lake serve as bird sanctuaries, environmentalists are often cautions about competing uses. The flood plain wetlands are used for a variety of other purposes such as navigation, jute retting, collection of edible aquatic mollusc and plants. Each activity affects other water uses.

The integration plan envisages developing agriculture and aquaculture in swampy portion, while leaving the deeper portion of opposite for capture and culture based fisheries. There will be a dyke separate the two segments of the lake and water flow to the agriculture and aquaculture activities in the southern segments will be regulated through small canals. A central marshy portion of the beels / floodplain wetlands will be left for to attract migratory bird species. In most of these lakes, exotic species have established and changed the species composition.

6.2.5 Main groups of fishing methods used in floodplains

i. Passive gear : Set barrier (banas), dip nets and traps gill net. They capture fish as they migrate to or return from the *beels*.

ii. Active gear : Drag nets, seine nets, frame nets, trawls and scoop nets. These are mainly used during by season.

iii. Fish Aggregating Devices (FADs) : Katal/jeng fishing. This is an indigenous method of erecting circular patches of weeds to attract fish. Katals are erected during August – September and harvested from December onwards. While harvesting, the katal area is encircled by banas/nets. After gradually reducing the encircled area, fishes are caught by using cast and drag nets.

iv. Falling gear : (Polo, castnets), hook and line, wounding and grapping, catching with hands, etc. are of minor importance.

v. Dewatering : Which is destructive fishing practice, has also become an important method in many small, closed beels in recent years.

6.2.6 Guidelines for fishery management of floodplains

Biological productivity of water body depends primarily on the capacity of the system to trap solar energy and store them in the form of chemical energy. The energy conversion efficiency at trophic levels of consumer differs considerably from one water body to another, variations in the biotic communities.

The infestation density per unit area of aquatic weed is extremely high (16.5 – 31.2 kg/2). Therefore ecological niche of various fish species is lost, and production of natural fish food organism is adversely affected. Aquatic weeds provide congenial condition for growth and multiplication of predatory and weed fishes but adverse condition for commercially important carps. The spectrum of species composition indicates that the marsh inhabitants are increasing in taunal composition. The catch composition has changed towards abundance of species of lesser economic importance. The present trend is warning signal on the problems that may arise in larger dimensions in near future.

6.2.6.1 Culture based fisheries and enhancement

When the fish harvest in an openwater depends mainly or solely on artificial recruitment it is referred as culture based fishery. Fisheries enhancement is the process by which qualitative and quantitative improvement is achieved from water bodies through exercising specific management options. This can be in the form of improving stock, changing the exploitation norm, changing craft and gear, introducing new forms of access and so on. The common norms of enhancement which are relevant to Inland water bodies of India are as follows:

a. **Stock enhancement:** Augmenting the stock of fish has been the most common management measures followed in the beels. Augmentation of stock is necessary to prevent unwanted fish to utilize available food niche and flourish at the cost of economically important species. The main aspects of stock enhancement are the selection of species for stocking, determination of stocking rate and the size at stocking.

b. **Species enhancement** : Is planting of economically important, fast growing fish from outside with a view to colonizing all the diverse niches of the biotope for harvesting maximum sustainable crop from them. It can be just stocking of new species or new introduction.

c. **Environmental enhancement** : Is improvement of nutrient status of water by selective input of fertilizers. Although this is common management option adopted in intensive aquaculture, a carefull consideration of the possible impact on the environment is needed before this option is resorted to in the floodplain wetlands.

d. **Adoption of pen culture technology** : Owing to multiple ownership, great number of uses, conflicting land use practices, high cost on reclamation, the exploitation and management of then resources are not an easy task, and therefore aquafarmers are facing problems for undertaking fish culture activities in these lakes. Similarly, improvement of lake condition is difficult task due to high cost of reclamation. These problems have to be resolved if the enormous potentialities of these water bodies are to be trapped for production of fish crop. Under multiple ownerships and multiple use system, exploitation of the production potential is possible through adoption of pen culture technology developed by the CIFRI, Barrackpore.

6.2.6.2 Capture fisheries of floodplains

Some floodplains retain their riverine connection for a reasonably long time, which are relatively free from weed infestations. These floodplains are typical continuum of rivers where the management strategy is essentially akin to riverine fisheries. Thus, basic approach is to allow recruitment by conserving and protecting the brooders and juveniles. These measures have the dual advantage of conserving the natural habitat of the beels along with extending the benefits of conservation to the lotic ecosystem of the parent stream. In capture fishery management, the natural fish stock is managed. In order to recruitment, the following parameters are taken into consideration.

i. Identification and protection of breeding grounds

ii. All free migration of brooders and juvenile from beel to river and vice-versa.

iii. Protection of brood stock and juveniles by conservation measure.

The growth overfishing is prevented by taking appropriate measures for gear selection. Adjustments in quality and quantity of fishing gear are an essential component of capture fishery management.

Common strategies followed are summerised as:

i. Increase the minimum mesh size.

ii. Increase or decrease the fishing effort

iii. Observe the closed season to protect brooders.

iv. Strict adherence of the restriction on the minimum size of capture.

v. Diversity of the gear

vi. Selective augmentation of stock, only if available.

6.2.7 *Beel* fisheries in Assam

Assam is gifted with many extensive water bodies commonly known as *beels* that are the only source of fish for the poor people in the surrounding villages. Historically there have been three distinct groups of people involved in organized fishing in the *beels*: (i) those who catch fish for their own daily consumption; (ii) those belonging to the fisher community and depend on fishing for their livelihood; and (iii) rural entrepreneurs (lease holders). Ordinary people usually fish daily for food, while fishers are full-time operators working independently or under the lessees. The lessees further auction the leases to the fishers and provide capital at usurious rates of interest to them.

6.2.7.1 Classification of *Beels* in Assam

All natural wetlands are called *beels* in Assam. In 1992, the Assam Remote Sensing Application Centre, Assam Science and Technology Education Council, and the Space Application Centre of the Indian Space Research Organization developed a classification system for the wetlands in Assam that divided them into six categories: (i) lake/pond; (ii) oxbow lake/cut-off meander; (iii) waterlogged areas; (iv) swamp/marsh; (v) reservoir; and (vi) tank. The first four are natural water bodies while the last two are human-made. Natural wetlands sometimes have feeder channels controlling the inflow and outflow of water. Lakes and ponds have a unique physiographic setting with undulating terrain, while oxbow lakes/cut-off meanders are crescent-shaped water bodies located along streams in abandoned oxbows after a net cut-off is formed. Areas where water stands near, at or above the land surface so that the roots of all plants except hydrophytes are drowned and the plants die are in the waterlogged category. These water bodies are perennial, irregular in shape and occur in low-lying areas. They normally have feeder channels and the water varies from season to season. During the monsoon, a number of waterlogged areas join together to form single big wetland. A swamp is an area intermittently or permanently covered with water, with shrubs and trees, but essentially without the accumulation of peat. A marsh is defined as waterlogged ground with a large mineral basin.

6.2.7.2 Resources

A total area of 101 232 ha is covered by 3 513 wetlands. This is close to 4% of the total floodplain area and 1.3% of the total area of the State. The lakes/ponds occupy an area of15 494 ha and number 690. There are 861 oxbow lakes/cut-off meanders covering 15 461 ha. The water Logged areas number 1 126 and occupy 23 436 ha (dry season satellite data). The swamps and marshes cover an area of 43 434 and number 712.

Type	Number	Area (ha)	%
Natural			
Lake/Pond	690	15494	15
Oxbow lake/cut-off meander	861	15461	15
Waterlogged area	1125	23432	23
Swamp/marsh	712	43434	43
Subtotal	**3388**	**97821**	**96**
Human-made			
Reservoirs	10	2663	3
Tanks	115	750	1
Subtotal	**125**	**3413**	**4**
Total	**3513**	**101234**	**100**

The resources of these wetlands are important for human nutrition and the economy as they provide a habitat for a number of aquatic flora and fauna, including migratory and indigenous birds. Fishing is the main economic activity in the *beels*. A total of 106 fish species has been reported from the Assam *Beels*. They are listed below.

Chela spp. (2 species), *Securicula gora*, *Salmostoma* spp (2), *Esomus danrica*, *Danio devario, Rasbora* spp (3), *Aspidoparia* spp (2), *Barilius* spp (7), *Cyprinus carpio* var. *communis, Cyprinus carpio* var. *specularis, Puntius* spp (6), *Osteobrama cotio* , *Labeo* spp (9), *Chagunius chagunio*, *Tor* spp (2), *Cirrhinus* spp (2), *Catla catla*, *Crossocheilus latius latius, Noenacheilus botia botia,Botia dario*, *Lepidocephalichthys guntea*, *Somileptes gongota*, *Rita rita*, *Batasio* spp (1), *Chandramara chandramara, Mystus* spp (6), *Ompok* spp (3), *Wallago atu*, *Ailia cotla* (2), *Pseudeutropius atherinoides ,Clupisoma garua, Silonia silondia*, *Pangasius pangasius, Amblyceps mangois* , *Bagarius bagarius* , *Gagata cenia, Nangra viridescens, Erethistes pussilus, Glyptothorax* (2), *Clarias batrachus, Heteropneustes fossilis, Chaca chaca, Xenetodon cancila, Channa* spp (5), *Amphipnous cuchia*, *Chanda* spp (2), *Badis badis, Nandus nandus*, *Sicanugil cascasia, Anabas testudineus, Rhinomugil corsula, Glossogobius giuris, Colisa* (4), *Macrognathus* (3), *Tetradon cutcutia, Gadusia chapra, Ambypharyngodon mola, Notopterus (2) and Setipinna phasa.*

Note: Figures in parantheses indicate the number of species in the particular genera

6.2.7.3 Fish yield potential

Most of the fish catch is consumed as food by the local people. *Beels* are very rich in nutrients and have a great production potential Based on eco-energy studies, Jhingran and Pathak (1987) estimated the production potential of *beels* at 1,80,00,000 Kcal of energy/ha/year or 1,500 kg/ ha/year. A recent study indicated very high fish yield potential in the range of 476-2324 kg/ha. The beels of Assam are one of the prime natural sources of natural capture fishery dominated by small fish species including many species of ornamental importance. The yield rate ranges from 14 to 488 kg/ha/yr. The productivity of oxbow lakes can be increased to 2,000-4,000 kg/ha/year by introducing extensive or semi-intensive aquaculture. In other wetlands, productivity can be increased significantly by strictly implementing the existing fisheries regulations.

6.2.7.4 Trap fishing in Assam *Beels*

Traps are artificial devices for capturing fish. Trap capturing of fish is based on the principle of leading the fish to enter into a trap by enticing or attracting them. After entering into the trap, it will be difficult for the fish to exit through the same and the only opening, as it is defended with a non-return valve or labyrinth. A wide range of fish traps to collect fish and other aquatic animals has been evolved by the fishers of Assam who contribute to the fish production of Assam and the economy of the local community, An attempt has been made in this communication to classify and describe the different fish trapping implements and their mode of operation in the floodplains of Assam. The identified fish traps can be classified into 28 different types of five major categories, based on the principle of capture, design, and operational methods. These traps vary widely with shapes ranging from conical, cylindrical, pyramidal to rectangular, mostly of fine screen-work, made of slender splices of bamboo.

Hiding places: Artificial implements or devices stuffed with bunches of twigs, bushes, and weeds are placed in the water body for luring fish. The fish so lured are captured. The major fish catches that result from this system are *Mastacembelus armatus*, *Mystus* spp *Puntius* spp *Clarias batrachus*, *Channa gachua* and small prawns. The various devices used to serve as hiding places for the fish are explained here under.

(a) ***Dolonga/ Derjakori/ Tak****:* This is a bowl shaped bamboo woven trap usually filled with weeds, tree branches and twigs to provide shelter to the fish. The anterior open end of the trap is supported with bamboo hoops to provide rigidity. The trap is placed and lifted from water with the help of two whole bamboo poles along the diameter (2.5 m) of the trap. The trap is mostly used to catch fish in *beels* and slow flowing water bodies throughout the year. A bamboo pole or a banana trunk is used to mark the location of the trap in water. The approximate cost of this gear is Rs,500.00. These have a life span of 2-3 years.

b) ***Hukuma:*** This is a funnel shaped bamboo-made trap stitched intermittently with bamboo splits to provide rigidity. Fish enticed from its open end (09-1.3m dia) cannot retreat back. The 2.25 m long trap is mostly operated in *beels* and mild flowing rivers.

(c) ***Khoka:*** This trap resembles *hukuma* in its shape, except in respect of its mode of construction. This trap is constructed of a single piece of a bamboo of 1 m length where one end is closed, while the opposite end is split so as to enable them to have space between one another (0.6 m). The trap is operated in weed infested water bodies at lesser depths. The trap is lifted periodically to remove the fish. The price of this trap ranges from Rs.30.00-100.00 in the market.

(d) ***Chunga/ Dhun:*** This is a simple piece of bamboo or betel nut trunk of 0.5-1.0 m length. It is closed at one end by a node. The trap is placed at the bottom of a water body at a reachable depth and is marked with a float to locate its position. Fishes that get enticed to enter inside it are caught.

Barricades/Barriers

These are complete barriers, principally made of various non-textile materials which prevent the escape of fish from a certain natural area in which they have voluntarily entered after having been intercepted in their course of migration or movement in their search of food and breeding grounds.

(a) ***Barriers:*** Locally known as *banas* these are often installed across rivers and channels connecting to *beels* in the configuration of alphabet "V". These are made of closely woven bamboo splits fastened together with coir and plastic ropes permitting Interspace as low as 0.5-1.0 cm between them. The inner wall of the submerged portion of banas is further lined with mosquito netting serving as a guide wall to lead the fish into a lever operated dip net installed at the end of the passage, This set is generally installed during the winter season from September to

April when water flows at a lesser speed. Priced fishes such as *Chitala chitala*, *Wallago attu*, *Labeo* spp., *etc.* are its major catch.

Tubular traps

These are the set traps or enticing devices, exclusively of those made of textile, which prevent the escape of fish by means of trap doors provided with non-return valves. The traps vary in shapes. The catch comprises fishes such as *Mastacembelus aculeatus, Mastacembelus armatus, Mystus* spp, *Mystus tengra, Monopterus cuchia. Channa punctatus, Channa gachua, Channa marulius, Clarias batrachus, Aorichthys aor, Chitala chitala. Puntius spp,* small prawns etc.

(a) ***Seppa/ Tepa:*** It is a spindle shaped trap with the maximum girth at the middle and tapering at the ends. This bamboo woven trap varies from 0.2-0.9 m in length and is provided with 1-4 numbers of trap doors along the mid alignment of the base. The trapped fish are removed from an opening at the posterior extremely. These traps are operated in inundated paddy fields and shallow water bodies during monsoon season. The trap costs Rs.50.00-100.00 each.

(b) ***Bhari/ Seppa*** *:* This is a spindle shapped trap made of a single piece of thick bamboo. The piece is split up at one end while the other end remains complete and whole. The trap attains a maximum girth at the mid region and is provided with a trap door located near to the anterior end guarded with non-return valves.

(c) ***Koita/ Kotia/ Seppa:*** It is an elliptical shaped trap (32-87cm length) with maximum girth (0.6-1.5 rn) at its middle. This trap has two tap doors, one at the anterior extremity and the other at the mid girth. The trap is operated during rainy season in all types of shallow water bodies. Dry fish, large ants and earthworms are used as baits. The cost of each of the traps varies from Rs.10.00-25.00 and the life span ranges from 1-6 years.

(d) ***Ubhoti/ Queen/ Faron/ Kuni/ Tuni:*** This tubular trap is longer (0.4-0.9 m) than its breadth (0,2-0.7 m) and has a uniform Circumference from tile base to a certain height. The split spieces of the trap converge into an apex as a bunch, bound round by a chord or rope. The trap is guarded with two trap doors having non-return valves of which: one rectangular shaped value arising from the base to its height and the other, circular in form, fastened to its inner circumference. Trapped fishes are taken out by untying the bunch at the apex. The trap is operated in flooded paddy fields, catchment areas of river, derelict water bodies and muddy areas during flood season (Aug-Sep). Molluscs, earthworms and mussels are used as baits. Cost of each of the traps varies from Rs.15.00-100.00 and a trap may last for 3 months to 3 years depending on its usage.

(e) ***Paori/Doo/Juti/Sasha:*** This is one of the biggest traps used in Assam. The length varies from 1.2-2.5 m with a diameter of 0.5-0.9m. Like ubhoti, this trap is made of bamboo splits (0.3-0.8 cm thickness) and has a uniform circumference from the base up to a certain height from where the strips converge into a tapering point as a bunch, bound round with a chord. The trap is supported with bamboo hoops along its inner and outer circumferences at regular intervals to provide rigidity. The base is concave shaped with a trap door for the entrance of fish. Based on harvesting method and mouth opening, three varieties have been observed. The trap is operated during monsoon months in rivers and *beels.* The cost of each ranges from Rs.100.00-1500.00 and the life span is 1-3 years.

(f) ***Dumukhi/ paori*** **:** This trap resembles the earlier trap(item e) in all details except for having a uniform circumference (85 cm dia) all along its height (1.75 m). Both the ends are provided with an oblique trap door tilted inwardly for a length of 28 cm from the base. Both the ends have a diameter of 25cm. The trap is operated in *beels* and rivers with mild flow. The trap is fixed with bamboo poles for holding it in position, when operated in deeper areas. Approximate cost of the gear is Rs. 350.00 and its life span is 4 years.

(g) ***Dingoral/Bundh dingoral/Runga/Farom:*** This is a drum shapped trap with 1-2 numbers of non-retractable trap doors, one followed by the other. The anterior end is circular in configuration and possesses a door, while the posterior end is closed and varies from triangular to trapezoid shape. A small outlet at the posterior end is used for removing the enticed fish. This trap varies in design and rigging from one place to another and hence the cost and life span also very.

❤***Ghumal khowa:*** The trap is drum-shaped with a circular base of 0.7 m diameter fixed with a trap door. Usually a bamboo screen is erected towards the trap door to lure fish into the trap. The trap is closed at the opposite end. Fish is harvested from a small window measuring 19x14cm constructed at the mid part. This bamboo woven trap measures 1.6m in length and is operated in *beels*, rivers and lotic water bodies. The cost of the gear is Rs.600.00 with a life span of 5-6 years.

(i) ***Ghonli:*** The trap is cylindrical in shape with a uniform circumference of 1.3-1.9m diameter and 0.8-1.5m in overall length. The anterior end has a non-return trap door while the posterior end is closed. The webbing over the trap door is further extended as a hood for a length, which is half of its circumference. During operation, two traps are placed facing each other with a bana fixed to the mid of the doors luring fish to enter from both the directions. The trap is operated in *beels* and rivers during monsoon with a peak season from May to August. The trap costs Rs. 250.00-500.00 each and has a life span of 3 years.

(j) ***Khoka:*** This is a bottle shaped trap measuring 0.5 m in length. The narrower end (6 cm dia) is plugged with weeds at the time of operation, while the broader end (16 cm dia) is provided with a non-retractable trap door. The non-retractable door is inwardly projected (23 cm) with an inner diameter of 14 cm. The trap has a life span of one year and priced at Rs.25.00-30.00 each. The trap is operated in low – lying areas and in pond channels with mild current.

(k) ***Hufa/Hufi/Sohora:*** This is a funnel shaped trap made of a cut-off piece of a whole bamboo (0.8 m long). One end of the trap is spliced in a manner letting the splits to diverse from one another. The trap is without a trap door and the anterior end forms the mouth (15 cm dia) for letting the fish in. The mouth part is stitched with thin strips in circular fashion. The price of the gear is Rs.10.00 and has a life span of 4-6 months. The trap is operated during rainy season in paddy fields and in low-lying water bodies with swift current.

Box traps

These are made of bamboo splits, finely knitted with cane bamboo strings. Big sized box traps are provided with a bamboo screen at the mouth to guide the fish into the trap door. The prized catches are *W. attu,* C. *gariepinus,* C. *batrachus,* big sized murrels, *L. gonius, Mystus* spp., *M. armatus, Colisa fasciatus, Puntius* spp., *Anabas testudineus, H. fossilis, Botia* spp. and prawns. The variations seen among the box traps are as follows.

(a) Ghoni/ Gui/ Kholoha/ Sepeti : These are box shaped traps with minor variations among them. All these traps are taller than the width and are provided with a trap door from the base to the apex along the height. The fish is removed from an opening at the top. The trap ranges from 50-78 cm in height, 37-66 cm in length and 37-67 cm in width. Mouth width varies from 4-23 cm. The traps are operated in slow flowing rivers, *beels,* and paddy fields. These are generally set against the current and are provided with baits, usually earthworm. The cost of the gear is Rs.60.00-500.00 each with a life span of 1-2 years.

(b) *Dingori/ ghoni:* The trap resembles the trap mentioned under (a) in most of the details. Here, both the anterior and posterior sides are curved outwardly. The trap is 0.7-0.8 m in height, 0.3-0.5 m in length and 0.3-0.4 m in width. The trap is operated in shallow portions of *beels,* rivers, and stagnant water bodies, mainly during flood season. A bamboo screen is erected at times across a water body between two traps to guide the fish through the trap doors.

(c) *Dori/ Seppa:* This is a box trap with a 'U' shaped cross section. It is higher than its width. The trap door extends from the base to the apex at one end. The trap is operated during rainy season in shallow depth water. The trap measures 0.5-1.1 m in height and 0.3-0.4 m in width. The width of the trap door varies from 18-24cm. The cost of the gear varies from Rs.60.00-1200.00 depending on the size. The life span of the gear is 2 years.

(d) *Farom:* This trap is similar to the earlier ones listed, except that it is having two numbers of non-retractable trap doors on either side of the shorter axis. The trap doors are constructed of separate webbings to the main body. This trap measures 0.9m in height, 0.6 m and 0.4m at its longer and shorter axis respectively. The trap is operated in the river banks, ditches and small impoundments to catch fishes weighing less than 1kg. The cost of the gear is Rs.80.00. It has a life span of one year.

(e) *Noganda farom:* The trap is shorter than the width, measuring 29 cm in length, 22 cm in width and 18 cm in height. The trap door has a width of 13 cm and height of 18 cm and it projects inwards for a depth up to 14 cm. The apex and the base are closed. The apex has an opening for harvesting the trapped fish. The cost of the trap is Rs.20.00. It has a life span of 2 years.

(f) *Boldha/ Ghoni:* This is a long box trap with its height shorter than its length. This trap is somewhat intermediate in design between the rectangular type boxes and the ones with circular posterior ends. The length of the trap varies from 0.3-0.9 m, width 0.2-0.3 m and height 0.2-0.3m. These traps are operated in shallow region of rivers, *beels* and paddy fields. Small snails or crushed bigger snails are used as baits. Cost of the gear ranges from Rs.40.00-150.00 each, with a life span of 1-2 years.

(g) ***Koliha:*** This trap is similar to the preceding one (f) with the exception that instead of one, two trap doors run from the base to the apex on either side of the shorter axis. The width of the trap door is 10cm, projecting inwards for 23 cm. The length of the trap is 0.5 m, width 0.4 m and it has a height of 0.5 m.

❤***Darki/ Seppa:*** This is a long box trap provided with 1-2 trap doors placed just above the base along the longer axis. The length of the trap varies from 0.6-1.5 m, width 0.14-0.43 m and height 0.3-0.7m. The trap door measures 4.5-25 cm in height, 3-18 cm in width and 8.5-17 cm in depth. The trapped fishes are harvested from an opening at any of the rear ends of the apex. The opening measures 8-16cm in length and 4-16cm in breadth. This trap, provided with bamboo screens, is operated either single or in series.

(i) ***Bosna:*** It differs from the above one in having three small sized trap doors placed at the periphery along the length of the box on each of the sides. In some varieties, the middle door of the three is replaced by a bigger door running throughout the height on either of the sides. The door measures 16 cm in width, having a depth of 20 cm.

(j) ***Boldha:*** This is similar to the two traps described above. This trap has a trap door that runs from the base to the apex along one of the shorter axis. The small sized trap doors are absent. The trap is provided with a bamboo-made device for keeping earthworms as bait to lure the fishes to enter. The trap measures 0.28 m in length, 0.09 m in width and 0.3 m in height. The cost of the gear is Rs.30.00 with a life span of 2 years.

(k) ***Diar / Bosna:*** This is a basket shaped trap with bulging sides from base to the apex. The trap has a broader base and narrow apex. The trap is longer than its height and is provided with 2-4 trap doors at the periphery of the base. The fish is harvested from an opening at the apex. The trap is 0.41-0.81 m in height, 0.7-2.1 m in length and 0.10-0.47 m in width. These traps are operated in series fixed to the ground with mud or by anchoring with stout bamboo sticks, usually in rivers and paddy fields, during the onset of monsoon. The cost of the gear is Rs.300.00. It has a life span of 2 years.

(v) ***Trap nets:*** Trap nets are devices made of knitted fabrics, consisting of wings and a series of funnel shaped entrances, which lead into a closed sac, which functions as a trap from which exit is difficult.

Trap nets or *fyke* nets are 3-4 m in length fixed to the ground with sticks. These traps are made of small mesh size nets. The rigidity of the trap is provided by 2-3 bamboo or iron made rings of 0.4-0.5m dia stitched to the inner circumference of the body with an inter space of 0.7-0.8 m. The fish is harvested from the cod end. The mouth part is provided with two rings of 1.5 m length and 0.5-0.6 m width, projected from either side of the first ring to lure the fish into the trap. The net is operated in shallow regions of rivers during the rainy season mainly during April to September. Cost of the gear is Rs.300.00 with a life span of one year. IMacrobrachium spp., and small sized fishes are the major catch.

A large number of traditional fishing gears and methods used for harvesting of the fishery resources have been developed by the fishers of State of Assam. Of these, traps are unique. These are indigenously designed and fabricated by the traditional fishermen themselves, taking into consideration, the area, location and behaviour of the fishes. Majority of the traps are made up of bamboo strips and are widely used throughout the State in the rivers, *beels* and other wetland areas. They are fabricated in different shapes and sizes and are comparatively cheaper and efficient that other traditional fishing gears. However, factors such as thinning out of fish population and reduction in natural shallow water areas, poor returns, and attitudinal changes of the fishermen can lead to reduction in the use of fishing traps. Traps can be made selective fishing gear, if proper escape devices are provided in the traps to facilitate the escapement of juveniles.

6.2.7.5 Ecological degradation of *beels*

The ecological degradation of *beels* started with the arrival of the water hyacinth a century ago. Rampant growth of this fast-growing weed obstructs the penetration of sunlight, inhibiting planktonic growth and contributing to eutrophication by slowing down water currents and depositing debris at the bottom. The second phase of enhanced eutrophication resulted from the construction of embankments along almost the entire length of the river Brahmaputra and many of its tributaries after the devastating earthquake of 1950. These levees substantially reduced the periodic flushing by monsoon floods. The final onslaught on the wetlands has been from human activities such as buffalo and cattle rearing, agriculture and horticulture, and overfishing. These have resulted in further siltation and damage to the microflora and water quality. The injudicious use of pesticides in farming activities has resulted in the accumulation of residue through surface runoff, leading to the problem of biomagnification. Freshwater dolphins, crocodiles, winter monitor lizards and various species of turtles that were abundant in various *beels*, are either extinct or highly endangered. A number of fish species, such as *Puntius jerdoni*, *Begarius bagarius* and *Semiplotus semiplotus* are on the verge of extinction. Biodiversity can be an important component in the economic valuation of the wetlands. The change in biodiversity has implications for the food security and livelihood of the population that depends on the *beels*. The economic value of the biodiversity has not yet been studied. Information on ecological interrelationships between changes in biodiversity and changes in the primary productivity of the *beels* is required to establish appropriate policies for *in situ* and *ex situ* conservation and for other environment related initiatives.

6.2.7.6 Community-based co-management

Assam is struggling to build its economy through efficient resource utilization, specially the *beels*. However, the current management strategy does not allow for the local fishing community to have a role in the management paradigm. Historically, village and community-based management of *beels* and traditional fishing rights have existed. However, for the most part, these systems have disappeared. Recognition of the need for sustainable development and the need to address the ecological, economic and social objectives, makes a change in the management policy for *beels* an imperative. Biotope improvement is a must for the long-term optimum exploitation of the *beels* (Jhingran 1979), in terms of both environmental protection and productivity. The resources will dwindle in due course of time if biotope improvement is not made (Yadava 1987). Under the present management system no one is responsible for this aspect. Historical information shows that the *beels* were once the common property of the community and conservation ethics were followed. Catching and killing of brood fish and juveniles were prohibited. Such conservation practices still prevail among the *Tiwa* community of the Morigaon district in central Assam. Jon *beel* is a classic example of such management. Hence, Indian Fisheries Act needs to be enforced strictly to conserve the rich aquatic biodiversity through community participation.

6.2.8 *Beel* fisheries in West Bengal

Floodplain wetlands of West Bengal, Gangetic West Bengal represents the deltaic reaches of river Ganga, its tributaries and distributaries, where the river course passes through alluvial plains of a very low gradient, resulting in extensive changes in floodplain configuration. The state has more than 150 *beels* covering an area of 42000 hectares and constituting 22 per cent of the total freshwater area of the state. Fish potential of West Bengal beels indicated poor to moderate status from 43.8-320 kg/ha/yr. Based on selected studies made by CIFRI, the fish yield varied from 0.6 to 1.6 tonnes/ha. Thus, the *beels* are an important natural resource playing vital role in the fisheries, rural economy and environment of the state.

Unit 7: Coldwater fisheries in India

Chapter 1: Ecology and classification of cold water bodies and fishes in India

7.1.1 Introduction

From fisheries view point, waters of temperatures falling within the tolerance limits of the trouts belonging to the family Salmonidae are termed as cold. Such temperature limits are 0^o C to 20^o C with an optimum range from 10^o – 12^oC. In India, lakes and streams located 914 m above mean sea level where the Indian major carps do not live, qualify for cold waters. The characteristics of coldwater lakes include high oxygen, low carbon dioxide, inorganic soil, sparse vegetation and food, low fertility and high transparency. The characteristics of coldwater streams (trout streams) are ‘V’ shaped valley, high gradient, clear water, rocky to gravelly bottom, little organic matter and cool temperature. The National Commission on Agriculture stated that cold water fisheries comprise fisheries in streams and lakes, situated in high altitude regions of the country consisting of indigenous fishes, chiefly mahseer, the snow trout and the exotic species, mainly trout. Natural lakes situated in the colder upland regions of India cover an area of 720,000 ha. But, these lakes have not been studied for their fishery potential. On account of their limnological characteristics, they are suitable for developing cold water fisheries.

Lakes are those water bodies of standing water completely isolated from the sea and having an area of open, relatively deep water sufficiently large to produce somewhere on its periphery a barren wave swept shore (Welch, 1952). The fishery of the lakes is termed as ‘lacustrine fisheries’.

7.1.2 Classification of lakes

Welch (1952) classified lakes into three types based on the nutrient status of the lake. They are namely,

1. Oligotrophic lakes

These lakes are very deep. Littoral and sub-littoral zones are narrow and less productive. Profundal zone is extensive. They are poor in nutrients. Oxygen is at high concentration in hypoliminion. Phytoplankton are low in density. These types of lakes are found in India.

2. Eutrophic lakes

These lakes are very shallow and warmer. Littoral and sub-littoral zones are abundant, sides are sloppy and bottom is sandy. They are rich in nutrients. Primary production is high due to light penetration and availability of oxygen. Phytoplankton are high in density. These types of lakes are also found in India.

3. Dystrophic lakes

These lakes have high concentration of humic acid making water unsuitable for organisms to grow. Oxygen is nearly lacking. They are rich in phosphorus, nitrogen and organic materials. However, calcium is absent. These types of lakes are also available in India.

7.1.3 Types of lakes in the upland of India

Broadly, the lakes in the uplands of India are of two types. They are

1. Lakes which do not freeze at any time of the year

This type of lakes is generally situated in valleys or plateaus at relatively higher elevations. These are Wular in Kashmir, the Renuka in Himachal Pradesh, the Bhimtal, and the Devariatal in Uttar Pradesh, the Nainital and the Sattal in Uttaranchal, the Ooty and the Kodaikanal in Tamil Nadu and the Devikulam and the Elephant in Kerala.

2. Lakes which freeze partly or fully during a part of the year

This type of lakes is generally situated in higher elevations. These are the Dal, Kishansar, Vishensar, Shishnag, Tarsar, Marsar and the Neelnaa which remain frozen for a considerable part of the year. Most of these lakes except the Dal and the Wular in Kashmir are small ranging between 1.8 and 9.3 ha in area. Although the majority of the upland lakes are fresh water, yet there are several salt water lakes in Ladakh, notably the Pangong Tso and Tsomoriri.

These lakes support a lucrative indigenous and exotic fish fauna comprising snow trouts, trouts, mahseers, crucian carps, mirror carps and tenches.

7.1.4 Categorization of fish species according to temperature tolerance

On the basic of temperature tolerance, the cold water fish categorized as eurythermal (having broad temperature tolerance range) and stenothermal (having narrow temperature tolerance range).

Eurythermal species: *Schizothorax richardsonii, Barilius bendelisis*

Stenothermal species: Brown trout (*Salmo truta fario*)

Eastern brook trout (*Salvelines fontinalis*)

Tibetian snow trout (*Diptychus maculates*)

These stenothermal species tolerate only a narrow range of temperature up to freezing point of water

Thermal limits

Snow trout – 5 to 25º C

Mahaseer – 10 to 30º C

Exotic trout – 4 to 20º C

7.1.5 Ecological adaptation

The coldwater fishers often endowed with great powers of locomotion.

Such species have streamlined body.

The occurrence and distribution of coldwater fishers in addition to temperature, are also dependent upon the swiftness of current and nature of substation and plant and animal communities present or available in the bottom.

Majority of coldwater fisheries possesses structures especially adapted for clinging borrowing or otherwise to withstand fast water currents.

The variable features of environment have induced remarkable made fixations among coldwater fishes, both externally and internally. Normally there is little food available in hill stream for resident fish species. Coldwater fish species have acquired modifications of mouth suitable for rasping encrusted organisms and boulders. The modification of lips for removing periphytic organism is well seen is snow trout, mahseer and certain minor carps.

Another characteristic feature of coldwater fish is their adaption to living in highly oxygenated water available in torrential streams of mountains. Such oxygen rich environment has induced structural modification in organs of respiration also. Owing to richness of water in its oxygen content, the gill opening have narrowed and gill themselves are greatly reduced so much so that such fishes cannot survive for long in waters poor in oxygen.

7.1.6 Indigenous cold water fishes

The important and common fish species inhabiting the mountain waters of India are mahseer, snow trout and Indian hill trout.

Mahseer : It is one of the major game fishes of Himalayas. However, it has not received adequate attention as exotic fishes in India. To certain extent, it is a migratory fish. It migrates down streams when the water recedes in rivers and ascends the rivers to spawn during monsoon when the streams are fed with rain water. Important species of mahseer include the followings:

Tor tor , *T. putitora, T. mosal, T. mosal mahanadicus, T. khudree, T. mussulah, T. nelli, T. progeneius* and *Acrossocheilus hexagonolepis*

Snow trouts: It is represented by *Schizothorax richardsonii, S. plagistomus, S. molesworthi, Schizothoraichthys esocinus, S. progastusi* and *S. kumaonensis.*

Indian hill trouts : It is represented by *Barilius bendelisis, B. bola, B. vagra* and *B. gatensis*.

Others: *Glyptothorax pectiniopterus, Labeo dero, L. daycheilus, L. gonius, Garra lamta* and *G. gotyla*.

7.1.7 Exotic cold water fishes

The exotic cold water fishes introduced in India include trouts, mirror carps, crucian carps and tenches.

Trouts: *Salmo gairdneri gairdneri* (steel head trout), *Salmo tutta fario* (brown trout), *S. lavensis, S. salar* (Atlantic salmon), *Onchorhynchus nerka* (golden rainbow trout) and the tiger trout. The first attempt to transplant trout in India was made at Nilgiris in 1907. In the Himalayas, trout has been transplanted in Kashmir and Himachal Pradesh, in Garhwal Himalayas, Arunachal Pradesh, Nagaland, Meghalaya and in certain waters of Nepal.

Tenchs: *Tinca tinca* (also called the doctor fish). It was first introduced into the Ooty Lake as early as 1874.

Mirror carps: *Cyprinus carpio communis* (scale carp), *Cyprinus carpio specularis* (mirror carp) and *Cyprinus carpio nudus* (leather carp). These carps were inroduced into the Nilgris in 1939 and Kumaun hills in 1947. Mirror carps are regarded as an ideal fishes for cold waters of India.

Crucian carp: *Carassius carassius* (also called the golden carp). It was first introduced into the Ooty Lake in 1874.

Chapter 2: Fish and fisheries of cold water bodies in India

7.2.1 Resources of Coldwater Fisheries in India

In India, a number of coldwater streams, river, lakes, reservation are present. The Indian Himalayas are drained by 19 major river systems which include drainage of the Indus, Ganga, Brahmaputra river system. The snow fed Himalayan rivers transverse from these physiographic regions. The cumulative length of the major uplands rivers is estimated at about 10,000 km. The lacustrine Resources also varied from high altitude freshwater lakes, high attitude brackish to mid and lower attitudinal lakes. Total area under lacustrine resources is about 20,500 ha and 2,65,000 ha of water spread area under reservoir.

Approximate resource of streams, lakes, and reservoirs holding Coldwater Fisheries including in Indian water

No.	Name of water body	Stream length (km)	Remarks
A.	**Himalayan Zone**		
1.	River System		
(i)	Indus	939	Including principal tributaries in India
(ii)	Jhelum	1248	do
(iii)	Chenab	1535	do
(iv)	Ravi	494	do
(v)	Beas	923	do
(vi)	Sutlej	963	do
(vii)	Yamuna	940	do
(viii)	Bhagirathi	315	do
(ix)	Alakananda	405	do
(x)	Dhauliganga	135	do
(xi)	Pindar	135	do

B. Natural lake/valley lake

No.	Name of water body	Lengh (km)
1.	Siruinsar	29
2.	Mahasar	45
3.	Dal	1170
4.	Mahasbal	280
5.	Anchar	700
6.	Walar	1600
7.	Renuka	22.8

8.	Nainital	73.8
9.	Bhimtal	86.5
10.	Sattal	93.0
11.	Naukuchiatal	65.0

C. High altitude lakes

No.	**Name of wate body**	**Length (m)**
1.	Nilang	6.0
2.	Krishnasagar	40.0
3.	Vishansar	10.0
4.	Gangabal	157.0
5.	Nudhkol	10.0
6.	Tasar / Manar	7.0
7.	Kaunsarnag	140.0
8.	Khajjear	1
9.	Devaviatal	12.4
10.	Pangong Tso	29.0
11.	Tso Moriri	2100
	Peninsular zone	
A.	River System	Length in km
1.	Cauvery	142
B.	**Natural lake**	**Area**
1.	Ooty	34.0
2.	Kodaikanal	39.0
3.	Devonion	6.0
4.	Elephat	2.0
C.	**Man Made Lake**	
1.	Upper Bhavani	455
2.	Mukurti	2000
3.	Parsons Valley	202
4.	Porthmond	28.4
5.	Avalanche	315.0
6.	Emerald	494.0
7.	Sandynulla	
8.	Kandelly	231.0
9.	Madupatty	324.0

Area wise list of different kinds of aquatic resources in Indian uplands

Water Resources	Length / Area
Himalayan and Deccan plateau river system	8310 km
Brackish water lakes (above 30000 masl)	2,340 ha
Fresh water Natural lakes (1,500 – 2000 masl)	18,150 ha
Kashmir high mountain lakes (above 3,000 masl)	400 ha
Valley wetland ecosystems	3000 ha
Shivalik Himalayan lakes	74 ha
Central Himalayan (F.W lake in Kumaon region)	355 ha
Himalayan man made lakes and reservoir	43,770 ha
Peninsular region natural lake	85 ha
Man made lakes and reservoirs	4,400 ha

7.2.2 Piscine Diversity

The attituditional and geographical variation, mountain slopes expansion of river valley and vegetation cover has given rise to varying climates in different parts of country. As a result, the vast and varied water resources in the uplands harbour rich piscine diversity. The list of fishes comprises 258 species. Belonging to 21 families and 76 genera. Out of these, 255 species are recorded from North East Himalayas, 203 from West and Central Himalayas and 91 from the Deccan plateau. Among the coldwater fishes Salmons, trouts, mahseers and the mirror carp comprise the major chunk of the economically important fishes. Different species of these fishes and major distribution are summarized below.

7.2.2.1 Exotic fishes

SI. No.	Name of the species	Family	Main Distribution
1.	*Salmo trutta fario* (Brown trout)	Salmonidae	Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Andhra Pradesh
2.	*Salmo gairdneri iridous* (Rainbow trout)	Salmonidae	Jammu & Kashmir, Himachal Pradesh,

			Tamilnadu, Kerala
3.	*Salmo gairdneri Shasta* (Rainbow trout)	Salmonidae	Kerala
4.	*Salmo hucho* (Danube Salmon)	Salmonidae	Jammu & Kashmir
5.	*Salmo salar* (Atlantic salmon)	Salmonidae	Jammu & Kashmir
6.	*Salvelinces fontinalis* (Eastern brook trout)	Salmonidae	Jammu & Kashmir
7.	*Onchorhynchus nerka* (Sock eye salmon)	Salmonidae	Tamilnadu
8.	*Carps - Carassius carassius* (English & Golden carp)	Cyprinidae	Nilgiris, Andhra Pradesh
9.	*Tinca tinca* (Tench)	Cyprinidae	Nilgiri & Ooty
10.	*Cyprinces carpio* (Common carp)	Cyprinidae	Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh, Nilgiri

7.2.2.2 Endemic Fishes

SI. No.	Name of species	Family	Main Distribution
1.	*Barillius bola* (Indian trout)	Cyprinidae	Arunachal Pradesh, Orissa
	Snow trouts		
2.	*Schizothorax moles worthic*	Cyprinidae	Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh
3.	*Schizothorax richordsonii*	Cyprinidae	Himalayas
4.	*Schizothorax niger*	Cyprinidae	Jammu & Kashmir
5.	*Schizothorax planidoxmes*	Cyprinidae	Himalayas
6.	*Schizothorax longipinis*	Cyprinidae	Himalayas
7.	*Schizothorax esocinus*	Cyprinidae	Jammu & Kashmir
	Mahseer		
8.	*Tor tor* (Deep bodied mahseer)	Cyprinidae	Uttar Pradesh, Arunachal

			Pradesh, Madhya Pradesh
9.	*Tor putitor (Golden mahseer)*	Cyprinidae	Jammu & Kashmir, Uttar Pradesh
10.	*Tor khudree (Deccan mahseer)*	Cyprinidae	Tamil Nadu & Jammu & Kashmir
11.	*Tor mosal*	Cyprinidae	Himachal Pradesh, Uttar Pradesh, Arunachal Pradesh, Madhya Pradesh
12.	*Tor mussullah*	Cyprinidae	Nilgiris
13.	*Tor mahanadicus*	Cyprinidae	Orissa
	Minor carps		
14.	*Labeo dero*	Cyprinidae	Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Arunachal Pradesh
15.	*Semiplotus semiplotus*	Cyprinidae	Arunachal Pradesh
16.	*Chrossocheilus lattices latius*	Cyprinidae	Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh

7.2.3 Commercial importance of the species

As far as commercial importance is concerned, some cold water species are known for sports, some others as food fishes and few for their ornamental value.

Sport Fishes : The important fishes present in cold waters of India with good sport value are – golden mahseer (*Tor tor*), copper mahseer (*Tor mossal*), black mahseer (*Mazirifor chelynoides*) Chocolate mahseer (*Neolissochelilus hexagonolepis*), Indian trout (*Raiamas bola*) among indigenous species and rainbow trout (*Oncorhynchus mykiss Salmo gairdeneri)* and brown trout (*Salmo trutta fario*) among exotics.

Food fishes: Besides the sports fishes, the piscine groups, snow trout, minor carps, major carps, catfish, bagirds, barils, murrels and eel are generally used as food fishes in the region. The important genera among them are – snow trout (*Schizothorax* and *Schizothoraicthys*), garras (*Garra* sp), minor carps (*Labeo* sp) bariels (*Barilius* sp), exotic carps (*Ctenopharyngodon idella*, *Hypopt htalmichthys molitrix*, *Cyprinus carpio*), eels (*Mastacembalus armatus*)

Ornamental fishes: - Some are very colourful and fascinating species also inhabit in different aquatic resources of cold water zones. Some of these have been recognized as ornamental fishes in other parts of country where as few others have some ornamental traits. North east region is known as repository of 187 (74%) are known for their ornamental value. Some of the important species are *Car rassius car rassius*, *Car rassius auratus*, *Puntius conchonius*, *Puntius gelius*, *P. ticto*, *P. sophore*, *Brachydanio rerio*, *Badis badis*, *Barillus vagra*.

7.2.4 Lacustrine fisheries

Since, the lakes are quite bigger in dimensions than reservoirs and are of natural origin, they support healthy and varied fish fauna ranging from Indian major carps and large catfishes to small sized minor carps, catfishes, clupeids, murrels etc., The lakes situated in coldwater zones of Himalayas or peninsular India support trouts (*Salmo gairdnerii*), snow trouts (*Schizothorax niger*, *S. planiro* and *S. curvifrons*), mahseers (*Tor putitora* and *T. khudree*), common carp (*Cyprinus carpio*) and minor carps (*Labeo dero*, *Crossocheilus*, *Latius latius*) as chief economically important fishes. These lakes are either stocked with the natural seed from rivers or with the seed developed after adapting cultural practices. The catches in most of the cold water lakes are dominated by *C. carpio* with sizable contribution to schizothoracids and mahseers in the northern lakes and *Oreochromis mossambicus* in the Deaccan lakes like cold water lakes in Tamil Nadu. Very little is known about the fishery potential of upland lakes. On account of their remoteness and the low water regime, drastic increase in yield and production are not expected from these water bodies. The data on fish catch statistics vary from place to place. From the capture fishery of different indigenous coldwater fisheries, the declining trend in fish catch statistics has become obvious due to changed ecological conditions and improper management. In the lakes of plains, rate of primary production is high. Until recently, development work in cold water fisheries was directed towards establishing trout fishery which is the most popular sport fish in the world. There has, however, been growing realization for developing indigenous cold water fisheries. The production from cold water fisheries is, however, not of much significance in the total inland fish production in the country.

7.2.5 Important cold water lakes in India

The cold water lakes that constitute sizable fishery are in Tamilnadu, Manipur, Jammu & Kashmir and Kumaun region.

7.2.5.1 Lakes of Tamilnadu

a) Kodaikanal Lake

It is situated in the Palani hills. Its total area is 26 ha with a maximum depth of 10 m and an average depth of 2 m. The annual fish production is 1.8 – 9.3 kg/ha.

b) Yercaud Lake

It is located in the Shevaroy hills. Its total area is 8 ha with a maximum depth of 5.5 m and an average depth of 2 m. The annual fish production is 16.7 – 49.5 kg/ha.

c) Ooty Lake

It is situated in the Nilgiri hills. Its total area is 34 ha with a maximum depth of 10 m and an average depth of 3 m. The annual fish production is 33 - 111 kg/ha.

7.2.5.2 Lakes of Manipur

Loktak lake

It is situated in Manipur. Its total area is 390 km^2 (4,480 – 27,300 ha) with the depth ranging from 1.5 m to 4.5 m. It receives water from the streams like Nung, Turel, Nembal, Thangia, Orak and Phubalarek. The annual fish production is about 50 kg/ha (262 tonnes/year). It is heavily infested with weeds. The Ichthyofauna of the lake is dominated by air-breathing fishes such as *Channa striatus, C. punctatus, Anabas testudineus* and *Clarias batrachus.* Other forms are *Wallogo attu, Osteobrama belangiri, Puntius sarana, P. sophore* and *P. ticto*. The recently introduced *Cyprinus carpio* also contributes significantly to the fishery of the lake.

7.2.5.3 Lakes of Jammu and Kashmir

Dal lake, Kishenser lake and Wular lake are the important cold water lakes in Jammu and Kashmir. The trout hatchery established in Harwan (Kashmir) is one of the potential sources, from where the brown trout has been transplanted to nearby upland waters. The annual fish production is 8.0 – 22.5 kg/ha in Dal Lake and 15 – 45 kg/ha in Wular Lake.

7.2.5.4 Lakes of Kumaun

Nainital, Bhimtal, Sat Tal, Naukuchiya Tal, Devaria Tal, Khurpa Tal, Garun Tal and Malwa Tal are the coldwater lakes situated in Kumaun hill regions. Nainital is highly polluted. Now only *Puntius spp* are found in this lake. Important species found in other lakes are mahseer (*Tor tor*, *T. putitora*), *Cyprinus carpio* and *Schizothorax* spp. (snow trout). Total fish yield from these lakes is very low. Fishery of snow trout and mahseer has declined considerably, while that of mirror carp (*C. carpio*) is dominant.

7.2.6 Fishing gears and crafts in cold water lakes

Fishing gears and crafts employed for commercial landing in these lakes do not vary much from those used in reservoirs. However, the methods of fish capture in the streams, lakes and reservoirs fall under four categories, viz., nets, traps, angling and illegal methods (poisoning, electrocuting, dynamiting).

7.2.7 Riverine resources of cold water fishery (Hill stream fishery)

Stream is a mass of water flowing towards a lower level following the line of least resistance. The streams, depending upon their source, are either seasonal or perennial.

7.2.7.1 Himalayan region

A large number of rivers, rivulets, and streams form a vast network in the central Himalayan Mountains (Garhwal and Kumaun region) and have a large no. of indigenous fish species. About 68 species of fish are reported from Garhwal region. Major rivers of Garhwal are the Alakand, the Mandakini, the Bhagirathi, the Asiganga, the Bhilaganga, the Ganga, the Nayar and the Pinder.

Important fish species are: *Schizothorax* spp., *Tor* spp., *Garra gotyla, Labeo* spp., *Crossocheilus latius, Glyptothorax, Psedechenies*, *Barilius* spp., *Noemacheilus* spp., *Puntius* spp., *Botia* spp., *Homaloptera, Danio, Mastacembelus, Channa, Lepidocephalichthys* etc.

The fisheries of Himalayan region are poorly developed primarily due to difficult terrain and its inaccessibility. Low temperature allows scanty production of primary and secondary level organisms. Due to low biological productivity, most coldwater fishes in this region are generally of small size in contrast to their counterparts and hence commercial fisheries virtually non-existent except in the man-made reservoirs and natural lakes in the Siwalik Himalayas.

7.2.7.2 Kumaun Region

Five major rivers and their tributaries form a network in Kumaun region. They are Kali, W. Ramaganga, Kosi, Pinda and Gaula rivers. River Kali is the largest in Kumaun. The important species of this region are:

- **Carps:** *Tor tor, T. putitora, Schizothorax richardsonii, S. plagiostomus, Barilius bendelisis, B. kagra, Labeo dero, L. gonius, Puntius conchonius, P. chilnoides, Garra lamta.*
- **Catfishes:** *Glyptothorax pectinopterus, Psedecheneis sulcatus*
- **Loaches:** *Noemacheilus botia, N. rupicola, N. montanus, Botia almorhae.*
- **Others:** *Channa gachua, Mastacembelus* spp

Of these species, some fishes have become rare and considered threatened species due to unwanted man made activities. The exotic species introduced into the coldwater to enhance fish production are the trout (*Salmo)*, the mirror carp, the golden carp and the tench.

7.2.7.3 State-wise Inland Fish Production in Hill States

SI. No.	States	Production (t)
1.	Jammu & Kashmir	19,150
2.	Himachal Pradesh	7,300
3.	Uttarakhand	2,790
4.	Sikkim	150
5.	Arunachal Pradesh	2,750
6.	Meghalaya	4,120
7.	Mizoram	3,750
8.	Manipur	18,220
9.	Nagaland	5,500
	Total	63,730

7.2.8 Status of Trout Culture

Efforts at trout culture in upland region of India had been initiated as early as 1863. Trout farming was also initiated in North Eastern Hill state of Arunachal Pradesh in 1967 – 68. However fisheries in almost hill states are still in developing stage. The important factors responsible for its poor, land unsuitable for pond construction in most of the places due to high gravel –sand percentage in soil, high seepage, mon availability of quality’s temperature – linked low productivity and lack of proper support and extension facilities in the region. But since about last two deadly Directorate of Cold water Fisheries Research (DCFR), Bhimtal, Uttarakhand & some other government agencies have initiated work of fish cultures in uplands. As a result, the scenario has changed and aquaculture in general and trout culture in particular is gaining momentum in the cold water region.

7.2.8.1 Trout Farming

Trout farming needs high investment in the form of pond construction, procurement seed, feed, maintenance of fish health. Quality of water is also required. So, expansion of trout farming has limitations due to these barrier. At preset 23 trout hatchery established under government section. These are engaged in breeding and rearing of rainbow and brown trout in different region with an estimated production at 500 tonnes of yealing and capacity at 105 to 2.0 million seed every year.

Trout farms located in different states		
S.N.	States	Number
1.	Jammu & Kashmir	7
2.	Himachal Pradesh	5
3.	Uttarakhand	4
4.	Sikkim	1
5.	Arunachal Pradesh	2
6.	Manipur	1
7.	Tamilnadu	1
8.	Kerala	2
	Total	23

7.2.8.2 Trout hatcheries

The credit for constructing the first ever hatchery of the country to breed and rear the transplanted brown trout goes to Mitchell. This hatchery was built in 1905-1906 at Harwan near Srinagar in Kashmir. Mahili Hatchery at Katrain in Himachal Pradesh was next to be built in 1909. Wilson built first trout hatchery of Nilgiris at Avalanche in 1909 – 1910. The important trout hatcheries in the country are at

Avalanche – Nilgiri (Tamilnadu)

Rajmallay – High Ranges of Travancore (Kerala)

Achhabal, Laribal, Harwan – Kashmir

Patlikuhal, Mahili, Baort, Chirgaon and Sanghaoa – Himachal Pradesh

Kaldayani & Talwari – Uttar Pradesh

Bomdilla – Arunachal Pradesh

Shillong – Meghalaya

The culture of Schizohoraeins is in experimental stage. Like the Mahaseer, this cryprinids also shows sharp decline in catches all along the himalays due to indiscriminate fishing and enviormental degration. However, it is also believed that introduction of exotic common carp adversely affected the Schizothoraeine fishery in the lacustrine enviorment at Kashmir valley lakes.

Chapter 3: Sport fisheries in India

7.3.1 Introduction

With the changing values of the society in terms of modernization and development, 'Fish sport' has become most reputed and delighted entertainment. Millions of tourists both from home and abroad visiting scenic corridors in Indian Himalayas enjoy angling in the upland streams, rivers and lakes. In reality the angling is enjoyed by the people of all ages, social and economic strata of the society and hence in present days it is considered as the best resort entertainment. Besides the tourists folks, the local masses residing nearby these fishing resorts are also fascinated for angling and catch the fish for enjoyment as well as for food. Angling is an activity executed mainly for pleasure and not for food. It is the source of recreation to a variety of naturalists belonging to different strata of society. An angler should practice angling with real ethics of sport. It is necessary to do angling on catch and release basis regardless of fishing technique as a conservation measure. In India, angling as a sport, was introduced by the British during the nineteenth century and were also the reason for introduction of such exotic species like the Brown and Rainbow trout in Indian rivers and streams. The introduced species of trout soon bred and propagated fast in view of rich oxygenated waters, ideal ecological conditions of this region. The geographical variation along the course of each river is immense, full of endless opportunities for anglers. Himalayas has been rightly rated as the Anglers' paradise with a network of rivers and streams as well as high altitude lakes.

7.3.2 Common Sport Fishes

Among the fishes inhabiting in the upland waters, the trouts and mahseers are known as the best game fishes because of their magnificent qualities to quench the angler's fishing thirst by providing thrills and excitement while hooking. The Schizothoracids, another group of game fishes of the Himalayan waters do contribute to the fishing bags of the anglers in some Coldwater streams especially in the high mountain region.

7.3.2.1 Golden Mahseer

Mahseer is known to be the toughest among the fresh water sport fish. It is a cold water fish. Mahseer's habitat has high oxygenated water with rocky bed. It is found in Indian Himalayas. Mahseer is migrating fish, during winter fish moves to the warm water. As this fish has great smelling sense, it can detect food from quite a distance. Angling period for Mahseer can be well split in two parts Spring (pre-monsoon) and Autumn (post-monsoon). Fishing is strictly prohibited during monsoon as it is the breeding time for the fish. The best ways of Mahseer fishing is Spinning, It is a fish known for its fight. It is the largest member of the carp family in the world. Mahseer is a dream fish for anglers. However, like other wildlife, this fish is trying hard to survive the strokes of urbanisation & development. Other major threat for Mahseer is poaching. There are different poaching techniques used such as bombing, electric current, bleaching powder etc.

7.3.2.2 Brown Trout

Brown trout is the most wary and cautious of all the trouts. It can live in relatively warmer waters compared to most other trouts and despite the inroads of civilisation, they seem to hold on their own, better than many native trout. Brown trout prefer the larger streams and are also found in rivers and lakes. They like waters where there are submerged obstacles and crevices under overhanging banks. They frequent the lower ends of pools and like to lie just ahead of rocks in the current. While brown trout prefers to feed on flies and insects, it also feeds on minnows, worms, snails, crawfish and other crustaceans.

The Brown Trout is a very fine game fish and makes excellent eating. It is a native of European waters and were introduced to Himalayan streams first in Kashmir in the 1860's and later from there to the Beas in the 1920's.

7.3.2.3 Rainbow Trout

Rainbow trout is a favourite of most of the anglers, due to its splendid fighting ability and its tendency to move up when hooked. The rainbow trout does not like to stay in one location, and as a result, it migrates in a sharper manner and at a greater degree than do the other members of the trout family. While rainbows have been known to inhabit waters where the temperature reaches 80ºF in mid summer. Rainbow trout prefers fast, turbulent waters. In streams, they are found in stretches of swift flowing waters, rather than in the slow flowing portions, and at the edge of strong currents and at the head of rapids. Rainbow trout prefers to feed on flies, insects, worms, minnows, crustaceans, on its own eggs and smaller fishes.

7.3.2.4 Other sport fishes

They include snow trouts (schizothoracids), peninsular carps - rohu (*Labeo rohita*), mrigal (*Cirrhinus mirgala*), catla (*Catla catla*), lanchi or mulley (*Wallago attu*), singhara or shovelhead (*Aorichthys seenghala*), the lesser snakeheads (*Channa* spp.), goonch (*Bagarius bagarius*) and needlefish (*Xenentodon cancila*).

7.3.3 Fishing Tackle

Fishing equipment is very important for such a sensitive sport, Equipment can make whole lot of difference to our hobby. It is necessary to always use fish friendly gear and tackles. We need to use different tackles for different species of fish.

Rod:

Earlier, cane sticks and split-cane rods were used. Nowadays, fiberglass rods and steel rods are used. The fiberglass rods are stronger and better than the steel rods. Moreover, it does not rust. Balance, elasticity, toughness, pliancy and lightness are the essential prerequisites in a fishing rod. In India, Ringal-cane rods are widely used since they are cheap and possess all the good qualities of a fishing rod.

Reel:

Big reel- fixed spool and small reel- fixed spool are used to carry line.

Line:

It may be made of silk, braided linen and flex or nylon. However, anglers prefer monofilament nylon lines as its maintenance is easier than others. Wire leaders are essential for goonch and heavy mono leaders are required for mahseer.

Hooks:

A typical hook is made of a rust proof metal and has the parts like eye, shank or shaft, bend, barb or spear. There are single or treble hooks. These hooks may be either eyed or uneyed. Less damage will be caused to fish if barbless and circle hooks are used.

Spoons:

It is an oval piece of an ordinary sheet metal, pressed with the help of hammer from one side. The convex side can be rubbed or polished. Both ends of the spoon have holes for attaching a swivel on one end whereas a hook on the other. Spoons are available in various designs. It is specifically used for attracting mahseers.

Bait:

It is akind of lure, fixed on the hook for attracting the fish and then hooking it with the hook.

7.3.4 Types of gear used in angling

Spin casting: This is the simplest gear to master and is used frequently by beginners. It is easily recognised by the closed reel face. When casting, the angler needs to push down a button with his or her thumb in order to release the line. This minimises tangles. These outfits are the best suited for casting small and medium sized lures for catching smaller fish.

Spinning: An angler can cast farther with this kind of outfit than with spincast gear, but the exposed fishing can result in tangles of the line, while casting. Spinning outfits come in a variety of sizes and weights. Smaller outfits can cast small lures to catch trout, while larger outfits are excellent for casting large lures to catch salmon and steelhead.

Bait Casting: These outfits excel at casting heavy lures a long way. However, it takes time to learn to cast them. These outfits work well when fishing off-shore or in very deep waters, or when pursuing large fish like salmon or sturgeon.

Fly Fishing: This gear is very different because it is designed to cast a virtually weightless lure (flies are often tied with fur, feathers and others), unlike the heavy plastic or metal lures used in spin-or bait casting. This kind or fishing requires more highly specialised gear and techniques, but many anglers find mastering these techniques almost as rewarding as catching of the fish.

7.3.5 Sport fisheries potentials in Himalayan regions

From the information available on physiography, biological characteristics, productivity status of main coldwater ecosystems in this region, it has been revealed that in Himalayan uplands, there are ample potentials to develop sport fishery of both exotic trouts and native mahseer species.

In India, the sport or recreational fishing for mahseer, trout and snow-trout indulged in by a section of relatively well to do families who are fond of sports and outdoor thrills and by the tourists visiting India for adventure and enjoyment. Great potentials lie in the streams and rivers of Himalayan for sport fishing. Most of the glacial rivers in their upper reaches and all snow-fed streams can be the abode for exotic trouts, especially the brown trout, however if they are managed properly with utmost care while stocking of fingerlings and yearlings. The important trout waters in country include most of the snow-fed streams including Lidder, Simal, Erin, Madhmati, Tricker, Kokernag, Berinag (J&K), upper reaches of Beas & Sutlej (HP), Ashiganga, Birehi, Pinder, Bhagirathi (Uttaranchal) besides a few upland lakes/streams in North-East region.

The lower stretches of these upland streams/rivers meandering in lesser or outer Himalayas are good resource of golden mahseer and catches of sizeable mahseers by angler's in the previous decades strengthen the views to develop them as mahseer waters for game purposes. Among the himalayan streams/rivers, Beas and its tributaries in the foot hill region and rivers, Giri (HP), Yamuna between Tajwala (Haryana) to DhakPathar (Uttaranchal), Ganga between Rishikesh to Tehri and its tributaries, the Kali, Saryu, East & Western Ramganga, East &Western Nayar, Song, Kosi (All in Uttaranchal), Chenab and its tributaries, Tawi, Ikhnee Nala and Anji (J&K), and Rivers Jia-bhoreli, Diwang, Subansini and Manas (NEH Region) are important as mahseer fishery in concern. Apart from these, the lakes of Kumaon (Bhimtal, Khurpatal, Naukuchiatal, Nal-Damyantital and Sattal do contribute substantially to Mahseer fishery and provide ample scope for fish sport. Most of these waters are not only fished by anglers or sports loving people but many of them are known for angling competition.

7.3.7 Mahseer angling sites in Kumaon Himalayas

Certain stretches in Kumaon rivers can be developed as sport waters to give boost to the tourist industry which will ultimately help in upgrading the economic status of the society. The spots identified for mahseer angling are given below.

Sl.No	River / stream	Stretch/ Area
1.	Kali	i. From Pancheshwar upto Boom
		ii. 5 km upstream Jhulaghat bridge
2.	Saryu	i. 5 km upstream Pancheshwar
		ii. 5 km upstream Bhageshwar town
		iii. 5 km up- and down stream Sheraghat
3.	Ramganga (E)	i. 2 km upstream Thal upto Nachni
4.	Ramganga (W)	i. From Bhikiyasen to Chaukhutia
5.	Kosi	i. From Betalghat to Kherna bridge

7.3.8 Factors affecting fishing

The wind and the weather do affect success in trout fishing, but in a very uncertain manner. A fresh and even a strong wind is usually a good thing for the trout fisher. Trout seem to dislike haze and gloom, and they seldom respond to angling rod either in hot and hazy weather or in dull gloom. But if the air is clear and without mist the day may be as hot or as cold, as sunny or as dark. Still it may be a fine day for trout fishing. Rain is by no means against success in trout fishing. Rather, on the contrary, fish often take well in slashing storms of the rain. Even in snowstorms and thunderstorms, the trout rises well to catch the fly.

7.3.9 Night Fishing

Trout take the bait very well, when it is dark or almost dark. In late evening fishing, smooth and swift running water is the best to fish for trout. As to the places in which an angler may look for fish, there is no guide like experience and constant knowledge of water. If an angler does not know the water, and has nobody who knows it thoroughly to advise, he may go out early in the morning and be on the water till late in the evening, and you will see where the fish are lying.

7.3.10 Suggestions to promote sport fisheries

- Conservation measures for mahseer, snow-trout and allied fisheries may be framed and employed to check the depletion of these native fishes in these Himalayan resources.
- Facilities like approach road to the fishing sites, rest camps, angler's hut etc. should be developed to allure maximum number of tourists and anglers.
- To ensure the availability of game fishes in these aquatic resources seed production units and hatcheries may be established in the fishing areas.
- Fast growing varieties of trouts should be transplanted in the upper reaches of glacial rivers.
- Artificial propagation of mahseer and snow-trout may be taken up for large scale production of its seed to stock in all suitable waters in the area.

- Extensive teaching programmes exposing various facets of fisheries in far flung localities be undertaken so that the local masses could also be benefited from the sustained fishery.
- Fish acts and regulations may be adopted strictly so that the fishery of endangered fish species like mahseers and schizothoracids could be augmented.
- Angling competitions may be organized with vast publicity by news media, pamphlets, audio and video visions etc. so that maximum number of tourists/anglers could visit the area.

Unit 8: Fishing crafts and gears of inland water bodies in India

Chapter 1: Fishing crafts of Inland water bodies in India

8.1.1 Introduction

Fishing crafts are most essential for catching the fish in large scale in water bodies. A large variety of crafts (boats) have been designed for marine and inland fishing in India. The types of fishing crafts of India falls under two general categories. These are non-mechanized and mechanized fishing crafts. Based on the topographical variations and difference in habits and habitats of fishes, different types of crafts and gears are used in various inland water systems of India. The simplest and most primitive types of craft used for fishing in inland waters are the rafts and songas, operated in calm waters. In the larger rivers and estuaries subject to strong current and tidal movements, sturdier plank built boats are used.

8.1.2 Major fishing crafts

1. Rafts: The rafts are made of various materials as:

i. Inflated buffalo skin and bamboo sticks are used as platform in lower reaches of Ganges.

ii. Banana stems or shoal bundles tied to form a floating platform as in ponds, and calm waters of West Bengal, South Bihar and Thanjavur district in Tamil Nadu. They are also used in low and marshy land.

iii. Earthen pots tied together to support alight platform of bamboo as in the river Ganges near Patna, Gaya and in the river Cauvery.

iv. **Coracle -** A shallow circular framework of wicker covered with a well-stretched cowhide as outer layer with a thin layer of tar to make it fully water proof – today replaced by tarred calico or canvas, or simply fiberglass. The structure has a keel-less, flat bottom to evenly spread the weight of the boat and its load across the structure and to reduce the required depth of water often to only a few inches, making it ideal for use on rivers. They are commonly used in rivers Cauvery, Tungabhadra, Mettur Dam and Nagarjunasagar.

2. Catamaran: The simplest type of fishing craft may be taken as the one formed by a few curved logs of wood joined together forming a kind of floating raft, such as the ones used along the east coast of India. Four types of catamarans are prevalent in Indian waters, namely the Orissa type, Andhra type, Coromandal type and Kanyakumari type.

3. Dug-out canoes: A simple type of fishing craft for fishing within short distances from the coast is a small-sized canoe, made by scooping logs of wood in the form of boat. The “Odams”, “Thonies”, “Vanchies” etc. of the southeast and south-west coasts of India come under this category. In calm weather, oars may be enough for propulsion; but if winds and currents prevail, sails may be used. A simple form of dug-out, made by hollowing out the butt and stem of the Palmyra palm is commonly used in West Bengal for angling and cast net fishing in inundated calm waters. Similar but sturdier dugouts known as Vallam are used in fishing in the backwaters and estuaries of Kerala.

4. Plank built boat: This is an enlarged variety of dug-out canoe made of planks on the sides, largely used in Kerala. The plank built boats are of various types and are used for fishing in rivers with strong currents and tides, and in the larger backwaters and lakes for operation of large nets. The boat, (Chhandi nauka) used for operating drift nets, may be as large as 18 m. long and 3 m. wide. In the Chilka Lake and the river Mahanadi, flat bottom plank built boats, known as Nava are in use. Machua type boats are used for the operation of large nets in the estuaries of Gujarat. Small riverine and estuarine crafts, known as 'dinghis' are employed extensively in West Bengal for operation of purse nets and dip nets. These dinghis have narrow tapering bows and sterns and have no keels, larger boats of this type are used for operating larger nets.

5. Large fishing boats: Large fishing boats are used for carrying fishing operation with the dragnet. It is generally 35ft. long, 5 ft. broad and 1 foot deep. It is partially decked with splitted bamboo.

6. Bachhary boat: It is a long boat but narrower than chhandi boat. It is specially used for fishing with the bachhary jal. The boat has valley like projections with shallow spaces or ponds in which live fishes like *Channa* spp., *Clarias batrachus, H. fossilis, Anabas testudineus* that are placed and transported through boat from the catching area to the consuming centre, i.e., to any of desired places in the living condition.

7. Mechanised boats: There has been addition of further facilities in the form of mechanised boats for quick transport of fishes from the midwater, i.e., fishing site, to the bank. Motor machine is fitted to the large boats and a rapid transport action of the fishes is thus obtained.

8.1.3 Fishing crafts of backwaters

1. Dugout canoe, Catamaran and Outrigger canoe **–** Used in backwaters and estuaries of Kerala, Orissa and Tamilnadu.

2. Shoedhoni **–** Used in estuaries near Kakinada in Andhra Pradesh; shoe shaped; length about 10 m; wide flat forward and narrow aft with a transom stern (Fishing platform)

3. Plank built flat bottom boat (without keel) – used in Chilka lake

8.1.4 Fishing crafts of reservoirs

They include coracle, float with sealed tins, catamarans (Teppa), dried water gourd, inflated rubber tubes, dug-out canoes, plank built canoe, flat bottom plank built boats, tin boats, ferro-cement boats and transport boats.

Chapter 2: Fishing gears of Inland water bodies in India

8.2.1 Classification of fishing gears

Fishing gears may be classified based on

1. The place of their use (pond, reservoir, river)
2. Their mobility (e.g. whether active or passive)
3. Depth of operation (surface, pelagic, demersal, mid-water, bottom gear, etc).

8.2.1.1 Gears according to the place of their use

1. **For ponds:** Cast nets, stick-held seine nets, plunge baskets, tangle nets, traps, hand lines.
2. **For reservoirs and lakes:** Cast nets, gill nets, beach seines, stick-held seines, trap nets, scoop nets, hand lines, long lines
3. **For rivers:** Cast nets, drag nets, stick-held seine nets, gill nets, lift nets, bag nets, dip nets, cover pots, traps, hook and lines and long lines.
4. **For estuaries, lagoons and back waters:** Bag nets, bamboo screens or walls of netting, purse net, seine net, drag net, drift gill net, lift net, dip net, rod and lines

8.2.1.2 Gears according to their mobility

5. **1. Active nets:**
6. These are moved by man-powers (group of persons) or machine power to encircle the shoal of fish and bring them to shore (bank). In active netting, the floats and sinkers are so adjusted as to keep the two ends of the net stretched apart during the entire operation. They include drag nets, bag nets, seine nets, trawls, purse seines, cast nets, scoop nets, movable traps, hook and line (angling).
7. **2. Passive nets:**
8. These remain stationary at a place and the fish moving around are caught or gilled. The net is either set at the bottom with the help of anchors and stakes (stake net), or suspended at intermediate depths with the help of drop-lines from larger buoys at the surface or suspended near the surface by its own float line, but the net is attached by means of ropes to larger sinkers at the bottom. They include various kinds of gill nets, ‘trammel’ nets, hook and line.

8.2.1.3 Gears according to the depth of operation

1. **Surface –** Surface gill net, surface trawl net
2. **Mid-water –** Mid-water / column gill net, mid-water / column trawl net
3. **Bottom** - Bottom gill net, bottom trawl net

8.2.2 Fishing without gear

Hand Gathering

This is the simplest method used in both freshwater and marine environment. It is mainly done in shallow waters; particularly hill-streams, shallow channels, intertidal zone, lagoon, mangroves etc. In hill streams an isolated channel is dammed by putting the stones and then the flow is diverted to the other side. The fishes trapped in the dammed area are then picked up by hand. Generally, these fishes are not of much economic importance. Poor villagers or tribals usually adopt these tactics. In the intertidal zones, fishers mainly fisherwomen gather gastropods, clams, oysters, mussels, seagrasses, seaweeds etc. In the estuaries, they collect young ones of penaeid and non-penaeid shrimps. Sometimes they collect even marine ornamental fishes in the shallow waters. Molluscan shells are sold for making lime and for ornamental use. Seaweeds are used for preparing agar, algin and carrageenan.

8.2.2.1 Fishing by hunting

Spear is the earliest weapon employed by man and still in use to-day in many parts of the world. Besides spears, harpoons, lance, rake and rifles are used to catch large-sized fishes like *Bagarius*, *Wallago*, *Pangasius*, *Mystus* when seen trapped in shallow channels, irrigation channels, inundated fields, bundhies etc. during monsoonic floods. A ‘Spear’ tip is fitted on a bamboo shaft of 1.50 to 2.0 m and operated by throwing on the target from a boat or standing on the bank. The harpoon has a shaft of about 3 m long to one end of which is attached a barbed iron point (single or double) of about 20 cm long. The rake is a highly specialized weapon consisting of a long and thin blade at each end (look like a double-bladed oar)

8.2.2.2 Fishing with animals

Fish and other aquatic animals are caught using trained animals like dogs, otters, cormorants (a bird), etc.

8.2.2.3 Grappling and wounding gears

Certain instruments are used to grapple and wound the fish prior to their capture. These instruments can be hand instruments or sharp projectiles.

Hand instruments

These are broadly classified into clamps, tongs and rakes.

1. **Clamp** is a stick with one end split into a few branches. Clamps are mainly used to catch mussels and snails.
2. **Tongs** are similar to scissors with long handles and are used to operate slightly deeper than the clamps.
3. **Rakes** are used to catch mussels and they rake and dig animals hidden in the mud.

Sharp projectiles

Instruments with sharp points are used, thereby catching the fish in a damaged or injured condition.

1. **Spears** are simplest form of sharp projectiles and they range from single pronged stick to many pronged barbed ones.
2. **Fish plummets:** Metal weights with barbed points called fish plummets pierce the flatfish over the bottom as they are dropped down.
3. **Fish combs** provided with prongs which pierce the fish when pressed into the mud are mainly used in eel fishery.

8.2.2.4 Stupefying Gears

Certain devices are made use of in stupefying the fish either mechanically, chemically or electrically to ease their capture. These methods are prohibited in responsible fisheries.

Mechanical stupefying is done by throwing stones at the fish, beating with clubs or mallets and by using explosives like dynamite (**Dynamite Fishing**). However, the use of explosives is environmentally harmful for the entire fish population and also the fishing grounds.

Fish poisoning - Chemicals like copper and lime are used to poison the fish. Plant poisons extracted from ichthyotoxic plants containing saponin are used to poison and stupefy the fish. Traditionally some tribals used to kill or narcotize fishes using latex or powdered parts of some plants. Some plant poisons are used in aquaculture programme to eradicate undesirable (weed) fishes from the nurseries or fish farms. Derri's root powder (Roots of *Derris trifoliata*) containing an ingredient called 'Rotenone' is the most commonly used fish poison, acting like a contact poison which damages the respiratory system and ultimately causes death. The poison is effective in shallow waters up to 1.5 m depth on hot sunny days with water temperature above 25º C. Powdered seed kernel of *Croton tiglium*, powdered root of *Millettia sp*., seed powder of *Barringtonia sp.,* unripe fruit powder of *Randia sp*., bark powder of *Walsura picidia* are indigenous plant poisons. Mahua oil cake and sugarcane jaggery are also piscicides. Some of the common ichthyotoxic plants are Safed Siris (*Albizza procera*), Nogdona (*Artemisia vulgaris*), Dar-hald (*Barberis aristata*), Banalu (*Discorea* sp.), Chaulmugra (*Hydnocarpus hurzee*), Akhrot (*Juglans regia*), Hazarmani (*Phyllanthus urinaria*), Kuchla (*Strychonus nuxvomica*), Sarphonka (*Tephrosia purpuria*), Ban Tambaku (*Verbascum thapsus*) and Timru (*Zanthoxylum* spp.)

Electrical fishing – Effect of pulsating electric field on fishes such as first reaction, electrotaxis (anode attraction), electro-narcosis and electrocution are utilized in electrical fishing equipment. Effect of electric field is also made use of in other fishing systems such as trawls and hook and line to enhance efficiency.

8.2.3 Common Inland Fishing Gears

1. Fixed or Stationary net

These nets are rectangular or conical nets of various shape and size. They are mainly used in the tidal regions of the river or in the shore water during low tide period. They are provided with floats and sinkers to keep the net straightened. The nets are kept fixed to the bottom at the bank of the river. At the time of high tide the water containing fishes pass over the net. When the tide recedes, the fishes are tapped with water in the nets. They are of two kinds: Khalpatta Jal and Bag net or Boat seine.

(a) Khalpatta Jal. This type of net is largely used in Sundarbans, Chilka lake, in the lower reaches of Ganga and Palluvala of Kerala. They are widely used to catch a variety of clupeid fishes and carps. The net is fixed by two bamboo poles. The water is enclosed in a vertically disposed net and the fish is entrapped in the meshes of the net.

(b) Bag net or Boat Seine. It is a triangular conical bag net with a tapering apex and a rectangular mouth, but without wings. The two ends of the mouth are tied with floats. The size of the mouth increases from the bag portion towards the outer flank. This bag net is popular in South India but with different names, e.g. Viaga valai in Andhra Pradesh (bag net with long tapering flanks), 'thuri valai' in Madras coast and boat seines in Kerala coast. With the help of the above sort of bag net, small fishes like clupeids, feather backs, etc., are caught from the Ganga basin rivers.

8.2.3.1 Drag Net (Shore Seines)

A dragnet consists of a pocket net, wing net, ropes, sinkers and floats. The nets are generally made of cotton or nylon with cotton ropes. Depending on the area of fishing and the type of the fish to be caught, their lengths, depths and mesh sizes may vary from place to place. It has got different names in different places of the country, such as 'Ber Jal' in Orissa, 'Maha Jal' and 'Kona Jal' in Bihar and Bengal. The 'Ber Jal' of Orissa and 'Alvi' of Andhra Pradesh are almost the same.

8.2.3.2 Gill Net and Drift Net

Gill nets are wall-like nets with floats attached to the head line rope and sinkers fixed, to the foot line rope. The mesh size varies with the size of the fish species to be caught. The net is set in transverse direction of the moving fish or fish shoal so that when the fish tries to cross the net wall, the head portion along the gill line gets entrapped. When the fish struggles to escape, it gets stuck up behind the opercle. Because of this entrapping at the gill line, the net has been assigned the name of gill net. They are also called drift nets as they drift vertically with the help of floats and sinkers. On the basis of setting, gill nets are of floating types, anchored type and staked type. Among drift nets, Chhandi jal is more popular.

Three types of gill nets are in common use. They are

1. i. Surface gill net

This gill net is generally meant for entrapping surface feeders among carps. Two types of surface gill nets are in use – one is the set type and the other is the drift type. The fishes caught are generally surface feeders such as some major carps.

2. ii. Column gill net

The basic form of this net resembles the surface gill net. The length of the float rope is however, kept such that the net remains suspended in mid column of water. This net is operational in deep water. The catches are generally major carps.

3. iii. Bottom gill net

The material used and mesh work design is the same as mentioned before for surface gill net, As the net is to be set at the bottom of water, additional sinker weights are attached to the foot rope and the marker buoys or floats, kept hanging on the surface of water are given increased length of the rope.

8.2.3.3 Trammel Net

This net is a modified form of gill net, comprising three layers of gill nets. The inner or middle net possesses a small mesh but larger depth. It is held between 2 outer nets with a large mesh but smaller depth. Because of this peculiar set up of three nets, fishes of various sizes are generally caught by this modified form of gill net. It has been observed that small fishes are gilled in the fine mesh working of inner nets, but larger fishes, while swimming, strike against the outer nets. Consequently they get entangled in the pockets formed by the inner net as extrusion. In large tanks and reservoirs of many places, this net is operational to catch fishes of various sizes.

8.2.3.4 Cast Net

They are well adapted for the capture of small shoaling fishes. This net is commonly used in shallow waters. This is a circular-mouthed or umbrella shaped conical net with about 2.5 cm mesh size. A strong cord or warp is attached to the apex of the cone or umbrella and a number of lead or iron cylindrical sinkers are fixed all along the circular periphery. The net is cast into the water from the margin of the tank or pond or from a boat or stakes made of bamboo or wood in such a way that a group of fishes get covered over by the net and, thus, entrapped. The hand rope is carefully pulled to close the spread skirt. The overall result of operation is such that the fishes are caught in the pocket of the net. Its operation is always in shallow water areas devoid of weeds and submerged obstructions of any sort.

8.2.3.5 Dip Net or Lift Net

Several kinds of dip nets are in use for catching small sized fishes. They are triangular, rectangular or square in shape and are made up of bamboo frame along which the net is laced skillfully. Some bait such as the ball of wheat flour or cockroach or earthworm is often put on the net or somehow kept suspended over the net to attract fishes. Small sized nets are provided with handle and are generally operated by hand from some boat or raft, but for the operation of larger ones a long bamboo pole, which is kept fixed to the centre of the dip net, is used like a lever. There are four types of dip nets which are in common use in the rural areas: Triangular dip net (also called 'Bhesal jal'), Kharra jal (another form of triangular dip net), Hela jal (another triangular net), Khorsula jal (rectangular dip net).

8.2.3.6 Purse Net

This is purse shaped net, operational from a boat. It is generally used in Ganga river system for catching *Hilsa* fish. Two types of purse nets are in use: (a) Kharki jal and (b) Shangla jal.

8.2.3.7 Bag set net

The bag set net has appearance of a conical type of net and is provided with wing or is without wings. The size of the mesh varies as per expectation of kind of fish species to be caught. The length of the net is variable between 5 m to 10 m. The cod end of the net is kept closed by a knot, but when entrapped fish are to be taken out, the pocket is unfastened by loosening the knot. Before operation two strong bamboo poles or wooden stakes are fixed erect by exerting pressure against the soft bottom of the river or tank or reservoir. The next action is that the net is fastened to poles with rope and it gets stretched against the direction of water flow. The stretching may occur automatically as a result of water current or thin strip of bamboo is used as frame work to support the mouth, i.e., to provide firmness. The fishermen, generally two in number, use a boat for the operation of this net. The operation is generally done at night and the fishing places are long rivers, with the existence of some current in water, or streams joining reservoirs or large tanks.

Hooks and lines

Among some other devices of minor grade for catching fishes, more popular are (i) pole and line and (ii) hook and long line, (iii) hand line which are used generally in ponds, tanks, rivers and reservoirs.

i. Pole and Line

This simple gear consists of a pole, a line and hook. A suitable bait (e.g. generally the earthworm piece) is fixed to the hook, and the line with hook is dropped at a distance in front, after selecting a prospective fishing site. Fish gets lured in water and bites the bait. Instantly, the indicator vertical float gets drowned and the pole holder pulls the pole by a swing action on the pole.

ii. Hook and long line

The gear consists of a long main line, shorter branch lines tied to the main line, hooks, buoyant or floats and sinkers. A suitable bait (earthworm piece, fish piece, wheat paste) is used depending upon the type of fish to be caught. The line is spread with the help of a boat taking care that the hooks are in proper position. Main catches are *Wallago*, *Mystus*, Murrels, major carps. However, cold water fishes (eg. Trouts) are the main catches in cold water lakes.

iii. Hand line

The polyamide monofilament lines have a terminal lead sinker and a hook. The length of the line varies according to the depth of the operating area and various size hooks are in use. Different types of baits are used according to the fish sought for.

8.2.3.8.1 Bait and its types

Bait

It is a kind of 'lure', fixed on the hook, used for attracting the fish and then hooking it with the hook.

Types of baits

Live bait: It is a natural organism fastened to the hook. The most common baits are small sized fishes, worms, insects, crustaceans, molluscs, frog etc.

Paste bait: Rice flour, Gram flour mixed with finely grated cheese, wheat flour added with a little honey, boiled rice mixed with mustard oil cake powder etc. are used to make the paste. The best way to keep the paste on the hook is to cover the barb and the shaft in such a manner as the barb is not covered with a thick layer and that it can pierce through the flesh of the fish, as soon as the fish bites. Several fishes (mainly herbivores) are lured by 'paste baits'.

Gram bait: Gram seeds are threaded on the hook (at least 3 on one hook) to bait Mahseers.

Artificial baits: Certain kinds of artificial baits are used when others fail. They may be **spinning baits** (aluminium painted body revolving around a bead head), **plug baits** (an imitation of a living fish and made of plastic or wood and painted in different colours), and **artificial flies** (imitation of an aquatic insect).

8.2.3.8 Dredges

Dredges are dragged gear, with an oblong iron frame with an attached bag net, operated on the bottom usually for collecting shellfishes such as mussels, oysters, scallops, clams etc. They are of varying weight and size and are operated from boat or in shallow waters by hand.

8.2.3.10 Traps

They are stationary nets and fishes are directed towards an enclosure through guarded entrance. Various types of traps are used for catching aquatic organisms. The following types are used in inland waters.

Pots: They are small traps designed to catch fish and shellfish. They are fabricated as small cages or baskets from locally available materials such as wood and wicker and also by using wire netting, metal rods, synthetic netting and reinforced plastic. Target organisms are enticed into the enclosure by bait or shelter spaces. They are provided with one or more entrances. The size, shape and position of the entrance are optimized for the target species.

Barriers (Barrage traps): Barriers like walls or dams made of stones, mud, netting or split bamboo pieces are used to trap fishes during low tides. In water where there are no currents, fences are provided to guide the fish into pockets. These are then removed by other gears. In rivers where there are strong currents, the fishes are guided on to a slanting screen of gratings constructed in the river and ascending in the direction of the current. The fishes are caught when the water disappears through the screen. The migrating fishes are best caught in a watched catching chamber, which is a large chamber open on three sides. These require constant watch so as to close the entrance as soon as the fish enters. This is normally done by pulling up the netting from the bottom thus trapping the fish. They are operated by small scale fishermen**.** *Hilsa* traps are operated below the confluence of Ganga and Yamuna.

Fish screens: Fish screens are of common use to enclose a selected water area of the river for fishing. Thin pieces of split bamboo are woven to form a sort of screen of generally 10 m length and 1 to 1.5 m height. Several such screens are joined together to surround as shallow tidal area at the time of high floods in the river. When the flood water recedes, several kinds of fish are left behind on the surrounded water area and these are easily collected by the lift net or properly handling a manicuring net. Generally carps, catfishes, and murrels are thus collected.

8.2.3.11ish Aggregation Device (FAD)

Fish Aggregation Device (FAD) is a man-made object that is used to attract fishes. It consists of buoys or floats tethered to the floor of the water body with concrete blocks. FAD's attract fish for numerous reasons that vary by species. Submerged bundles of twigs or branches of trees make attractive hiding places for fishes. The fishermen can catch the aggregated fishes easily by using small scoop net. This method is practiced in certain downstream areas of the river.

8.2.3.12 Fishing gears of rivers

Sl.No	Gear types	Characteristics	Area Operatable	Method of operation	Remarks
1.	Seines a. Berjals	Different dimensions and different mesh size are used	Gangetic Area	---	These jals have a stout foot rope, absence, of bag at mid length and no sinkers. Net may be loaded upon more than one boat and then hauled on shore by several fishermen
	b. Kona jal or Bhasa gulli	Size 91n* gm cotton net	Used in Hilsa fishing	Small meshed pockets. Conical in shape are attached along net to catch fish. Due to valves in these pockets fish cannot escape and thus captured	---
	c. Jagat ber of Mahajal	--	Riverine area	---	Captured throughout year except july to September
2.	Drag net a. Moi or Moiajal		Shallow water	---	Can be operated by two fishermen
	b. Chunti jal		Bihar		
	c. Mahajal (long drag net)	Size 4*2m	Rivers with strong current	--	Huge amount of fishes are captured
3.	Drift net a.Keral or Katla jal	Carp and Katla capture	Narmada river	---	It consists of two bamboo poles crossing each other near two long sides

4.	Dip net a. Mela jal	Catfish capture	Narmada river	---	It is like Hela jal but is operated from bamboo stage
	b. Karra jal	Hilsa capture resembles open bag			Bhil fishermen catch Hilsa by this net
	c. Jamda	Stationary net with mouth kept open by vertical rod			
	d. Suti jal				
5.	Purse nets a. Kharki jal	Hilsa capture	---	---	In this jal a vertical bamboo rod is attached to lower margin of mouth to open and close it.
	B. Shanglo Jal or Skarki		Upper reaches of estuaries		In this purse is opened and closed with weighted cord
6.	Cast net a. Bechari or Otter jal	Catla, Rohu capture(area more than 55m)	---	---	Since peripheral area is large, so 3-4 fishermen operate it from boat
7.	Kuriar net	Catched big carps and Hilsa	Used in shallow waters	Net is kept inverted and dipped and then taken out of water	This net can be operated single handed
8.	Bamboo screens	---	Shallow ponds and small rivers	Manipulated and handled like seine	Bamboo screen and drip net are combined sometimes for operation
9.	Fixed nets	---	Used in rivers and tributaries of Uttar Pradesh	Long rectangular piece of mesh stretched from one bank to another bank and held up by bamboo sticks in the middle .	---
10.	Triangular net commonly known as 'Bhog'	Conical net shaped like butterfly and made up of stings	Eastern districts of Uttar Pradesh	Mouth of net is kept open by bamboo sticks. One of the sticks is longer and used as handle. The closed end of the net serves as reservoir for collection of fish	The net may be operated from boat also
11.	Trap nets a. Basket trap	Commonly used Consists of 2	Uttar Pradesh -do-	The opening is guarded by bamboo sticks and fished entering baskets	---

	net	domen shaped baskets with suitable bait in the form fo ball is placed in it.		are trapable to come out due to recurved nature of sticks guarding the opening	
	b. Pot trap net	Commonly used by poor people	Eastern Uttar Pradesh	Wide mouthed earthern pot is used as trap with a thick cloth having few holes and suitable bait put inside the pot tempts fish to enter	Live fishes like Channa, Clarias, Heteropneustes inside pot are captured by hand
	c. Konch trap net	Used in shallow muddy waters of summer	---	Made split bamboo pieces in form of conical basket with small circular opening at the top to allow the hand to enter. The trap is dropped in water and the wide mouth is presses in southmud. The fishermen then brings his hand through the top opening and catches the fishes which wriggle in muddy shallow water.	Channa, Heteropneustes, Clarias, Cuchia, eels are collected by this method
12.	Electric equipment	Current is provided by generator or battery	Ponds	Fish with electric field receives shock and they are mae numb for a few moments and during this period they are seized.	---

8.2.3.13 Fishing gears of hill streams

Sl.No	Gear types	Characteristics	Area Operatable	Method of operation	Remarks
1.	Seines	Commonly used	---	---	---
2.	Dragnets	Commonly used	---	---	---
3.	Basket trap	Some part of stream is bunded off	Stream parts	---	---
4.	Explosives & Poisons	To capture on large scale	--	---	---

8.2.3.14 Fishing gears of lagoons and backwaters

Sl.No	Gear types	Characteristics	Area Operatable	Method of operation	Remarks
1.	Bag nets a. Cast net or Dip net b. Khalpalttajal c. Charpatta jal d. Thatturala e. Janos	Used against tidal currents	Sunderbans Sunderbans Sunderbans Thatturala (keral) Chilka	Some area is enclosed by bamboo screen and then by draining it fish are caught	---
2.	Bush netting	---	Sunderbans	Bamboo screens reused to enclose and area and that area is piled with bush to attract fish	---
3.	Seine net a. Kochal jal b. Jangle jal	Having 4-5 boats and 24 fishermen	Sunderbans Sunderbans	---	---
4.	Drag Net A. Mori Jal B. Khadi Jal C.Sahalo Jal D. Patua Jal E. Mani Jal D. Ber Jal g. Jagal jal	---	Chilka Lake Chilka Lake Chilka Lake Chilka Lake Chilka Lake Chilka Lake	---	----

5.	Purse net a. Shanglo jal b. Kharki jal	To capture large fishes	Estuarine area of Ganges Upper areas of estuaries	--	--
6.	Drift gill net a. Chandni jal	More than 300m long and 3m wide	Estuarine of W. Bengal	--	--
7.	Gill nets a. Menji jal b. Noli jal	---	Chilka lake	----	----
8.	Rangoon nets	Hilsa capture	Estuaries of Krishna and Godavari	----	-----
9.	Chine dip net a cheenavala or kambuvale b. Changatopayllal or Changadem c. Road and line Fishing and Handling	9-11m size Mullet fishing	Backwater of Travancore and Cochin -do- Backwaters of Kerala	---	---

Unit 9: Exotic fish introduction and conservation of inland fish biodiversity in India

Chapter 1: Introduction of exotic inland fish species in India

9.1.1 Introduction

World is experiencing biotic invasions at an unprecedented rate, causing unforeseen adverse impacts on native biodiversity, ecosystem functioning, human health and regional economies. The gradual but insidious replacement of native biota's by non indigenous species is leading to 'biotic homogenization', which results in global erosion of regional distinctiveness and loss of native species. The tempo of such homogenization is particularly evident in freshwater systems. According to the Union of Concerned Scientists (2003), "the accelerating introduction and spread of invasive species is among the most serious of the threats to global biodiversity".

9.1.2 Ways by which exotic species affect native species

Non indigenous species

- eliminate native species through competition or predation
- contribute to a reduction in local biodiversity
- bring with them novel parasites and pathogens into the invaded area
- erode or dilute local genetic diversity by hybridising with the indigenous species
- alter habitat in ways that render it unsuitable for the local species
- reduce ecosystem productivity and thus cause economic losses

9.1.3 Indicators of potential invasiveness

The success of an introduced species in becoming invasive and harmful to native species and ecosystems depends on certain traits of that species as well as certain characteristics of the invasion site. Traits of a species that are indicators of potential invasiveness include

- wide distribution and abundance in the source region
- high physiological tolerance
- special traits not present in the invaded community
- ecological versatility
- high population growth rates and it correlates high fecundity and short generation time
- rapid dispersal

Invasion success is also determined by the invisibility of a habitat.

9.1.4 Characteristics making a region vulnerable to biological invasions

Characteristics that make a habitat or a geographic region more vulnerable to biological invasions are

- Similarity to the source area
- Presence of vacant or underutilized niches
- Low native species richness
- Anthropogenic disturbance of the ecosystem. Among human activities that make a region particularly vulnerable are extreme alterations in soil characteristics, frequent fires, grazing, nutrient inputs, hydrological shifts and habitat fragmentation.

Ecologists find it puzzling that many non indigenous species which turn out to be invasive in the introduced region are generally innocuous in their own native range.

9.1.5.1 Inadvertent (Accidental) Introductions

For aquatic invaders the route of accidental introduction is most often the ballast water carried by transoceanic cruise ships. Ballast water had been reportedly the major pathway of non indigenous species that have become established in the Laurentian Great Lakes of North America. It is the most dominant mode of dispersal for a wide variety of aquatic organisms ranging from ciliates to fish. Although ballast transport may not be a significant source of exotic fish introductions, non indigenous zooplankton could adversely affect native fish directly by altering trophic dynamics of the invaded water bodies.

9.1.5.2 Deliberate Introductions

Several reasons are usually offered for introducing a new species into a lake or river:

1. Create new fisheries that are more resistant to fishing pressure or have greater market value than native fish. New species are introduced into recreational fisheries to improve the variety available to the anglers or to insert a species of particular trophy or sporting value into an area.
2. Fill a "vacant trophic niche" where existing species do not fully use the trophic and spatial resources available
3. Control pests – several species have been introduced in an effort to biologically control pests and vectors of human disease.
4. Control water quality – where suitable phytoplankton eating species are lacking to remove excessive algae in eutrophic systems
5. Develop aquaculture – this remains one of the main motives for the movement of species around the world. Many species have been introduced for culture. Escapes from aquaculture installations have contributed to many successful introductions into the wild.

The major factors that lead to consider introduction of exotic fishes in the aquaculture field include:

- Growth of indigenous species was not up to the mark
- Indian Major Carps do not breed in confined waters
- Natural recruitment of carp species failed at times due to monsoonal disturbances
- Stocking of reservoirs could only be done by collecting seeds from the wild

- With the available fish community the trophic niches could not be utilised fully.
- Improve sport fishery - Introduction of alien fish for recreational fishing has resulted in extirpation of many native fishes around the world. The adverse impacts of salmonid sport fishes like brown trout on multiple ecological levels have been well documented.
- Fulfil aesthetic and other reasons – ornamental species are now widely distributed throughout the tropical world through escapes from rearing installations and aquaria. Some species have also been introduced for particular religious or cultural reasons.

9.1.6 Global perspectives

Welcome (1988) reported that 168 species of fishes, representing 37 families have been introduced outside their natural distribution range world over, and a minimum of of 67 species have become established in different water bodies, with 27 species turning out to be real pests. Experts also opine that transfer of fishes to different habitats within the country should also be done with as much precaution as those across the borders. A typical example for the disastrous effects of introducing species is available from Lake Victoria, the world's largest tropical lake. In the 1970s, there were over 300 endemic cichlid species, representing 99% of the lake's fish species. Eight million humans in Kenya, Uganda and Tanzania depend on this lake for food. The physical and biological properties of the lake changed considerably since the introduction of the exotic fish, Nile Perch (*Lates niloticus*). The majority of cichlids endemic to the lake became extinct and now the group represents only one percent of the lake's fish diversity.

The introduction of carnivore *Clarias gariepinus* to the Eastern Cape in South Africa has similarly affected some native fishes and crabs. The introduction of sea lamprey (*Petromyzon marinus*), Rainbow smelt (*Osmenus mordax*) and common carp (*Cyprinus carpio*) have affected the native species like Mosquito fish (*Gambusia affinis*) and *Fundulus heterochitus*. Nearly 40% of all introductions have been attributed to "aquaculture" purposes. Sport fishing has provided the second major motive for introduction (16%) followed by "improvement of wild stocks" (14%), ornamental purposes (11%) and biological control of unwanted organisms (7%).

9.1.7 Challenges to global fish introductions

While the global interest in search for target species, which have achieved or could achieve success in mass cultivation especially during the 1950's and 1960's has resulted in rapid expansion of aquaculture, fish introductions worldwide have resulted in spectacular successes and failures. As pointed out by Welcome (1988), developed nations in the temperate zones with strict regulations to protect the environment and biodiversity tend to approve species introductions with nil or minimal damage to the natural systems. The converse is true with countries in developing region of the world. In the latter case, there have been many positive socio-economic benefits than negative ecological impacts. For example, approximately 17% of the world's finfish production is due to alien species. Production of the African Tilapia is much higher (over 20 – 25 times) than in most of the African countries combined. Introduced salmonids in Chile support a thriving aquaculture industry that is responsible for approximately

20% of the world's farmed salmon and directly employs approximately 30,000 people. Therefore, the very scale of measuring 'success' and "failure" of a given introduction becomes subjective in nature. The issue then is not to ban fish introductions altogether or to wilfully abandon regulation of their movements. The issue is clearly the associated risks and benefits and then, if appropriate, develop and implement a plan for their responsible use.

9.1.8 History of exotic fishes in India

The introduction of exotic fishes in the Indian waters can be traced as having more than a century old history. While the country was under the British rule, such fisheries were possibly introduced as a means for recreational fisheries. Sir, Francis Day, the author of the classical work on the Fish fauna of Indian region, was probably the first person who tried to introduce the brown trout, *Salmo trutta fario* in the Nilgiri waters in the year 1863, but his attempt was unsuccessful (Jhingran, 1975). This was followed by introduction of several exotic fish species from various parts of the world to different regions of India for augmenting fish production through aquaculture, for sport fishery, for mosquito / weed control, for ornamental purpose etc with successes and failures. The larvicidal fishes, such as, *Poecilia retiuculta* and *Gambusia affinis* were introduced in the year 1908 and 1928 respectively, to contain mosquito larvae in confined waters. But the larvicidal value of these species is not well established. There are hundreds of ornamental fish species being imported to our country since the aquarium trade is in progressive growth stage/ insecticidal value of these species is not well established. The ornamental fishes, although remain confined to aquarium tanks, their release into natural habitats is not uncommon and the impacts in case of escapee were not yet assessed. The following table shows the list of exotic fish species introduced in India.

Table 1. Exotic fishes introduced in various Indian uplands

Species transplanted	Imported from	Period of	Transplanted to	Purpose	Remarks
1	**2**	**3**	**4**	**5**	**6**
Family: Cyprinidae *Cyprinus carpio*	Sri Lanka	1939	Nilgiris (T.N)	Commercial Aquaculture	Transplanted to upland water bodies of northern and southern Indian and establishment well
Carassius carrasius	U.K	1870	Ooty lake (T.N)	Commercial Aquaculture	Remained restricted to the same system
Tinca tinca	U.K	1876	Ooty lake (T.N)	Commercial Aquaculture	Remained restricted to the same system
Hypophthalmichthys molitrix	Hongkong, Japan	1959	Cuttack	Commercial Aquaculture (Orissa)	Transplanted to various upland lentic system and doing well
Ctenopharyngodon idella	Hongkong	1959	Cuttack (Orissa)	Commercial Aquaculture	Transplanted to various upland lentic

					systems and doing well
Family: Poeciliidae *Gambussia affinis holobrooki*	Italy	1928	Cuttack (Orissa)	Larvicidal	Transplanted to various upland lakes and established
Family: Salmonidae Salmo trutto fario	U.K	1899	Harwan (Kashmir)	Sport & Aquaculture	Established well, later on the fish seed was transplanted in different water bodies of western, central and eastern Himalayas.
Salmo gairdneri (Onchorhynchus mykiss)	Sri Lanka, U.K	1904, 1912	Harwan (Kashmir)	Sport & Aquaculture	Established well; later on the fish seed transplanted to Nilgiris
Salvelinus fontinalis	U.S.A	1963	Harwan (Kashmir)	Aquaculture	Not fared well
Lake trout (Hybrid: Lake Trout X Brown Trout)	Canada	1968	Harwan/Laribal (Kashmir)	Aquaculture	Not fared well
Salmo salar	Canada	1960-1970	Harwan/Laribal (Kashmir)	Aquaculture	Not established
Rainbow trout Selective quick Mann	Isle of (U.K)	1984	Kokernag (Kashmir)	Aquaculture Growing variety	Established well
Salmo trutto fario	U.K	1863	Nilgiris (T.N)	Sport	Not established
S. gairdneri	Sri Lanka, Germany, New Zealand	1909-1910	Nilgiris (T.N)	Sport and Aquaculture	Established
Onchorhynchus nerka	Japan	1968	Nilgiris (T.N)	Aquaculture	Not established
Salmo trutta	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture	Not established
Japanese Rainbow Trout	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture	Established
Tiger Trout (Hybrid : Brown Trout X Eastern Brook Trout)	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture	Not Established
Albino Rainbow	Japan	1968	Nilgiris (T.N)	Aquaculture	Established
Salmo trutta	U.K	1909-1938	Munnar High Range (Kerala)	Sport and Aquaculture	Not Established
Salmo gairdneri	U.K, Sri Lanka	1938-1940	Munnar High Range (Kerala)	Sport and Aquaculture	Established

Salmo gairdneri Shasta	U.K	1941	Munnar High Region (Kerala)	Sport and Aquaculture	Established

(**Source: National Bureau of Fish Genetic Resources, Lucknow - reproduced from NATCON PUB. 05)**

Table 2. List of approved exotic freshwater ornamental aquatic species

Sl.No.	Scientific name of species	Common name
1.	*Balantiocheilus melanopterus*	Bala shark
2.	*Barbodes everetti*	Clown barb
3.	*Betta smargdina*	Blue beta
4.	*Botica macracantha*	Clown loach
5.	*Capoeta tetrazona*	Tiger barb
6.	*Carassius auratus*	Gold fish
7.	*Epalzeorhynchus bicolor*	Red tailed black shark
8.	*Labeo frenatus*	Rainbow shark minnow
9.	*Macropodus opercularis*	Paradise fish
10.	*Paracheirdon innesi*	Neon Tetra
11.	*Poecilia latipinna*	Sail fin molly
12.	*Poecilia reticulate*	Guppy (developed and cultivated)
13.	*Pterophyllum scalare*	Angel fish
14.	*Rasbora heteromorpha*	Herlequin rasbora
15.	*Symphysodon discus*	Red Discus
16.	*Symphodon aequifasciatus (axelrodi)*	Blue Discus
17.	*Tricogaster leeri*	Pearl sword tail
18.	*Xiphophorus helleri*	Red sword tail (green/wild caught not allowed)
19.	*Xiphophorus maculates*	Platy
20.	*Cyprinus carpio var Koi*	Koi carp (free from Herpesvirus)
21.	*Botia modesta*	Red tailed boti
22.	*Botia lecontei*	Silver loach
23.	*Apistogramma luelengi*	Dwarf cichlid
24.	*Botia morleti*	Shunk botia
25.	*Botia sidthimunki*	Dwarf chained loach
26.	*Betta splendens*	Siamese fighting fish
27.	*Cichilisoma carpinte*	Texas cichlid
28.	*Cichilisoma temporalis*	Emerald cichlid
29.	*Hypessobrycon grieni*	Gold spotted tetra
30.	*Pseudotropheus socolofi*	Pindani
31.	*Puntius nigrofasciatus*	Black ruby barb
32.	*Puntius waandersi*	Kepiat
33.	*Tricogaster microlepis*	Moonlight gourami

34.	*Pterygoplichthys gibbceps*	Spotted sailfin sucker catfish
35.	*Apteronotus albifrons*	Black ghost

Source: (National Bureau of Fish Genetic Resources, Lucknow)

Table 3. List of restricted, banned and not approved exotic freshwater ornamental fish species

Sl.No.	**Scientific name of species**	**Common name**	**Category**
1.	*Astronotus ocellatus*	Oscar	Restricted
2.	*Aequidens rivulatus*	Green terror	Restricted
3.	*Labeo chrysophycon*	Black shark minnow	Banned
4.	*Leptobarbus hoeveni*	Maroon shark	Banned
5.	*Osteoglossum bicirrhosum*	Arowana	Banned
6.	*Haplarchus psittacus*	Acara	Restricted

Source: (National Bureau of Fish Genetic Resources, Lucknow)

Chapter 2: Impacts of exotic fish species in India

9.2.1 Impacts of exotic fish species in India

Impacts of introduced species may be categorized under:

1. Ecological (including biological)
2. Genetical
3. Socio-economical

However, these categories at the same time are not independent. The socio-economic change brought about by alien species can in turn cause more ecological or genetic changes which may be from direct interaction with an exotic species or it may result from increased fishing pressure or changes in use pattern brought about by presence of newly established species,. Analysis of database reveals that aquaculture development was the most often cited reason. But most of the ecological and genetic effects in the open waters reported are negative.

9.2.1.1 Ecological impacts

Competition of exotic fishes with the native species for living space with same niche preference, for food with similar types of feeding habits, or omnivorous habitat eating preferred food of all others, predation on native fishes, spreading of parasites and pathogens are some common ecological concerns.

9.2.1.1.1 Tench and Crucian carps

Both the tench (*Tinca tinca*) and Crucian carps (*Carassius carassius*) were introduced in the Nilgiris in 1874 from Europe as food fish. They are essentially cold water species and established themselves in the ponds and lakes in Ooty area in Tamilnadu. In addition, *C. carassius* was also reported to breed at Sunkesula fish farm in Andhra Pradesh. Due to slow growth rate of the fish (15 – 20 cm in first year, at present no scientific culture practice exists in our country.

9.2.1.1.2 Common carp

The three varieties of common carp of Prussian strain, *Cyprinus carpio* var. *communis* (scale carp), *C. carpio* var. *pecularis* (mirror carp), *C. carpio* var. *nudus* (leather carp) were introduced in India in 1939.

9.2.1.1.3 *Clarias gariepinus*

African catfish *C. gariepinus* has been introduced in India in a big way but growing interest in culture of this exotic catfish is a serious concern in view of its devastating impact on the natural stocks of other species. Studies on the biology of this exotic catfish has constructed popular belief that African catfish is a ferocious predator. The African catfish *Clarias gariepinus* (Burchell) was introduced into Thailand and Vietnam and is used for hybridizing with the indigenous, walking catfish *C. macrocephalus* (Gunther) in Thailand. The hybrid is cultured extensively and is preferred by farmers in Thailand, because of its considerably higher growth rate than that of the indigenous species and the desirable flesh quality. The production of hybrid catfish, based on available FAO statistics (FAO 2002), occurs exclusively in Thailand and in recent years has accounted for greater than 17% of the world's catfish production (FAO 2002).

9.2.1.1.4 *Pangasius sutchi*

Business groups and individual entrepreneurs have already been promoting *Pangasius P. Sutchi*, also called "dory" or "sutchi fish" since late 2007, and its mass production was noted during the third quarter of 2008, it was also gathered. Data gathered from the DTI and BFAR of the three regions disclosed that the Philippines imports around 600 metric tons of *Pangasius* fillet, valued at $1.65 million from Vietnam every month. Markets for this species are also opening in Europe, the United States, and other countries in Asia. Aside from the rising income of business groups, farmers, and individuals, the DTI and BFAR also noted that the thriving industry is starting to generate job opportunities in communities.

9.2.1.1.5 Tilapia

Nile tilapia is the sixth most produced species in Asian freshwater culture in 2002 and must be considered the most important inter-continentally introduced aquaculture species into Asia. The resilience of tilapias is most apparent from the fact that it has been used effectively in sewage-fish culture systems in India, successfully for over four decades, and there has never been any report of disease transmission among consumers or mass mortalities of the cultured stocks (Nandeesha, 2002). The reasons for the success of tilapias in Asian aquaculture were also dealt with in detail by De Silva, Subasinghe, Bartley and Lowther (2004), and these authors concluded that there is no explicit evidence to show that bio-diversity of the region has been affected by this introduction. Within Asia the leading producer of cultured tilapias is China, and in fact this is the only alien species that is currently aquaculturally important to this nation. However, the contribution of tilapias to the total inland production in China is small while its proportionate contribution in the Philippines and Sri Lanka is considerably higher,

9.2.1.1.6 Exotic larvivorous fishes

There are several species of larvivorus fish in our country. These were applied in many places in the malaria control programme. Some of these fishes namely *Aplocheilus* sp., *Oryzias* sp. are surface feeder and very effective in controlling mosquito breedings. They can survive breeding. They can survive in saline waters also. Other local fishes are not as effective as these two do because they are column feeder. These species are *Danio rerio, Chela sp., Rasbora sp. Esomus sp., Puntius sp.* etc. In Karnataka, the main breeding habitat of *A. culcifacies* is village ponds which are flat at one side. Most of the breeding are found in these margins where local fish cannot reach due to their feeding behaviour. Guppy and *Gambusia* can reach such places and devour the mosquito larvae. This is why in places local fishes were found not effective. Guppy is very effective and sustainable in wells while *Gambusia* in ponds and streams.

9.2.1.2 Genetic impacts

The genetic impacts of introduction of exotic fishes on native fishes can be classified into 2 categories as:

Reduction of effective population size by genetic effects of introduction in addition to ecological and biological reasons

Alteration / extinction of gene pools of the species / stocks by crossbreeding or hybridization and backcrossing. Crossbreeding means inter-breeding between different stocks and hybridization is the inter-breeding between different species / genera.

9.2.1.3 Socio- economic impacts

The socio-economic impact can be seen at two levels (i) capture fisheries and (ii) aquaculture. Since the exotic fishes never fetch higher price than the native varieties and also the decline of native fish production is observed in presence of exotic species in natural waters, the total economic return declines for the stakeholders of the capture fisheries. In aquaculture, however it provides immediate gain in most cases without considerations of long term ecological sequences.

Image

Schematic diagram of potential direct and indirect effects on biodiversity impacts from alien species

Source: Sena S. De Silva et al., 2009

9.2.1.4 International and National Initiatives to control introductions

It should be recognised that aquaculture is the last frontier for food fish production. Species introductions will remain a valid means to improve production and economic benefits from aquaculture and fisheries. Various international, regional, and national institutes have been established to address the issue of species introductions. They are as below:

1. World Trade Organization (WTO)
2. World Organization for Animal Health (OIE)
3. International Council for the Exploration of the Sea (ICES)
4. FAO of the United Nations (Code of Conduct for Responsible Fisheries)
5. Regional Initiatives (NACA/SEAFDEC/ASEAN)

9.2.1.4 Strategies to be followed while introducing exotic fish species

As far as possible, introduction of fishes should be avoided and attempt should be made to enhance the production of native species by biomanipulation or biotechnological means. More native species that can be cultured on profitable basis should be identified in priority and evaluated.

If the introduction is essential, highest precautions should be taken before introduction and should not be allowed in the natural water before proper study of long term impact on the ecosystem. Ecological interactions, genetic concerns, socio-economic impacts and possible pathogen infestation should be studied thoroughly prior to permitting such introductions.

A nodal agency or panel should be made responsible to study the impacts and risks or benefits of the proposed introduction.

The import and cultivation of broods or seeds of certain species which have proved as harmful to the native fauna and ecosystem as a whole should not be permitted at all.

Stringent quarantine measures should be followed for the imported live specimen consignments in ornamental fish trade. It should be ensured that they don’t escape into natural waters, even accidentally, either from the aquariums of hobbyists or during transit.

Ornamental fish traders and customers may be persuaded by creating awareness through training and education to use native varieties

Banned or unofficial / illegal introduction or trade of fishes should be penalised by law. A comprehensive legislation needs to be introduced.

The global experience and the present status of introduction of exotic species in different countries including India, their ecological, biological and genetic impact analysis clearly show the negative impact in respect of some species. In addition to direct effect on eco-biological impacts, it has also been seen that some fish are even extinct owing to loss of genetic variability and heterozygosity, due to hybridization between exotic and native species, etc. It is therefore necessary to consider any introductions after through studies at appropriate Institutes and clearance by NBFGR and the Committee for introduction of exotic fishes.

Chapter 3:Conservation of inland fish biodiversity in India

9.3.1 Conservation of inland fish biodiversity in India

With the rapid development, population explosion and ever-increasing demand for fish as protein-rich food, aquatic ecosystems of India are under constant pressure due to anthropogenic stresses like habitat destruction, over exploitation, indiscriminate killing of juveniles and adults, excessive water abstraction leaving inadequate water for fish, aquatic pollution, diseases and uncontrolled introduction of exotics. Over exploitation of the fish resources coupled with habitat destruction resulted in the shrinkage of fish population. Due to these factors, a number of fishes in some conventional fishing grounds are declining rapidly and some have become threatened too.

Though the formidable task to categorize threatened fishes of India on the line of IUCN list is still to be completed, efforts have been made during the past in this direction. Menon (1989) compiled a list of 21 vulnerable fishes in India which comprised 4 Endangered (*Barilius bola*, *Puntius chilinoides*, *Semoplotus semiplotus* and *Enobarbichthys maculates*) and 17 threatened species (*Notopterus chitala, Acrossocheilus hexagonolepis*, *Cirrhinus cirrhosa*, *Labeo fimbriatus, Labeo potail, Labeo kontius, Puntius carnaticus, Puntius curmuca, Puntius jerdoni, Tor khudree, Tor putitora*, *Tor tor*, *Schizothorax richardsonii*, *Schizothoraichthys progestus*, *Silonio childreni, Pangasius pangasius* and *Bagarius bagarius*). Interestingly, out of 762 fishes featured in the IUCN Red Data Book of Threatened Animals (IUCN, 1990) throughout the world, the following 2 species, viz., *Schistira sijuensis* (Family Bolitoridae) and *Horaglanis krishnai* (Family Claridae) were included from the Indian waters as rare species.

9.3.2 Status of threatened fishes in India

The National Bureau of Fish Genetic Resources (NBFGR), Lucknow has tentatively identified 4 Endangered, 21 Vulnerable, 2 Rare and 52 indeterminate fishes from the different ecosystems of the Indian waters.

Ecosystem	Total species	Endangered	Vulnerable	Rare	Indeterminate	Total
Cold water	73	01	04	-	12	17
Warm water	544	03	13	02	28	46
Brackish water	143	-	02	-	04	06
Marine	1440	-	02	-	08	10
Total	2200	04	21	02	52	79

9.3.3 Factors affecting fish diversity

With the rapid overall development of the country and owing to ever-increasing demand of fish as food, the aquatic ecosystems are under constant pressure of man-induced stresses to the detriment of the aquatic flora and fauna. Though the decline of individual fish species is very often related to more than one proximate factors, the various causes of imperilment of fishes in the aquatic ecosystems have been identified as

Physical habitat loss due to construction of dams and weirs across the rivers, soil erosion due to deforestation and excessive utilization of waters,

Chemical pollution due to industrial and municipal wastes

Over-exploitation and indiscriminate killing of juveniles and brood fishes

Competition from the introduced non-indigenous species.

9.3.3.1 Habitat Destruction

Besides changing the ecology due to construction of dams, siltation from the catchment areas, has destroyed the feeding and breeding grounds of many fishes. Habitat alterations in Himalayan waters have affected distribution and abundance of native fishes in the mountain streams of India and Nepal. Power dams and reservoirs have dramatically changed fish habitats and local fish communities. The migration routes of important native fishes like mahseers (*Tor putitora* and *T. tor*) and snowtrouts (*Schizothorax richardsonii* and *S. plagiostomus*) have been blocked. The upland fast moving habitat has been lost due to reservoirs which are unfavorable for rheophylic species. Excessive withdrawal of water from the river courses for agriculture, domestic and industrial uses leaving inadequate water for comfortable fish life is also a major factor responsible for the depletion of fish germplasm resources.

9.3.3.2 Over Exploitation

Over-exploitation of fishery resources, due to its extraordinary economic value, has been a causative factor exacerbating the vulnerability of the population in different ecosystems. *Tor* spp. and *Schizothorax* spp. in upland waters, *Notopterus chitala, Ompok pabda, Pangasius pangasius, Eutropiichthys vacha and Semiplotus semiplotus* in warm waters, *Mugil cephalus, Liza tade, Nematolosa nasus and Lates calcarifer* in brackish water areas are declining at a faster rate.

9.3.3.3 Wanton Destruction

Wanton killing by the use of dynamiting, electric fishing and poisoning of brood fishes in spawning season and juveniles during post-monsoon periods have affected a number of food and game fishes of upland waters, especially in rivers and streams originating in Assam, Nepal, Bhutan, Garhwal, Kumaon and Himachal Pradesh.

9.3.3.4 Aquatic Pollution

Pollution is probably the single most significant factor causing major decline in the population of many fish species. These are causing havoc to the genetic thresholds, which would ultimately lead to permanent damage to genetic resources in addition to their direct toxic effects. Chemical pollution from factories and plants situated in the Nilgiris, Mysore and Coorg have exterminated certain groups of hill steam fishes available in local aquatic habitats. Certain neomacheiline loaches recorded from Bhavani river at Mettupalayam and Coimbatore Districts are no longer available.

9.3.3.5 Uncontrolled introduction of exotic Fishes

Many foreign species have been introduced in Indian waters and some are now well-established too. They include *Salmo salar, Salmo trutta fario, Oncorhynchus mykiss, Oncorhlynchus nerka, Salvelinus fontinalis, Cyprinus carpio, Carassius carasius, C. auratus, Oreochromis mossambicus, Ctenopharyngodon idella, Hypophthallmichthys molitrix, Tinca tinca, Osphronemus goramy, Gambussia affinis, Lebestes recticulatus, Clarias affinis, C. garipinus* and *Pygocentris nattereri.*

Introduction of exotic fast-growing species is causing threat to our indigenous fish diversity. Common carp introduced into Kashmir valley has almost exterminated the indigenous schizothoracids. Similarly, *Osteobrama belangeri*, the endemic fish to Loktok Lake is disappearing fast due to the introduction of common carp. In Gobindsagar dam, the Indian major carp, especially Catla, has already been replaced by the silver carp recorded that the establishment of *Cyprinus carpio* and *Hypophthalmichthys molitrix* have alarmingly declined the mahseer (*Tor putitora*) fishery in Govindsagar reservoir. Rercently, Sugunan has emphasized that all the three varieties of common crap, viz *Cyprinus carpio communis, C. carpio specularis* and *C. carpio nudus* are not suitable for stocking in most of the Indian reservoirs as they are vulnerable to predators and are seldom caught in passive gears. Besides, they compete with indigenous species like *Cirrhinus* spp, snowtrout and *Osteobrama belangeri.* The recent capture of *Hypophthalmichthys molitrix, Ctenopharyngodon idella* and *Cyprinus carpio in* Yamuna and Gomati rivers of Uttar Pradesh is causing concen.

The tilapia, *Oreochromis mossambicus,* introduced accidently into some South Indian reservoirs like Amaravati and Vaigai, has firmly established itself and has completely replaced the endemic fauna. Similarly, *Gambussia* spp. practically ousted all indigenous fish fauna of Ooty lake at one time. Sugunan (1994) has remarked that the three exotic species like *Cirrhinus molitrorella, Molypharyn godon piceus* and *Hypophthalmichthys nobilis*, being considered for introduction, are reported to be unsuitable. There are apprehensions that *Clarias gariepinus* may be adversely affecting our indigenous *Clarias batrachus.*

The introduction of trouts in almost virigin niche at high altitude coldwater streams have, however, remained encouraging in India. Some exotic food fishes have also been performing well by enhancing production in closed culture system. Sugunan suggested that *Oreochromis niloticus* which grows to 250 g in 6 months and its prolific breeding may probably be more suitable for Indian reservoirs. However, Dehadrai has remarked that the introduction and transfer of exotic species for aquaculture purposes may change or impoverish the biodiversity and genetic resources through inter-breeding, competition for food, habitat destruction and possibly through transmission of diseases.

9.3.3.6 Diseases

Among the range of various diseases caused by bacteria, fungi and viruses, the most virulent and menacing one threatening many species is the Epizootic Ulcerative Syndrome (EUS).

9.3.3.7 Genetic problems in threatened species

Inbreeding, negative selection and lack of adoption are considered as genetic causes for decline of natural fisheries and lack of recovery, restocking programmes involving hatchery stocks are unlikely to fully solve the problem since these stocks were selected for adaption to hatchery conditions and not to the natural environments. Since genetic variation is a major factor in population which enables species to adapt to the changes in their environment, any loss of genetic variation results in erosion of evolutionary flexibility. This leads to a poorer match of organisms to adapt to the environment increasing the probability of their extinction. The associated severe genetic problems in the small genetically effective population take the form of genetic bottlenecks, genetic drift and accumulation of homozygosity.

9.3.4 Strategies for fish biodiversity conservation

It is essential to prevent the further decline of our fish germplasm resources by devising all the possible measures of conservation and rehabilitation. The conservation policy should promote the management practices that maintain integrity of aquatic ecosystems, prevent endangerment and enhance recovery of the threatened species.

Allen et al. have identified five principal elements or tasks in the recovery programmes such as

1. Habitat management
2. Habitat development and maintenance
3. Native fish stocking
4. Non-native fish and sport-fishing
5. Research data management and monitoring

The irreparable harm caused to fish and habitats need be compensated through afforestation, eco-restoration, soil conservation, complete ban on deforestation particularly in the fragile mountains and strict implementation of Indian Fisheries Act 1897 (modified in 1956) along with the following measures would positively help in restoration of the threatened fish fauna.

9.3.4.1 *In situ* conservation

Stock enhancement through ranching is feasible only

1. If there is incomplete, colonization of available habitat by juveniles
2. If the tropic capacity of the habitat is under-utilized by a stock and/or its competitors.

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

9.3.4.2 *Ex situ* conservation and gene bank

In this measure, the threatened species are conserved outside their natural habitats. The two main pillars of *ex situ* conservation programme are (i) Live Gene Bank and (ii) Gamete / Embryo Bank. In a Live Gene Bank, the endangered species are reared in captivity, bred therein and genetically managed avoiding inbreeding depression, domestication and unintended selection. In Gamete / Embryo Bank, adequate samples representatives of the natural genetic variants of endangered species are kept in suspended state of animation under extra low temperature (-196˚ C) in liquid nitrogen. Establishment of Gene Bank by cry preserved milt, eggs and embryos assures further availability of genetic materials of threatened categories and for intensive breeding programmes of economically important species.