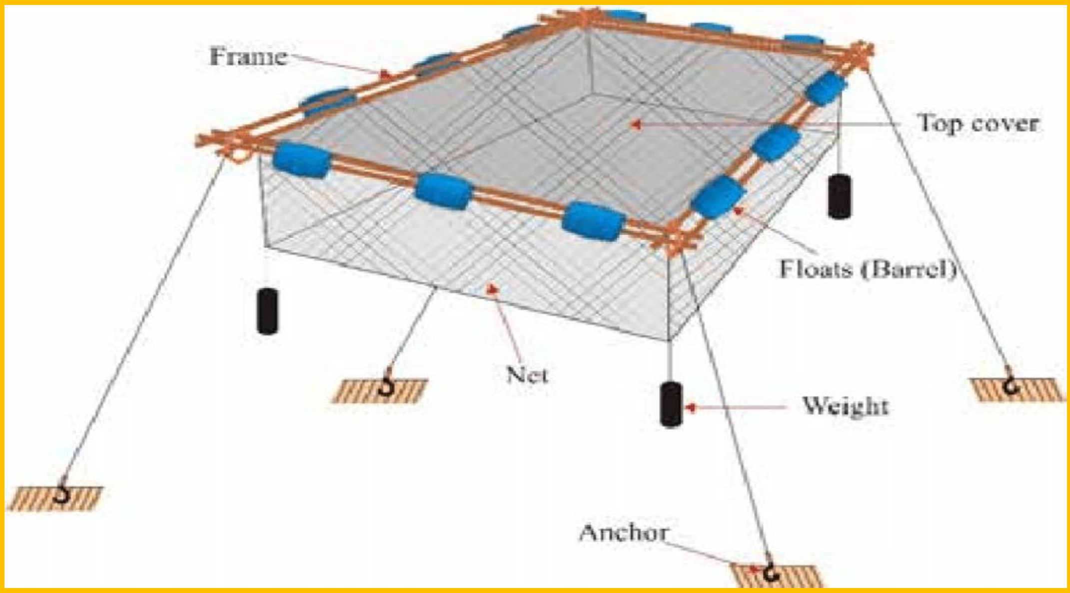
MSCZO-607

Fish and Fisheries (Applied Ichthyology)

M. Sc. IV Semester



DEPARTMENT OF ZOOLOGY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

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(MSCZO-607)

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Course I: Fish and Fisheries (Applied Ichthyology)
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UNIT 1: GENERAL FISHERY RESOURCE IN INDIA AND UTTARAKHAND

CONTENTS

1.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

i. Basic concept of Fishery Resources
ii. Riverine fisheries, their regulation and exploitation
iii. Improvement of fish stocks
iv. River pollution and dams
v. Lacustrine, Cold water, Estuarine and Marine fishery management, development and exploitation

1.2 INTRODUCTION

India is a South Asian nation bordered on both side by Pakistan and Burma. It is located in between the Himalayas in the North and the Indian Ocean in the South. India has a total area of 3287728 km^2 and is a federal country. India is a diverse country. The region's climate ranges from mild in the North to hot and humid in the South. There are high mountains, broad alluvial plains, riverine marshes, plateaus, deserts, coastal plains, and deltas in the terrain. The Himalayas, the Indo Gangetic plains, the Vindhyas, the Satpuras, the Western Ghats, the Eastern Ghats, coastal plains, deltas, and riverine wetlands are the key physiographic divisions. The nation's inland fishing resources include rivers, canals, tanks, ponds, estuaries, brackish water lakes, backwaters, floodplain lakes (oxbow lakes), *etc*. While inland water bodies are frequently utilized for both culture and capture fisheries, marine water bodies are mostly employed for this purpose. India's inland catch fisheries play a significant role in the country's fish production, making up around 30% of the total. A prosperous catch fishery has a lot of promise.

1.3 RESOURCES

With a total water surface area of 3, 14,400 square kilometers, 8129 kilometers of coastline, 0.5 million kilometers of continental shelf, and 2.02 million kilometers of exclusive economic zone, India has an abundance of rivers, streams, wetlands, lakes, and other bodies of water, as well as an average annual rainfall of 1,100 millimeters. The states of Uttar Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu have the majority of the river sections and canals. The states of Tamil Nadu, Karnataka, Maharashtra, Orissa, Gujarat, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, and Rajasthan contain the majority of the reservoir areas. The states of Andhra Pradesh, Karnataka, West Bengal, Arunachal Pradesh, Rajasthan, and Orissa have the highest concentration of tanks and ponds.

In Kerala, Orissa, Uttar Pradesh, and Assam, a sizable portion of the land is covered by lakes and abandoned water bodies on flood plains. The maritime states of Orissa, Kerala, West Bengal, Gujarat, Goa, Andhra Pradesh, and Tamil Nadu, as well as the union territory of the Andaman and Nicobar Islands, are particularly rich in brackish water areas. Orissa is determined to have the most total area under water bodies (apart from rivers and canals), followed in order by Andhra Pradesh, Karnataka, Tamil Nadu, West Bengal, Kerala, Uttar Pradesh, Gujarat, Maharashtra, Rajasthan, Madhya Pradesh, etc. Many wetlands are also shared with neighbouring nations, like in the cases of the Ladakh and Sunder bans. The Ganges, Brahmaputra, Narmada, Tapti, Godavari, Krishna, and Cauvery are the country's principal river basins. Inland fisheries resources Rivers, floodplains, estuaries, mangroves, reservoirs, and ponds are just a few of India's abundant and diversified inland fishing resources.

Inland fisheries in India are divided into three categories: capture fisheries in rivers, estuaries, lakes, reservoirs, *etc*.; freshwater aquaculture, which includes the pond culture of carp; brackish water aquaculture, which mostly involves shrimp culture. There are numerous rivers throughout the nation, totaling 45,000 km in length. These rivers are part of 113 river basins with a 3.12 million km^2 catchment area. There is a substantial network of perennial rivers, each of which is distinguished by very large seasonal variations in their discharge due to seasonal rainfall and prolonged dry periods.

1.3.1 RIVERINE FISHERIES

In riverine fisheries, a type of inland fishing, fish are harvested straight from the many river systems. For this, scientifically constructed boats and fishing equipment are employed. The huge number of fertile river systems in India contributes to the country's thriving riverine fisheries. The Ganges, Brahmaputra, Indus, peninsular East coast (which includes the

Mahanandi, Godavari, Krishna, and Cauvery), and the West Coast make up the majority of India's river systems (which includes basins of the Narmada and Tapti west of Western ghat). India's largest river system is the Ganga River System. The Ganges is a perennial river that originates in the Gangotri region of the Himalayas and finally joins the Bay of Bengal after passing through the states of West Bengal, Uttar Pradesh, and Bihar. The principal tributaries of the Yamuna include the rivers Chambal, Betwa, and Ken, as well as the Tons and Song, Ramganga, Gomati, Ghaghra, Gandak, Kosi, and Yamuna. All leads to a catchment area of about 9.72 lakh sq. km. *Cirrhinus mrigala, Labeo rohita, Labeo calbasu, Mystus aor, Mystus seenghala, Wallago attu, Hilsa ilisha,* and several other diverse species are the main carps of this river system.

- **The Brahmaputra River System:**

This river system originates from a glacier mass at Mansarowar Lake and travels through Bangladesh, Arunachal Pradesh, Tibet (where it is known as Ptsango), Tibet, and Assam before joining the Ganga at Goalundo. The Brahmaputra and the Ganga combine to produce the Padma, which flows into the Bay of Bengal via the Meghna estuary. Many of its tributaries originate in Assam, and the system as a whole has a catchment area of about 2,900 square kilometers. Although it is uncertain how much commercial fish are produced by this river system, some important fish species include *Labeo gonius, Wallago attu, Puntius sarana*, and *Notopterus notopterus.*

- **The Indus River System:**

The Indus River originates in Tibet and travels through that country before entering Kashmir, some 100 kilometers north of Mansarowar. It goes south after travelling of these 800 kilometers and enters the Ladakh range. It enters Pakistan through Kashmir. It has five tributaries on its left bank: the Jhelum, Chenab, Ravi, Beas, and Sutlej. It is impossible to estimate how much economic produce comes from this river system.

The East Coast System:

It consists of four significant rivers. **Godavari** begins in the Northern Western Ghat's Deolali Hills and empties into the Bay of Bengal. Its whole catchment area is 315 980 square kilometers. River Krishna has its source in the Western Ghat, flows south of Poona, and empties into the sea at its delta. Its catchment area is around 233,229 square kilometers. The Brahmagin Hills on the Western Ghat are the source of the Cauvery River, which flows south- east before emptying into the Bay of Bengal in Tamil Nadu. The main fishes of Godavari and Krishna are *Labeo fimbriatus, Cirrhinus mrigala, Labeo calbasu, Catla catla, Mystus aor, Mystus seenghala, Silomia childreni, Pangasius pangasius, Wallago attu, Hilsa ilisha etc*. Cauvery has some special features in fish fauna. It consists of *Acrossocheilus hexagonelopis, Tor putitora, Barbus carnaticus, Barbus dubias, Labeo kontius, Labeo oriza, Osteochilus brevidorsalis, Osteochilus nashi etc*.

The Western Coast River System:

The Narmada and Tapti rivers are its two most significant rivers. The Narmada River rises in the Amarkantak Hills of Madhya Pradesh and flows through Gujarat state before ending in the Gulf of Cambay. About 94,235 square kilometers make up the catchment area. The majority of the fish that are produced in this river are *Tor tor*. Additionally to this, there are other species like *Labeo fimbriatus, Labeo calbasu, Cirrhinus mrigala, Puntius sarana, Cirrhinus reba, Rita pavimentata, Mystus seenghala, Clupisoma garua, Ompak bimaculatus, Notopterus notopterus, etc*. River Tapti originates on Mount Vindhya and flows through Madhya Pradesh, Maharashtra, and Gujarat before joining the Arabian Sea in Dumas, which is close to Surat. Its catchment area is approximately 48,000 square kilometers. Fishes are *Tor tor, Labeo fimbriatus, Labeo calbasu, Labeo bata, Labeo boggut, Mystus aor, Mystus seenghala etc*.

1.3.2 REGULATION AND EXPLOITATION

A new and specialized subject of law is fisheries law. The study and examination of various methods for fisheries management, such as catch sharing, is known as "**fisheries law**."As an illustration, consider **TURFs (Terrestrial Use Rights for Fishing)** with individual transferable quotas. To create policy directives that promote sustainability and legal enforcement, it is crucial to research fisheries law. There is a dearth of advocacy and research in this particular legal area because it is rarely taught in law schools around the world. In order to assess fisheries management regulations, fishing law also considers international treaties and business principles. Additionally, access to justice for small-scale fishermen, coastal communities, and indigenous peoples as well as labour concerns such child labour laws, employment law and family law. Laws and regulations pertaining to aquaculture are also covered in the study of fisheries. Fish and aquatic plants are farmed as part of aquaculture, commonly referred to as aqua-farming.

Regulations and specifications for animal feed are included in this body of study. To reduce threats to human health and safety, it is crucial to manage the diet that fish are given. Aquaculture and fishing are significant economic natural resources in India that, since time immemorial, have fed millions of people there. As with any other industry that supports a practice's safety, health, and sustainability, laws and regulations are essential in the fishing sector. Let's examine the main conservation laws and rules that apply to Indian fisheries.

- **Historic laws and regulations**

1. **British Era Fisheries Act (1897):** For the first time, this law was formulated in the year 1897 with the view to prevent unhealthy practice of killing fish the thence times. Chiefly, this law penalized the killing of fish by use of poison and explosives. It is quite clear that poisoning fish or killing them with explosives will be unhealthy for consumption and will ruin the future of fish in affected areas.
2. **Wildlife Protection Act (1972):** Due to agriculture, urbanization and industry, wildlife habitats were lost or severely degraded. This law was written to help protect wildlife and their habitats by providing conservation programs. Local and international laws related to the trade of wild animals and setting up of law enforcement type agencies helped to enforce laws.
3. **Water Prevention and Control of Pollution Act (1974):**This law was established in 1974 with the intention of preventing industrial, agricultu ral, and domestic sources from contaminating waterways. The main goals were to prevent an d regulate pollution, rehabilitate water bodies, track pollution levels, and hold polluters accountable.
4. **The 1986 Environment Protection Act:**

This act, which was passed in the wake of the Bhopal Gas Tragedy, established a framework for cooperation between municipal, state, and federal agencies in order to safeguard the environment and reduce risks to people and other living things.

Current Laws and Regulations

- The federal government and state governments share the duty of passing legislation.

- States may also create laws governing fisheries and the pollution of streams and waterways in addition to the historical laws.
- The **National Fisheries Development Board** was established by the Indian government in 2006 and focuses on a variety of fisheries related activities and problems, including aquaculture in ponds and tanks, fisheries development in reservoirs, coastal aquaculture, deep sea fishing, tuna processing, and other fisheries-related activities.
- The Indian Fisheries Act, 1897, or ACT NO. 4 of 1897, was passed on February 4, 1897, and it addressed a number of fisheries related issues.

1.3.3 IMPROVEMENT OF FISH STOCKS

- **Sustainable Fisheries Management**

The improvement of fish output has a lot of room to grow in the inland open water sector without jeopardizing the aquatic ecosystems ecological and biological integrity. The most crucial environmentally friendly method for producing fish from inland waterways on a sustainable basis is stock enhancement/culture-based fishing. Cage and pen enclosure culture is a productive method for growing seeds and rearing table fish. Another crucial management strategy for river fisheries is the preservation of fish diversity and the rehabilitation of fish habitat.

- **Wetlands and reservoirs fisheries management:**

The basic management steps for sustainable enhancement of reservoir and wetlands include stock enhancement, culture-based fisheries and enclosure culture.

1. **Stock enhancement in medium and large reservoir:**

Stocking of quickly expanding, commercially significant species like Indian big carps has been shown to be an effective management method for increasing fish productivity. Natural fish stocks of economically important fish species have been diminished in open water bodies where riverine connection has been lost due to the building of embankments and siltation due to the disruption of the auto-stocking process from the main rivers. In such circumstances, it is discovered that stocking with fingerlings of the necessary fish species is useful for enhancing their fish yield. The primary goal of stock improvement is to increase fish populations that self-recruit.

2. **Culture-based fisheries in small reservoirs and wetlands:**

When the recruitment of targeted species is less than the carrying capacity, the primary goal of culture-based fisheries is to improve the fish production. Fish growth and survival in culture-based fisheries are influenced by stocking density and fish size, respectively. Stocking at the proper size and period, stocking density, fishing effort, size at capture (species dependant), species choice, and fishing gear can all contribute to the success of culture-based fisheries. Over the years, ICAR - CIFRI has supported reservoir fisheries management technologically in 21 states, which has led to a marked rise in average reservoir fish output across the nation. The average fish output of 2300 reservoirs increased as a result of stocking from 20 kg/ha/year to 110 kg/ha/year. Production levels of 1000-1500kg/ha/year have been demonstrated in beels in many parts of West Bengal.

3. **Enclosure culture (pen and cage culture):**

Through the maintenance of free water exchange, culture fish are raised in confinement in an enclosure to raise fish seed and grow fish to marketable size. Table-sized fish can be produced in good quantities in cages (Fig. 1) and pens (Fig. 2), enhancing the productivity of wetlands and reservoirs). A practical and economical solution for improving fisheries in wetlands and reservoirs is in situ seed growing in an enclosure. Technologies created for cage culture have been successfully used in other reservoirs across the nation. Currently, there are 20,000 cages operating in 20 different Indian State reservoirs, which is a significant quantity.

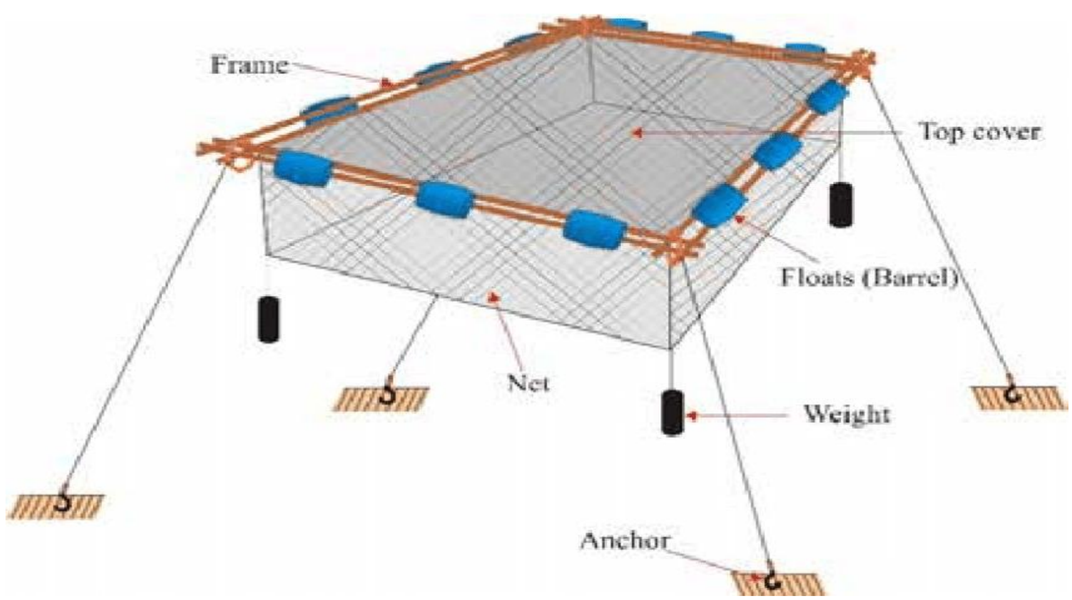

Fig. 1 Layout of a cage culture

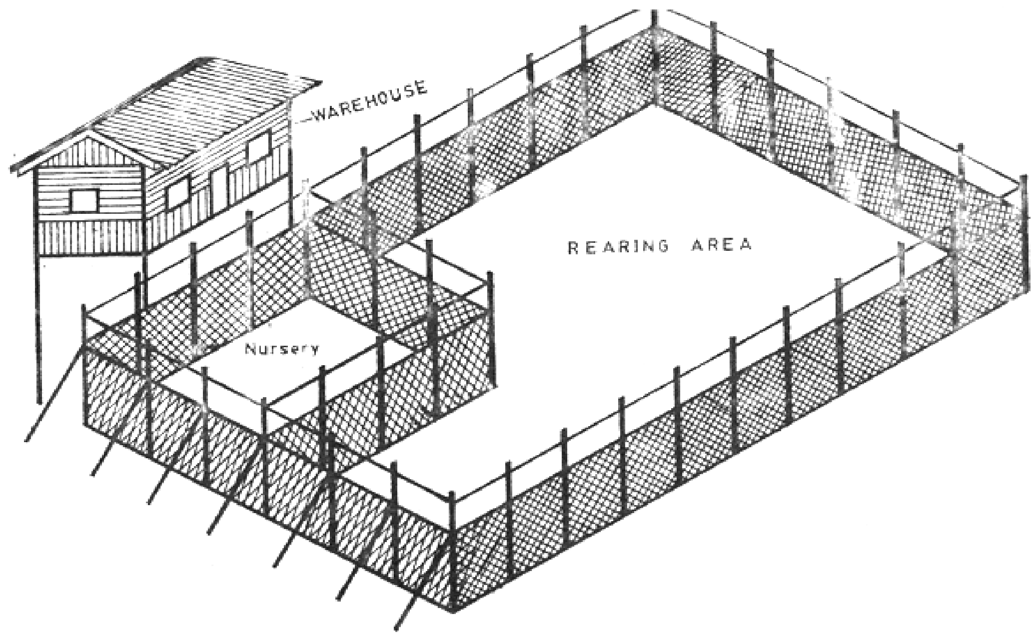

Fig. 2 Layout of a pen culture

1.3.4 RIVER POLLUTION

- **Causes of River Pollution**

The two main categories of river contaminants are naturally occurring pathogens and synthetic chemicals. In essence, germs are a variety of disease causing organisms, dead corpses, *etc*. Unconcerned people discard a variety of carcasses into the rivers. This might contaminate rivers. Faeces and sewage are freely being dumped into the water. Infectious disorders that affect both aquatic and terrestrial life are frequently caused by microbial contaminants from sewage. Pollutants released from numerous companies, industries, *etc.* include harmful chemicals. Before being released into the rivers, these wastes are not appropriately handled, which causes river pollution.

- **Most Polluted Rivers in India**

Ganga, Yamuna, and Sabarmati are among the most polluted rivers in India, according to a survey. Some of the most advanced cities in the nation are located along these riverbanks. They have proven to be the most heavily contaminated rivers due to a lack of an effective disposal mechanism. Domestic garbage is primarily to blame for the contamination of the Ganga river. This "**holy river**" is used for a variety of religious rituals. Mass bathing and rituals play a significant role in pollution. Additionally, the home and agricultural wastes are a significant cause of worry. However, industrial waste is primarily thrown into the Yamuna River. It becomes contaminated in Haryana by pesticides and agricultural trash. However, it transforms into a commercial waste disposal drain once it reaches Delhi. The Taj Mahal was even constructed by the Mughals on the banks of the Yamuna River because it was once thought to be so pure. However, the situation has changed since then. Even though there are only two examples shown here, other Indian rivers face a similar situation. River contamination is becoming more and more hazardous with time. We might not have access to any sources of drinking water if this keeps happening.

- **Harmful Effects of Water Pollution**

The repercussions of water contamination are numerous. However, the creatures and vegetation that live in these rivers will be affected most immediately. The surface water is covered in dangerous contaminants, making it difficult for aquatic life to breathe. The marine animals that die as a result cause a disruption in the natural food chain. The contamination of rivers has significant effects on people as well. It causes a decline in fresh water supply for drinking. Consumption of dirty water can cause a number of fatal diseases, including cancer. One of the fundamental requirements for maintaining life on this planet is potable water. The human race will vanish if it disappears. The environment is harmed by river pollution. The ecology around us is harmed by it.

- **How to Prevent from River Pollution?**

It hasbeen suggested that prevention is preferable to treatment. It is a very appropriate comment. Our river bodies have been damaged in numerous ways. River pollution can be avoided in a number of ways.

1. To start, it is crucial to inform people about the problem.
2. Next, a suitable sewage disposal system needs to be built

upon. The handling of garbage properly is crucial in today's society. Before dumping industrial trash into rivers, it should be treated properly.

3. River contamination should be addressed with tight regulations. Furthermore, regulations must befollowed.Every type of civilisation depends on rivers. For the survival and advancement of t he human
species, it is crucial.

1.3.5 DAMS, THEIR EFFECT ON FISH MIGRATION AND REMEDIAL MEASURES

The quality of any aquatic habitat, which supports all of their biological functions, have a significant impact on fish populations. For the key stages of their life cycles—reproduction, juvenile production, growth, and sexual maturation migratory fish need various settings

The reproduction of anadromous species occurs in freshwater, whereas catadromous species migrate to the sea for breeding and back to freshwater for trophic reasons. Diadromous species spend part of their life cycle in freshwater and part of it in seawater. It is also necessary to take into account the movement of potamodromous species, whose full life cycle is completed within the inland waters of a river system.

The building of a dam (Fig. 3) on a river can impede or delay upstream fish migration, which in turn causes species that depend on longitudinal migrations along the stream continuum during specific stages of their life cycles to diminish or perhaps become extinct. Fish migration downstream can result in severe mortality if they cross over spillways or hydraulic turbines. Experience has taught us that issues with downstream migration can also have a significant impact on the stocks of anadromous or catadromous fish.

Significant problems include habitat loss or modification, discharge adjustments, changes in water temperature and quality, increased predation pressure, and migration delays brought on by dams.

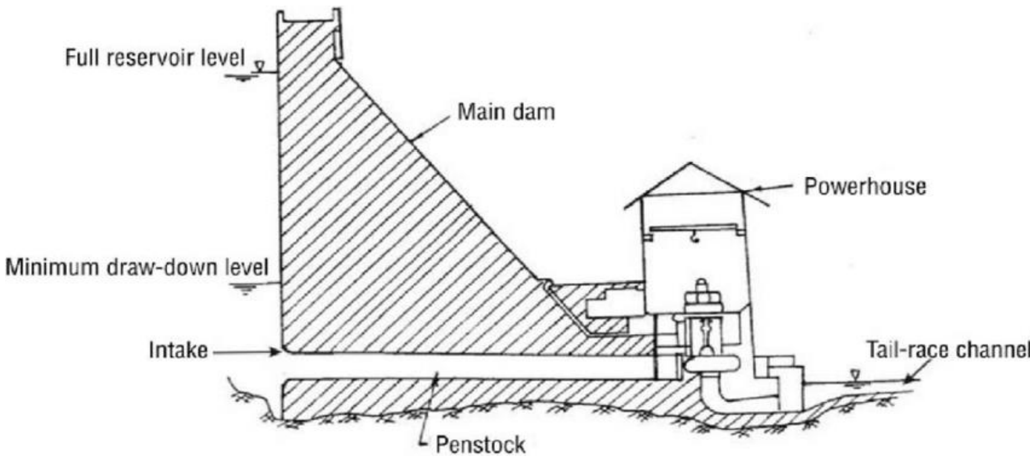

Fig. 3 Layout of a dam

Diverse fish ways, such as fish lifts or locks, collecting and transportation facilities, fish passes, natural bypass channels, pool- type fish passes, and fish lifts or locks, can be used to allow anadromous and potamodromous species to pass barriers upstream. Only a few unique designs, specifically for eels, have been created in Europe, Japan, New Zealand, and Australia for catadromous species. The position of the fish pass entrance and the attraction flow, which must take into consideration river discharge during the migratory period and the behaviour of the target species in relation to the flow pattern at the foot of the dam, are the key design elements for upstream fish passage.

Some locations could need several entry and fish passes. The issues related to downstream migration have not been as thoroughly researched or thought through as those related to upstream migration. Physical screens, angled bar racks, and louvers connected to surface bypasses are the most used downstream passage solutions to keep fish away from turbines. The effectiveness of behavioural guidance devices (attraction or repulsion by lights, sound, or electricity) has not been established, and they are still regarded as experimental. The usage of fish facilities at dams around the world is reviewed in a non-exhaustive manner, with the primary target species from North America, Western Europe, Eastern Europe, Latin America, Africa, Australia, New Zealand, Japan, and Asia.

The most frequent reasons for fish pass failure include a lack of attraction flow, an inappropriate entrance position, poor maintenance, and hydraulic conditions (target species-inappropriate flow patterns, velocities, turbulence, and aeration levels) in the fish pass. Only a few anadromous species, such as salmonids (such as Atlantic and Pacific salmon, sea-run trout) and clupeids (such as American and Allis shad, alewives, and blueback herring) in North America and Europe, can be deemed to have well-developed upstream transit mechanisms.

Better biological data, including information on migration times, swimming abilities, and migratory behaviour, are urgently needed, as is study on fish passage (both upstream and downstream) for other native species. A fish pass's effectiveness is determined qualitatively by determining whether it can permit passage of all target species within the parameters of environmental variables noted throughout the migratory period. Inspections and checks, such as visual inspection, traps, and video checks, can be used to gauge effectiveness. A fish pass's efficiency provides a more precise assessment of its performance. It can be described as the percentage of stock that is present at the dam that successfully enters and moves through the fish pass in a period of time that is deemed appropriate. The techniques for determining a pass's efficacy are simpler than those for efficiency. To evaluate the overall effectiveness of fish passages and the cumulative impact of several dams along a migration path, marking and telemetry are useful tools.

It is necessary to establish the targeted efficacy for a certain site in relation to the desired biological goals. As a result, it depends on the species under consideration, the quantity of obstacles in the river, and the location of the impediments along the path of migration. It must not be an excuse to do nothing at a dam that nearly no one knows anything about migratory species, particularly in poor nations. The fish passes must be made to be as versatile and adaptable as feasible in the absence of solid knowledge about the species. When pursuing a variety of migratory species, some fish passes—like vertical slot passes with succeeding pools—are better suited than others. Installing fish passage monitoring equipment is necessary. The fish pass will be able to be evaluated, thanks to this monitoring procedure, and the input gathered may be helpful for other fish pass initiatives in the same regional context. When there are several species with poorly understood varied swimming skills, migratory behaviour, and population size near high dams, it is better to focus mitigation efforts on the lower portion of the fish pass at first, which entails building and optimizing the fish collection system including the entrance, the complementary attraction flow and a holding pool which can be used to capture fish to subsequently transport them upstream, at least in an initial stage.

Designing a fish pass requires an interdisciplinary approach. Managers, biologists, and engineers must collaborate closely. Facilities for fish passage must be systematically assessed. It is important to keep in mind that the fish pass technique is empirical in the truest sense of the word, meaning it is based on feedback from experience. The most significant advancements in fish passage technology have been accomplished in nations that routinely evaluate the efficacy of the passes and where it is required to report monitoring results. The efficiency of fish passes has its bounds, which must always be kept in mind. Indirect consequences of dams, such as changes in flow, water quality, and an increase in predation, may prove to be quite significant in addition to issues with fish passage at obstructions and drastic changes to the habitat upstream or downstream. The protection of migratory species for a given dam must be studied in a much wider context than the strict respect of fish passage alone.

- **FISH MIGRATION**

The qualities of the aquatic habitat, which supports all of their biological functions, have a significant impact on fish populations. Migratory fish are particularly prone to this reliance because they need various settings to complete the four main stages of their life cycle—reproduction, juvenile production, development, and sexual maturation.

To live, the species must transit from one environment to another.

Fish are now typically categorised based on how well they can adapt to different salinities of water at different points in their life cycles.

- The **potamodromous species'** whole life cycle takes place in a river system's freshwater. The distances separating the reproduction and feeding zones can range from a few metres to hundreds of kilometers.
- The **diadromous species'** life cycle occurs in both fresh and salt water, with up to several thousand kilometres separating the reproduction zone from the feeding zone.

Between the reproduction zone and the feeding zone, which can be up to several thousand kilometres apart, the diadromous species' life cycle is divided between fresh and marine waters.

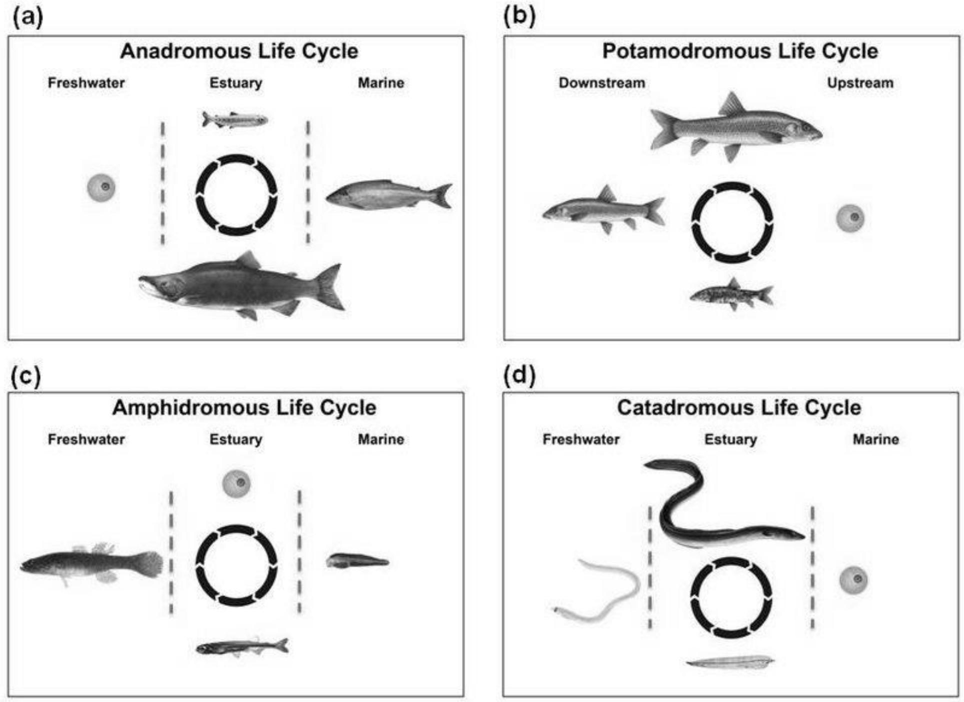

Fig. 4 Different types of Fish Migration

Anadromous species, like salmon, are those species growth phase occurs in the sea after a freshwater stage of reproduction. The objective of migration back to freshwater is to breed. Catadromous organisms, like eels, have a life cycle that is reversed. Migration to the sea is for spawning, while migration back to freshwater is for trophic colonization. Compared to anadromy, catadromy is far less frequent. Anadromous species are able to distinguish their home river basin and reliably return there to give birth. Homing, a phenomenon where people return to their natal river, is primarily dependent on the ability to smell streams. As a result, each river basin has its own stock, which is a distinct entity. Amphidromous animals, like the striped mullet, spend a portion of their life cycle in both freshwater and saltwater. Their travel is typically linked to the search for food and/or shelter rather than the purpose of breeding. There are approximately 120 species of fish that routinely transition between freshwater and saltwater, out of a total of about 8,000 freshwater species and 12,000 marine species.

Effect of dams on fish communities

The construction of a dam typically has a significant effect on fish populations. Migrations and other fish movements may be halted or delayed, and the habitat, which is crucial to the sustainability of population growth, may change in terms of quality, quantity, and accessibility.

Fish passing through hydraulic turbines or over spillways can sustain severe injury. Fish species may also be indirectly impacted by modifications to the water quality or discharge schedule. Dams are also associated with increased upstream and downstream predation on migratory fish because they delay and concentrate the fish and improve the habitat for some predatory species.

- **Upstream Migration**

1. The reduction of anadromous species is one of the main effects of dam construction on fish populations.
2. Migration between the breeding and feeding zones is stopped by the dam.
3. When there are no spawning grounds in the river or tributary downstream of the dam, the effect can grow severe and result in the extinction of species.
4. The idea of impeding migration is frequently connected to the height of the dam.
5. However, even small weirs can be a significant barrier to upstream migration.
6. The hydraulic conditions over and at the foot of the obstruction (velocity, depth of the water, aeration, turbulence, *etc.*) in connection to the swimming and leaping abilities of the species in question determine whether an obstacle may be traversed or not.

The ability to swim and leap depends on the species, the size of the individual, their physiological state, and elements affecting the quality of the water, such as temperature and dissolved oxygen. When migrating upstream, some catadromous species have a special ability to overcome obstacles. Some species, like gobies, have enlarged fins and suckers that allow them to cling to the substrate and climb around the edge of waterfalls and rapids. Young eels can also climb through brush or over grassy slopes if they are kept completely wet. A total blockage, or one that is permanently impenetrable for every member of a target species, is possible. It might be partial, or at least acceptable to certain people. It might just be ephemeral, *i.e.*, navigable during specific seasons (under certain hydrological or temperature conditions). Weirs may be impossible to cross during low flow circumstances because the water depth on the face is too shallow for fish to be able to swim. However, if water depth rises and the structure's overall fall lessens, they can become accessible at a higher discharge rate. The harm that temporary barriers do to fish, delaying their migration and maybe forcing them to stay in unsuitable areas in the river's lower reaches or even injuring them, as a result of repeated, fruitless attempts to pass, must not be underestimated.

- **Downstream Migration**
  1. Engineers and fishery biologists were focused on building upstream fish passage facilities during the early stages of the dam's construction.
  2. It was not thought that passage via hydraulic turbines and over spillways was a particularly significant factor in fish migration damage upstream.
  3. Experience has taught us that issues with downstream migration can have a significant impact on diadromous fish stocks.
     Diadromous species, including certain anadromous species, adults of catadromous species, and juveniles of anadromous species, migrate downstream (repeat spawners).

  In Europe and North America, downstream fish passage at hydroelectric power dams is typically viewed as less necessary for potamodromous species. The necessity for mitigation to facilitate passage for potamodromous fish must be evaluated species- and site- specific because some potamodromous species can travel over very large distances.

- **Delays in Migration**
  1. Fish downstream migration timing may be impacted by impoundments.
  2. When river flows are low in the Columbia basin, young Chinook salmon arrive at the estuary roughly 40 days later than they did before the dams were built. This is because river flows have been impounded by dams, more than doubling the time n eeded for juvenile salmon to migrate to the sea.
  3. By exposing fish to intense predation, nitrogen supersaturation, and a number of other dangers like exposure to disease organisms and parasites, such delays can have a pretty significant effect.
  4. A considerable fraction of the juvenile population may residualize and spend several months in fresh water as a result of the delay.

- **Loss of Habitat**

Dam construction is dramatically affected by migratory fish habitat. The consequences of river impoundment are the transformation of lotic environment to lentic habitats. Independent of free passage problems, species which spawn in relatively fast flowing reaches can be eliminated. Water levels and speeds may fluctuate due to electricity demand, which could be devastating for fish. For example, spawning behaviour may be hindered, immature fish may be washed away by rapid flows, and flow rates may suddenly drop which could leave eggs or juveniles stranded.

1.4 LACUSTRINE FISHERY: MANAGEMENT, DEVELOPMENT AND EXPLOITATION

Reservoirs are artificial lakes formed by damming rivers to hold water for irrigation, electricity production, flood control, and industrial water requirements. Since independence, many river valley projects have been ordered as a part of our development efforts, creating a series of these artificial impoundments. These water sheets are one of the most significant resources for the development of inland fisheries in the nation because of their immense size and strong biogenic output capacity.

A recent study by the Indian Institute of Management, Ahmadabad, found that the 975 reservoirs, ranging in size from 1000 to 10000 ha, covered an area of 1m ha. The national average production rate from Indian reservoirs is currently dismally low, with estimates ranging from 6 to 14 kg per hectare per year. This opens up this industry to enormous potential for growth and necessitates a quickening of efforts to raise productivity. According to estimates, the development of reservoir fisheries has the potential to increase national income by about Rs. 100 crores annually and to employ thousands of fishermen and people working in related businesses The lack of scientific management approaches as a result of inadequate understanding of the ecology and production functions of this biotope is mostly to blame for the low fish output from reservoirs.

The Central Inland Fisheries Research Institute's (CIFRI) research over the past four decades has essentially created the groundwork for India's notion of scientific reservoir fisheries management. A man-made habitat without comparison in nature is the reservoir. It demonstrates both lentic and fluviatile traits, as well as some distinctive qualities of its own. The reservoir fisheries management approach includes both standards for catch and culture, and it takes into consideration the current environmental variables.

- **Factors Influencing The Biological Productivity In Reservoirs**

Indian reservoirs receive runoff from a variety of catchment areas and are located in various geoclimatic regions. Additionally, the morpho-edaphic properties of reservoirs varies due to the various dam designs and purposes. The reservoirs are an interesting biotope because of all these variations. There are three basic categories of habitat characteristics that affect reservoir productivity: morphometric, climatic, and edaphic.

1. **Morphometric factors:**

The most significant single morphometric variable that can be linked to production is depth. Greater amounts of the substrates in shallower lakes are found in the euphotic zone. On the other hand, the majority of the substrate in deeper lakes is trapped in the aphotic zone. The degree of abnormalities in the shoreline is indicated by shore development, another helpful metric for assessing productivity. A defining aspect of the reservoir ecosystem is water level volatility. Plankton pulses have been seen to occur during the months with the fewest level changes. During the months with the highest level variations, all biotic communities are at their lowest point. It is easier for organisms to grow when the reservoir level is more consistently high. More or less fluviatile conditions occur in the months with higher inflow and outflow rates, as opposed to the seasons with lower water movements, when the reservoir is more lacustrine in nature. The percentage of shallow places (littoral formation), which varies depending on the reservoir level, is another crucial consideration.

2. **Climatic factors:**

The latitudinal location, which influences the amount of solar energy available for photosynthetic activities, is the most crucial climatic component that affects a lake's production. In the summer, warm air temperatures cause the upper layer to warm up and the thermal gradient to form. In peninsular India, there is no winter deserving of the name, and the temperature is consistently high. The high temperature at the bottom during the summer, when the surface water warms up, eliminates any opportunity for thermal resistance by the warmer upper layer. Because the water above and below the thermocline in thermally stratified lakes does not mix, the rich nutrients at the bottom layer are locked up, making thermal stratification crucial for limnology. Wind an important meteorological factor which helps in mixing up of water facilitating nutrient transport. The rainfall at the catchment areas is more important than the rainfall at the reservoir site due to obvious reasons. The soil status of any catchment area affects the nutrient status of the reservoirs.

3. **Edaphic factors:**

The primary determinants of a reservoir's biogenic productivity are the physico-chemical properties of its soil and water. Transparency is another physical factor important to production besides temperature. Poor light penetration could be caused by living creatures or suspended materials like silt and mud. While reduced visibility brought on by planktonic organisms is a positive indicator of production, turbidity caused by suspended particles slows productivity. The main sources of dissolved oxygen in water are photosynthesis and atmospheric absorption. The putrefaction of organic matter and respiration are the two basic processes that remove it.

The balance of the two processes mentioned above determines how much dissolved oxygen is accessible in water at any given time. Less than 5 ppm of dissolved oxygen can be fatal to biota. It is thought that productivity is enhanced by a pH that is not more than 8 and just slightly over alkaline. A total alkalinity of more than 50 ppm and a hardness of more than 70 ppm are signs of productive betting. The electrical conductivity serves as a trustworthy indicator of water quality and represents the total solvable solids. As opposed to the lower tropholytic zone, which is characterized by the breakdown of organic matter, the higher water column where photosynthetic activities take place is known as the trophogenic zone. The metrics like O_2, CO_2, pH, CO_3, and CO_2 show dramatic variations in productive reservoirs with high rates of the aforementioned processes. HCO_3 from surface to bottom while low productive reservoirs have uniform distribution.

Fisheries in reservoirs are mostly extractive in nature, and the development strategy is based primarily on catch lines. However, intensive aquaculture practices are used in smaller irrigation impoundments that are characterized by a nearly entire drawdown of water. There is minimal opportunity for maintained natural populations of commercial fish because the focus is on artificial recruitment and annual total collection. The three guiding concepts of ecosystem-oriented management norms are stock monitoring, stocking support, and effort monitoring. In a perfect world, the fish species that are used for commerce would share ecological niches in a way that maximizes the use of trophic resources. The fish should also have a short food chain in order to transform the primary food as efficiently as possible, converting food resources into usable materials.

Zooplankton like copepods, cladocerans, and rotifers are outnumbered by phytoplankton, which includes the families Myxophyceae, Chlorophyceae, Dinophyceae, and Bacillariophyceae. Insect larvae, nymphs, oligochaetes, nematodes, and molluscs all serve as representatives of the benthos. With the probable exception of insects, Myxophyceae, and molluscs, many of the aforementioned niches are shared by Gangetic large carps and trash fishes, highlighting the significance of managing carp minnows and weed fishes. The ecosystem oriented management strategy calls for giving the trophic strata the attention they deserve in terms of shared, unshared, and unoccupied niches.

- **Stocking :**

Stocking becomes important to broaden the range of species and to address imbalances in how commercial species use certain ecological niches. The reservoirs go through a brief period of trophic burst during the first two to three years after impoundment, which is marked by an abundance of fish food species. The best time to introduce desirable species to increase stock levels is right now. Any failure to implement this crucial management strategy might cause a trophic burst, which would lead to a proliferation of trash fish, which would then serve as a source of food for catfish. Due to significant energy loss at all trophic levels, from fundamental resources to catfishes, the whole condition becomes unsatisfactory. Additionally, inconsistent fish breeding creates circumstances that require stocking to be corrected. Even when mating is successful, certain undesirable aspects of lake morphometry can cause the progeny to sometimes not survive, as has been seen in several DVC reservoirs.

- **Selection of fishes for stocking :**

The main goal of artificial recruitment is to direct energy away from shared trophic niches and onto fish meat. Therefore, the choice of fish for stocking is based on an evaluation of the biotic communities that already exist and how well they are able to transform basic trophic supplies into usable goods. Our nation has access to a wide range of quickly growing fishes that eat in various trophic niches and can be effectively used for reservoir fisheries management. For instance, **Indian Major Carps** are essential when stocking reservoirs because to their close-to-primary-producer eating preferences and rapid development rate.

However, the Indian triad of Catla, Rohu, and Mrigal is unfit to make use of the blue-green algae, which makes up the majority of plankton. In the reservoirs of Kulgarhi, Getalsud, and Govindsagar, silver carp's extraordinary capacity for the quick and efficient conversion of phytoplankton into fish flesh has been established. Due to the potential harm to native populations, the introduction of alien fish into Indian waterways is still a contentious issue.

1.5 COLD WATER FISHERY: MANAGEMENT, DEVELOPMENT AND EXPLOITATION

- **Cold water fisheries:**

Coldwater fish have adapted to survive in temperatures between 100 and 200 degrees Celsius. In temperate regions, spring water at low height and upland water at high altitudes of mountains both remain cooler than the rest, where cold water fishes thrive. These bodies of water which include a number of hill streams, rapids, pools, lakes, and reservoirs, are widely distributed over peninsular India's Deccan plateau and Himalayan regions.

As in the North, these are either fueled by springs and melting snow, or as in the Deccan Plateau, by rainwater.Since the production from cold water fisheries is enclosable in comparison to total inland catch, there has been a growing realisation for the development of cold water fisheries in India in recent years.The trout hatchery established in Kashmir is one of the potential sources from where the brown trout have been transplanted to the upland waters of Jammu, Kashmir, Kullu, Shimla, Kangra, Nainital, Shillong and Arunachal. Other hatcheries are constructed at Nilgiris and Kerala.

- **Indigenous cold water fishes:**

The three main coldwater fish species that live in India's mountainous waters are Mahseer, Snow Trout, and Indian Hill Trout.

Mahseer cold water fishing:

It is a significant Himalayan game fish. However, it hasn't drawn much notice in India as an unusual fish. Great sizes and large volumes are usually found in mountain streams and rivers. Among the crucial Mahseer species are:

1) ***Tor tor* (Hamilton):** It is characterized by shorter head than the depth of the body. It attains a length of 1.5 m and occurs along the foot hills of Himalayas from Kashmir to Assam and in the river Narmada and Tapti. It is insectivorous in its juvenile stage but becomes herbivorous when adult. It has a prolonged breeding season from July to December. The eggs are laid in batches. It constitutes the major fisheries of rivers Narmada and Tapti.

2) ***Tor putitora* (Hamilton):** It is commonly called as golden or common Himalayan Mahaseer. It has head longer than the depth of the body. It occurs in Himalayas from Kashmir to Darjeeling

hills. This fish breeds thrice in a year, firstly during winter months (January to February), subsequently in summer (May to June) and lastly in August to September.

3) ***Tor mosal*** **(Sykes):** Mosal Mahaseer has head more or less equal to the depth of the body. It is found in the Mountain Rivers on foot hills of Himalayas, Kashmir, Assam and Sikkim.

4) ***Tor mosal mahanadicus*****:** It resembles the mosal mahaseer in all aspects except, it is found in the river Mahanadi and that its head having small eyes is often higher than the depth of the body.

5) ***Tor khudree*** **(Sykes):** It is characterized by its head being as long as the depth of the body. It is found in Orissa and throughout peninsular India. It attains a length of about 1.3 m.

6) ***Acrossocheilus hexagonolepis*** **(Mc Clelland):** It is commonly known as copper or chocolate Mahaseer. It has an oblong and compressed body with an obtusely rounded and prominent mouth. The colour of the body is deep bluish grey with darkish fins. These are mainly distributed Upper Odissa, Assam and Cauvery River in Tamil Nadu. It attains a length over 60 cm. It differs from *Tor tor* in having hexagonal shape of its scales and the thin lips.

7) **Snow trouts:** Snow trouts are chiefly represented by two genera, namely *Schizothorax* and *Schizothoracthys*.

Schizothorachthys**:** It is represented by three species in Himalayas *viz. S. richardsonii, S. plagiostomus* and *S. molesworthi*. These are found in snow fed streams of Assam, Eastern Himalayas, Sikkim, Nepal, and Kashmir. The genera is represented by *S. esocinus, S. progastus* and *S. kumaonensis*, of these, the *S. esocinus* is found in Kashmir and Ladhak, *S. progastus* in the hill streams of Ganges at Hardwar and Darjeeling and *S. kumaonensis* in Nainital.

The Indian hill trout: *Barilius* is known as Indian hill trout. It is represented by four species, namely *B. bendelisis, B. bola, B. vagra* and *B. gatensis*.

- **Exotic cold water fishes:**

The exotic fishes found in the hill streams of India chiefly include the trouts, mirror carps and crucian carps.

1. **Trouts:** Exotic trouts in India are represented by three species, two of them belonging to genera *Salmo* and one to *Onchorhynchus*.

(a) ***Salmo gairdneri gairdneri*** –

It is a native of the Pacific Ocean in North America, and it was imported to India in 1907. It is also known as rainbow trout or steelhead. Due to their ease of adaptation compared to brown trout, these are currently one of the most successful trouts in Indian waters for cultural purposes.

Additionally, they quickly consume artificial food and can endure both high temperatures and water with low oxygen levels.

They develop and mature more quickly, and their incubation period is shorter. They grow to be 400–500 mm long and weigh around 5.5 kg after three years of good nutrition. The mouth is rather small, the head is short, and the body is elongated. Depending on sex and surroundings, the colour of the body varies. It is chiefly a river fish but is cultivated in confined water as well.

It does not breed in ponds but artificial fertilization is possible. The fry feed mainly on planktons but half grown and adults are carnivorous. It is a game fish too.

(b) ***Salmo trutta fario*** –It is frequently referred to as brown trout. It originated in the water-filled mountains of Central and Western Europe. This fish was the first to be artificially generated and raised in India. Even though it was introduced to the mountain waters of all hills, it could only grow in Kashmir's streams and fields and Punjab's river Beas. It consumes huge living prey near the bottom, including crustaceans. It grows to a maximum length of 46.5 cm, depending on the availability of natural food. The fish migrates upstream during the breeding season to spawn in shallow water with a fast current and gravel beds.

1.6 ESTUARINE FISHERIES: MANAGEMENT, DEVELOPMENT AND EXPLOITATION

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 becomes 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 *Hilsa ilisha*, *Polynemus* spp, *Pama pama*, *Tachysurus* spp, *Pangasius* spp and the prawn, *Macrobrachium* spp.

The major estuarine systems in India are the Hooghly-Matlah estuarine system in West Bengal; the 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.

1.7 MARINE FISHERY: EXPLOITATION OF MARINE FISHERY RESOURCES OF INDIA

Resources:

India has approximately 8118 kilometers of coastline, nearly 2 million square kilometers of Exclusive Economic Zone (EEZ), and 500,000 square kilometers of continental shelf. India has a potential catch of 4.41 million tonnes from these maritime resources. Similar to this, our 3.15 million hectares of reservoirs, 2.5 million hectares of ponds and tanks, 1.25 million hectares of brackish water area, cold water resources of mountainous states, and all other inland fishery resources have an estimated 15 million tonnes of output potential. In comparison to this potential, the inland sector's fish production in 2016–17 was just 7.77 million tonnes. In this situation, effective resource management becomes essential to achieving the desired productivity. With this background in mind, we want to harness all possibilities for intensive and integrated development of fishery sector.

Responsibility of the DADF for fisheries development:

The Ministry of Agriculture and Farmers Welfare's Department of Animal Husbandry, Dairy and Fisheries (DADF), which is in charge of the country's fisheries development and management, develops sector-specific development strategies and publishes directives for the management of fisheries and aquaculture. Additionally, it offers different States/UTs and other implementing agencies technical and financial help for the execution of fishery development schemes.

Marine capture fisheries:

The increased fishing effort is causing significant changes in marine capture fisheries. Nearly all commercially significant marine fin fish and shellfish capture is declining, which has a negative impact on resource availability and increases unemployment. The availability of affordable protein for the general public and the expansion of the national GDP are both impacted by the decline in marine capture fishing. Mariculture, which includes the growing of finfish and shellfish in open marine cages, became significant in this environment.

What is Mariculture?

Mariculture is a specialized form of aquaculture that involves growing marine organisms for food and other goods in the open ocean or in seawater-filled tanks, ponds, or raceways. As an illustration, consider the farming of marine fish in salt water resources, including finfish and shellfish like cobia, pompano, sea bass, lobster, oysters, and seaweed. Mariculture also produces cosmetics, nutritional agar, jewellery (like cultivated pearls), and fish meal, which are non-food items. When compared to fish raised in ponds or tanks, mariculture fish are said to be of greater quality and come in a wider variety of varieties.

What is open sea cage culture?

Open sea cage farming is environmentally benign and carried out there where there is less wave movement. Due to the high value of the fish raised in cages, there is a significant export market for these fish. A cage is an enclosure that can be any size or shape and is used to cultivate biotic organisms like finfish and shellfish in captivity for a specific purpose. All sides of the cages are completely closed off, with the exception of the top entrance for feeding. For fish farming in open waters where the wave and tidal influence is adequate for farming, the size of a sea cage can range from 6 to 12 m dia. There are several cages spaced out in a battery for better operation.

Initiatives and status of Mariculture practices in India:

A. Marine Finfish Culture:

(i) Cobia (*Rachycentron canadum*):

Cobia is one of the suitable species for open sea cage farming. It can grow to about 3-4 kg body weight in one year and 8-10 kg in two years. Brood stock development of cobia was initiated by CMFRI at Mandapam during 2007-08. The technology of cobia seed production and farming was standardized by CMFRI and is being taken up by fish farmers successfully.

(ii) Sea bass (*Lates calcarifer*):

One of the most significant prospective species for pond and open sea cage cultivation, sea bass is very valuable commercially. The ICAR Institutes have created and standardized seed production technology. CMFRI and CIBA have developed a sea bass nursery and rearing protocol. Several demonstrations of pond and cage farming were successful.

(iii) Silver pompano (*Trachinotus blotchii*):

Due to its widespread acceptance and medium size that is ideal for a small family, silver pompano is another species that is good for marine aquaculture. It has a strong market demand, a wide range of water quality tolerance, and the capacity to adapt to taking pellet diets. The CMFRI has successfully increased the brood stock, stimulated spawning, and produced silver pompano larvae. Fish producers have successfully used the silver pompano seed manufacturing and farming technique that CMFRI developed and standardized between 2011 and 2015.

1.8 SUMMARY

India has significant coldwater aquatic resources in terms of upland rivers, streams, high and low altitudinal natural lakes, reservoirs that hold large population of indigenous and exotic, cultivable and non-cultivable fish species. Information on resources is obsolete and updating information is a challenge due to its kaleidoscopic topography of the sector. The lacustrine, cold water, estuarine and marine fishery also holds a promise but through proper management and development. Indian lacustrine, cold water, estuarine and marine fishery resources offer a vast scope if there is proper fishery management through laws and management practices. Dams also effect the fish behavior and their migration pattern. The capture and culture fisheries both have a huge possibility in terms of social, economical and ecological aspect.

1.9 TERMINAL QUESTIONS AND ANSWERS

Question No.1 Give a brief account on the fishery resources of India.

Question No.2 Explain methods for improvement of fish stocks.

Question No.3 Explain in detail river pollution and its control.

Question No.4 Explain various steps for conservation of fishery resources in India.

Question No.5 Give a brief account of the marine fishery resources in India.

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UNIT 2: FISH GROWTH AND AGE

CONTENT

2.1 OBJECTIVE

Study of this unit will let the students to:

- What are the Factors responsible for growth?
- What are the relationship of age and growth?
- Natural fish food organism and their role in fish growth

2.2 INTRODUCTION

Growth is a characteristic feature of living beings. Every organism grows and attains its normal size. Growth is really an increase in any measurement of any organism in relation to time. Growth is the process of addition of flesh as a result of protein synthesis.

A fact of fish growth is of vital significance for obtaining high yield of fish. The rate of fish growth varies from species to species and sometimes it varies even along with species also.

Growth of an organism can be defined as a change in its length and weight over a period of time. It indicates the health of the individual and of the population and has been broadly studied for a various species of fishes. The growth and age of a fish are closely related to each other and depends on several factors.

The length and weight are two parameters demonstrate growth of a fish. The growth in length indicates long term change, whereas growth in weight is further subject to seasonal variation.

Absolute growth: Absolute growth refers to a fish's perfect development from the time of its embryo to its senescence.

Relative growth: Growth in relation to one life period to another is referred to as relative growth. For obvious reasons, growth is never comparable between any two life stages.

Isometric growth: Fish with parity of measure and projection planes that are equally inclined to three vertical axes at right angles to one another are said to have isometric growth. The growth is referred to as isometric if the fish is obeying the cube law.

Algometric growth: This growth is asymmetrical. This form of expansion may take on a number of different patterns. For instance, more fish grow in length than in width or mass.

Growth is a bio-energetic process that is characterised by an increase in an object's length and weight over time. It provides information about population and individual fitness and has been extensively researched for a variety of fish species. A fish's age and growth are intimately related to one another and are influenced by various factors. The two factors that demonstrate a fish's growth are its length and weight. While growth in weight is more prone to seasonal volatility, growth in length implies a long-term shift.

2.3 FACTORS RESPONSIBLE FOR GROWTH

The growth rate in fishes is highly changeable and depends upon a number of environmental factors such as temperature, amount of dissolved oxygen, ammonia, salinity, photoperiod, degree of competition, quality of food taken, age and the state of maturity of the fish. Temperature is one of the most important environmental factors and along with other factors, influences growth rate. The optimum food consumption for maximum growth is temperature dependent. According to recent studies, endogenous regulators of growth may also include the individual's physiological state, hormones, and genetics.

Dissolved oxygen level depends on temperature and by itself is also an important factor affecting growth rate of fishes. Possibly, the fish is deprived of 'extra' aerobic energy required for growth and reproduction, if dissolved oxygen falls below a certain level. Ammonia if present in high concentration will slow down the growth and lower densities tend to increase it. This way also be due to competition for available food.

Food availability which depends upon temperature affects growth rate on a seasonal basis. Growth may be rapid during warmer months, when plenty of food is available and slow during winter. Similarly photoperiod may also affect seasonal growth. Age and maturity are also important factors. Fish typically grow very fast in length in the first few months or years of life until maturation. Later, large amount of energy is diverted for the growth of gonads, hence body growth slows down. Growth rate of mature fish are therefore, much less than those of immature fish. However, mature fish are typically heavier per unit of length than the immature fish, partly due to the large sized gonads. This is shown by their higher condition factor (K), condition factor represents the condition of the fish during a certain period, and is the ratio of the length to the weight of the fish, as calculated by the following formula:

$$K = \frac{W}{L^3} \times 100$$

Where, W is the weight of fish in grams, and L is the length in cms.

The condition factor is generally used by the biologists as an indication of the health of the fish population. A high value of K shows that plenty of food is available to support both somatic and gonadal development of the fish.

2.4 AGE AND GROWTH RELATIONSHIP

Growth rates in fishes can be determined by measuring the changes in size in relation to time. One of the following methods can be used:

DIRECT METHODS FOR DETERMINATION OF GROWTH

Fish can be raised under controlled settings to directly determine their growth rate. For this, known-age eggs or larvae are housed in an experiment pond. For the purpose of estimating growth rate, length and weight of each are measured at known intervals of time. The direct approach is particularly useful for determining the growth of cultured fish since it allows for the control of feeding rate, temperature, and other environmental parameters.

FISH TAGGING

With this technique, fish are tagged or marked for identification after being measured for length and weight before being released back into their natural habitat. These fish are taken again and measured after a few months. The amount of time a fish spent in its native habitat is used to compute the growth rate. Cutting the fin rays, using spray paint to colour the fish's skin, or placing fluorescent rings on scales or bones are all methods of marking that should be done without affecting the fish's behavior or rate of feeding. The fish may be injected with various colours, such as chromium dioxide, Fast Blue, Lead acetate, or Latex, to help identify it when it is caught again. The tagging technique is more widely used. To ensure that the tags stay in place and are not lost, various types of tags holding information about the fish, the date of tagging, etc., are fastened to the body. A tag is a circular object that can be constructed of plastic, aluminium, silver, nickel, etc. A tag lacking a caudal peduncle may be fastened to the body with a tiny wire. Sometimes a tiny wire is really utilized to puncture the bodily tissue. The wire carries the disc or plate, and to maintain it in place after piercing the tissue, the two ends of the wire are twisted. Another type of tag is a straight metal shaft that is inserted into the tissue. To keep it from falling out, the shaft has one or more barbs on one end. In order to keep it from falling out, the outside end. The disc, which contains information on the fish, is attached to the shaft's outer end. Small metal rods called magnetic tags are placed into the body and can be found in a magnetic field. A very large number of fish must be employed in this strategy since marked or tagged fish provide more accurate information about growth and movement of the fish but are more challenging to recapture.

LENGTH FREQUENCY DISTRIBUTION METHOD

This method is based on the assumption that a species' individuals from any given age group, gathered on the same day, will exhibit variation around the mean length when measured using a length-frequency analysis. Additionally, it is predicated on the idea that when data from the entire population are displayed in a basic manner, succeeding ages at successively longer intervals would group together, allowing for the separation of different age groups.

This method involves measuring the lengths of 300–500 fish from a population once a month at appropriately spaced intervals, making sure the sample is taken from a catch that includes fish of different sizes. The information is split up into frequencies. For instance, the length can be tabulated in frequencies of 1-19, 20-39, 40-59, 60-79, etc. if the highest recorded length is 400mm. On graph paper, the model values are shown with the time in equal intervals of months on one axis and the model values for each month derived from these. The age and rate of growth of the models are then calculated month by month. Young fish benefit greatly from this method. One can assess the growth rate at different ages by comparing the mean length between age classes.

The sample must be made up of a sizable number of people, ideally collected on a single day, and it must be representative of all population sizes and age groups in order for the above procedure to produce results that are quite reliable.

RINGS OR ANNULI ON HARD SUBSTANCES

In many species, the rate of growth in the size of the fish's bones, spines, and scales is inversely correlated with that rate. The otoliths, vertebral centra, opercular bones, coracoids, hyomandibular, and other hard parts can be studied to determine an animal's age. Of these, the scales and otoliths are the most frequently employed.

Spines and rays have occasionally proved helpful in determining age. To do this, rays or spine segments are broken apart and analysed. The vertebral centrum can also be helpful, and some researchers have employed vertebrae from various places. The chosen vertebrae are treated with an acidic solution to remove any connected tissue, then they are washed in soapy water, dried, and checked under a microscope for growth rings.

The vertebra's centrum displays annual growth rings. As zones of growth may be visible on their surface, opercular bones can also be utilised to determine age. To determine a fish's age, the opercular bone is extracted from a fresh specimen, boiled in water for 10 minutes, and then cleaned to get rid of any associated muscles. The bone is next treated for 10 to 20 minutes with 50% hydrogen peroxide, cleaned with water, and dried for two to three days in the sun. These bones exhibit annuli or rings under a microscope, which are counted to determine the age of fish.

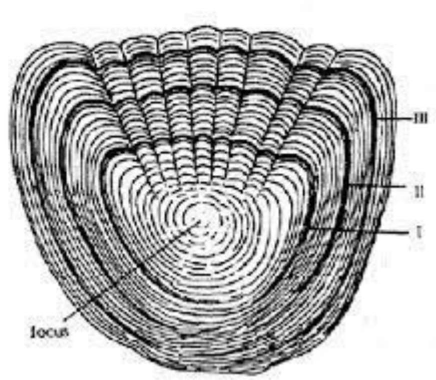

Fig.2.1 A scale with annuli

Scales are generally used to determine a fish's age. With a little practise, annuli on the scales can be easily numbered using this method, which is the simplest and most accurate. On average, 10 sales are extracted from the fish immediately above the lateral line, below the commencement of the dorsal fin. 'Key scales' are what these are known as. Scrubbing the scales in water removes them. Then, wet or dry mounts are made. Permanent preparations can be created either through the impression of cellulose or plastic, or they can be mounted entire in a glycerine, balsam, or glycerine-gelatin solution.

For quick and precise counting of growth rings, the scale is inspected through a binocular microscope or the image can be expanded by using a microprojector. The core of the scale typically houses the scale's focus, which is the first component to form. An annulus is typically identified by a distinct, concentric streak that surrounds the focus. An annulus is a year, and the addition of more annuli shows how many years the fish has lived.

Scales are used to estimate a fish's age because they produce successive rings as it gets older. Since there is a surplus of food available in the summer and autumn and the fish are growing more quickly, these seasons cause the rings to form to be spaced widely apart. Wintertime food availability and growth restrictions result in closely packed rings that look as alternating bands of light and dark. Together, these two bands—known as the annuli—are thought to have formed within a year. Age of the fish is determined by the number of annuli on the scale. The actual sites of dense bone deposition are called annuli, and they signify the year's slow development stage. A fake annulus does not run the entire length of the scale and can emerge at any time due to a variety of causes. Fake annuli can also occasionally appear in some species due to slowdown or temperature fluctuations. These must be identified from actual annuli, which form at the same time every year.

This strategy works for fish living in temperate zones where the amount of food fluctuates with the season, but it is unreliable for fish living in tropical regions where food is always accessible. Previously, it was believed that the availability of food was what caused the creation of rings. However, it is now thought that lack of nourishment throughout the maturation and spawning processes, as well as other factors, may also contribute to the annuli's creation. Since summer and winter are not clearly distinguished seasons in the tropics, it is simple to interpret the scales on marine fishes, claims Qasim (1973).

Thus, fish lengths at each year may be back-calculated by measuring the linear distance (radius) from the 'focus' of the scale to each annulus, and fish age can be established by counting the annuli.

For example, the length at ‘n’ years can be calculated by using the following formula:

$$Ln=a+\frac{(L-a)(Vn)}{Vr}$$

Where Ln= fish length at n years.

a=a constant that often approximates fish length at time of scale formation.

L= fish length at the time of capture.

Vn= Scale radius, distance from focus to nth annulus.

Vr= Scale radius from focus to scale edge.

Growth rates can be derived from these backcalculations of length at various years. Fish from the families Cypriniformes, Perciformes, and Channiformes have all been treated with this technique.

Otoliths, which are situated on either side of the skull where the upper arm of the gill arch is connected to the otic bone, are created in the embryo as soon as the inner ear is established. After the muscles of the pro-otic bone have been removed, the otolith can be viewed. The sagitta is the largest and is employed in thick at the extremities of the three otoliths (lapillus, asteriscus, and sagitta) on either side of the skull. The thinner otolths can be inspected directly, whilst the thicker ones need to be properly grounded. The rings are then counted beginning with the central nucleus while the specimens are being inspected under a binocular microscope. However, it is important to double-check and confirm the age estimated by the scale or otolith method, as well as ages determined by other techniques such random population sampling over a long period of time or by direct observation of fish raised in tanks or cages.

RADIO-CARBON UPTAKE METHOD

Scales from a live fish's epidermis were removed, and they were then incubated in a mixture containing the radioactive amino acid glycine created by C14.The amount of beta radiations released by the scale is used to calculate the rate of C14-glycine incorporation into the scale following an incubation of less than four hours. The scintillation counter indicates more incorporation of C14 by the scale, which corresponds to a quicker growth rate.

RNA- DNA RATIO METHOD

This technique calculates the rate of protein synthesis and provides a growth rate index. The amount of DNA in each cell is constant, whereas the amount of RNA depends on the rate of protein synthesis in the cell. Thus, the RNA DNA ratio in a tissue sample demonstrates this rate per total number of cells. Some fish have a correlation between this ratio and observed weight growth. However, within the same species, such comparisons are possible.

Animal growth is not steady throughout the course of a lifetime. As animal ages, its growth rate slows down until it eventually stops growing altogether, which is denoted by the letter L and is known as length at infinity. This length is the most that the fish can theoretically reach. However, in the wild, fish do not grow to this length because they perish from diseases or fishing-related natural causes.

Numerous growth characteristics, including the rise in absolute length, the rate of increase in weight, the growth constant, etc., can be estimated by examining a species' age and growth. Calculating these parameters is helpful when comparing growth constants and other factors. These variables are helpful for comparing the rates of growth of various species within the same water body or between different water bodies. These studies also show "good" and "bad" growth years for fish. When favourable conditions return, observations of a species' annual growth rate also imply the prevalence of the phenomena of growth compensation, as in the case of the carp species *Tor putitor, Lebeo dero*, and *Cyprinus carpio* (Tandon and Johal, 1994). A species' growth constant and average growth constant values demonstrate that there are three distinct life stages: youth, sexual maturity, and old age. These studies are very helpful for fishery management.

2.5 NATURAL FISH FOOD ORGANISM AND THEIR ROLE IN FISH GROWTH: PLANKTON, BENTHOS

Natural Fish Food Organism:

The natural food supplies all the necessary nutrients for a balanced diet. The desire for natural food differs between species and between age groups of people as well as between species. For instance, silver carp prefers phytoplankton, while catla prefers zooplankton. The fish may consume plankton when they are younger, but they may prefer animal food as they get older. The high protein and fat content of natural diets helps fish flourish. In order to boost fish growth, it is therefore required to increase the live food in the aquatic habitat.

A water body has a range of natural fish food organisms, which are dependent on the water body's output. Natural food sources for some fish include molluscs, annelids, worms, insects, and phytoplankton. Natural foods supply the elements of a complete and balanced diet. The need for natural food differs between species and between age groups of people. For instance, silver carp prefers phytoplankton, while catla prefers zooplankton. The fish may consume plankton when they are younger, but they may later prefer animal food. The growth of fish is supported by the high protein and fat content of natural diets. In order to restore the growth of fish, it is crucial to increase the live food in the aquatic habitat.

Plankton

Plankton is made up of tiny, free-floating plant and animal organisms that have weak locomotional systems and only float along with the water's currents. Macro, microscopic, and nanno plankton are the three types of plankton that are separated based on size. Macro-plankton consists of organisms that are larger than 3 mm and are readily seen. such as salpa, mysids, and larva.

Phytoplankton and zooplankton are additional types of plankton. These include non-photosynthetic plants like bacteria and fungi as well as organisms containing chlorophyll like Microcystis, Volvox, and others. It contains all of the microscopic plants, diatoms, and dinoflagellates that float passively. The zooplankton is a term used to describe microscopic organisms such as rotifers, copepods, ostracoda, amphipods, worms, eggs, and larvae.

Meroplankton, a type of transient plankton, may exist. These are planktonic eggs and larvae, which are only abundant during specific seasons depending on the spawning behaviours of the parents. However, these habits vary widely, therefore there is no single pattern for all parents. However, because there is a wide range in the timing of animal spawning, these plankton may be present in tiny or large amounts throughout the year. Holoplankton, often known as permanent plankton, is prevalent throughout the year.

Plankton exhibit a variety of adaptations that help them stay afloat in the surface layer of the water and avoid sinking. As an illustration, consider a cell that has grown to the size of a bladder and is filled with a thin fluid. Some have fine hairy extensions that resemble cylindrical hairs, while others are broad and flat like ribbons or may branch.

A pond's plankton will fluctuate quantitatively over the season. Peak plankton levels are said to occur in Uttar Pradesh's freshwater ponds throughout the spring and monsoon while a slack phase is seen during the summer. Zooplankton predominate at periods of minima, while phytoplankton are prominent during periods of peak production. In several ponds, a bimodal pattern of plankton production has been observed, with phytoplankton dominating the monsoon peak and zooplankton dominating the winter peak. The differences in the physic-chemical conditions of the pond are what cause these pronounced seasonal oscillations in the prevalence and abundance of plankton. Plankton blooms are what these abundance waves are referred to as. The cladocera, rotifers, and copepods in particular undergo diurnal vertical migration. Positive effects result from this downward migration during the day, and phytoplankton grows rapidly at this time.

Fisheries depend on zooplankton because they transform phytoplankton into food for fish and animals. Zooplankton availability affects the quantity and distribution of carnivorous pelagic fish. Diatoms, single-celled algae, *Volvox, Anabaena, Oscillatoria,* and *Microcystis* are some examples of planktons. Fish eggs and larvae, Eudorina, Protozoans (Foraminifera, Radiolaria, Ciliates, Flagellates, Arcella, Difflugea, etc.), Larvae of Crustaceans (like *Daphnia, Cyclops, Copepods, Sagitta, Tomopteris*, Pteropods, Hetropods and Rotifers.

Rotifers as fish feed organisms have a number of benefits: They procreate easily. According to estimates, populations can double every one to five days in ideal circumstances. Rotifers are a vital first food source for many fish and prawns because they are small enough to be accepted as food by some creatures that cannot eat larger zooplankton. They are nourishing, and like with other zooplankton, their true nutritional content can be increased by adding particular strains of algae or other feed to the rotifers.

Role of Plankton in the Survival and Growth of Fry

Research has demonstrated that zooplankton is the primary source of nutrition for newborn carp fry, and in the absence of predators, their ability to survive completely depends on the amount of zooplankton produced and the timing of pond stocking. However, the growth of dense algal blooms causes the water to become oversaturated with dissolved oxygen, which frequently creates gas problems for the fry and high rates of mortality.

The results of experiments have demonstrated that zooplankton is the primary source of nutrition for immature carp fry, and that, in the absence of predators, their ability to survive completely depends on the quantity and timing of zooplankton blooms in the ponds. However, the growth of a thick algal bloom results in a super saturation of dissolved oxygen in the water, frequently causing gas problems for the fry and significant mortality.

In around 10 days, *Volvox*, *Eudorina*, and *Anabaena* usually appear in blooms of various intensity after heavy manuring of ponds with cowdung. These blooms typically comprise of rotifers, cladocerans, and copepods. Additionally, algae grow, and Euglena could produce surface scum. Algal growth and multiplication occur very quickly; blooms may form and then entirely vanish in a matter of 2-3 weeks. Among zooplankton, they reproduce quickly, form swarms in 4-6 days, and then vanish in 7-8 days.

According to laboratory tests, if fry are stocked during zooplankton swarms and there is an abundance of food, 90–100% of them will survive. Fry prefer zooplanktons because they can digest them readily. Since phytoplankton is hard to digest, it is not used as food. Phytoplankton has a lower nutritional value than zooplankton.

However, the occurrence of zooplankton in a pond following intensive manuring is purely a question of luck. The occurrence of phytoplankton or the production of zooplankton is uncertain. Heavy doses of cowdung applied to tanks typically cause early zooplankton swarm generation, necessitating a change in fry stocking to coincide with the peak period of production.

2.6 SUMMARY

Growth is a trait shared by all living things. Every living thing develops and reaches its ideal size. Increasing any measurement of any organism in relation to time is what is meant by growth. As a result of protein synthesis, growth is the process of adding meat. A change in an organism's length and weight over time is referred to as growth. A fish's age and growth are intimately tied to one another and are influenced by various factors. Fish growth is shown by two parameters: length and weight. While development in weight is additionally influenced by seasonal variation, growth in length implies long-term change.

Fish development rates are very variable and influenced by a variety of environmental parameters, including temperature, dissolved oxygen levels, ammonia, salinity, photoperiod, level of competition, kind of food consumed, age, and fish maturity.

Fish growth rates can be calculated by observing the variations in size over time. Direct methods for measuring growth, fish tagging, the length frequency distribution approach, rings or annuli on hard objects, the radio-carbon uptake method, and the RNA-DNA ratio method are among the techniques that can be utilised.

A water body has a range of natural fish food organisms, which are dependent on the water body's output. Natural food sources for some fish include molluscs, annelids, worms, insects, and phytoplankton. For instance, silver carp wants phytoplankton whereas catla favours zooplankton, both of which help fish thrive. To restore the growth of fish, it is therefore required to enhance the living food in the aquatic habitat.

Plankton is made up of tiny, free-floating plant and animal organisms that have weak locomotional systems and only float along with the water's currents. Macro, microscopic, and nanno plankton are the three types of plankton that are separated based on size. Phytoplankton and zooplankton are additional types of plankton. These include non-photosynthetic plants like bacteria and fungi as well as organisms containing chlorophyll like Microcystis, Volvox, and others. It contains all of the microscopic plants, diatoms, and dinoflagellates that float passively.

The zooplankton is a term used to describe microscopic organisms such as rotifers, copepods, ostracoda, amphipods, worms, eggs, and larvae. Fisheries depend on zooplankton because they transform phytoplankton into food for fish and animals.

2.7 TERMINAL QUESTIONS AND ANSWERS

2.7.1 Multiple Choice Questions:

1. Age and maturity are usually the best predictors of ______ in fishes.

a. Absolute growth rates   b. Relative growth rates

c. Approximate growth rates   d. Convertible growth rate

2. Nursery ponds are used for growing

a. Marketable fishes   b. Brooders

c. Spawn to fry   d. Fry to Fingerlings

3. Wallago attu is commonly known as

a. Freshwater shark   b. Trout

c. Minor carp   d. Mahaseer

4. Width of the rings (scales/otolith) gives an estimation of:

a. Health of fish   b. Age

c. Growth   d. Ecology of fish

5. Most preferred food item of carp spawn

a. Clliorelln   b. Chaetocerous

c. Phytoplankton   d. Rotifer

6. Grass carp are used for control of–

a. Phytoplankton   b. Macrophytes

c. Zooplankton   d. Insects

Answers: 1(b), 2. (c),3(a),4(b),5(d), 6(b)

2.7.2. Short Answer Question:

1. What is the growth of fish?

2. Write about the role of plankton in the survival and growth of Fry.

3. Write short notes on: i) Fish tagging ii) Radio-carbon uptake method

2.7.3. Long Answer Question:

1. What are the relationship of age and growth?
2. What are the Factors responsible for growth?
3. Describe Length frequency distribution method.

2.8 REFERENCES

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UNIT 3: FISH BREEDING AND SPAWNING

CONTENTS

3.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

vi. Basic concept of Fish Breeding and Spawning
vii. Learn methods of Induced Breeding
viii. Detailed process of Hypophysation
ix. Different methods of breeding
x. Hatchery management

3.2 INTRODUCTION

Induced breeding is the process of artificially inducing fish to reproduce when it does not occur naturally. One of the most critical requirements for effective fish farming is the availability of the necessary quantity of preferred species of fish seed. In general, limited waterways are not where the widely cultivated major carps of inland Indian waters like Catla, Rohu, Mrigal, and Calbasu, as well as Chinese carps like Silver carp, Big head, Grass carp, Black carp, and mud carp, breed.

They do mature there, but they only breed in their natural habitat during the monsoon season in the flooded shallow areas along the path of the rivers. The specific settings of bundhs, both wet and dry, are where the Indian main carps do spawn. In such cases, fish farmers must rely on river systems for the fish seed collection, and the fish seed gathered includes both desirable species and unprofitable species, such as predators. Asiatic carps cannot reproduce in small, stagnant bodies of water because there are not enough environmental cues to cause the necessary amount of gonadotrophic hormones to be secreted. In order to get brood fish to reproduce, exogenous hormones like pituitary extract or synthetic hormones are administered into them. Indian major carps were successfully induced for the first time in 1957, followed by silver and grass carp in 1959 and 1962, respectively. Typically, pituitary glands are used as an inducer in India.

BREEDING TECHNIQUES

Indian Major Carps

- **Selection of Breeders**:

  When the temperature drops and there is a deposit of new rainwater, induced breeding typically begins. The spawners are carefully chosen, netted out, and weighed separately. Males can be identified by their pectoral fins, which are rough in contrast to smooth in females. By gently pressing the belly close to the vent, the males are chosen for injection if the milt oozes out freely or easily. The larger protruding abdomen of the females makes them easy to identify. Under normal circumstances, they may be chosen for injection if they have a fully protruding abdomen and a somewhat swollen pinkish vent. By using a catheter, a sample of ovarian eggs (oocytes) may be collected and examined to find out the ripeness of oocytes.

- **Dosage of Pituitary Injection:**

  The dosage of pituitary extract to be administered is determined by the gonad's maturity and the local climate. A very modest amount is enough to trigger spawning when the receiver is at their best. In most cases, a somewhat greater dose is initially tried at the start of the season, reduced later, and then increased once again tolarvals the end of the season. The pituitary extract is injected into the females in escalating amounts, usually in two separate injections, whereas the males only receive one. For the initial injection, female patients may receive 2-4 mg/kg of body weight, and for the second injection, 5–10 mg/kg of body weight. Males receive one injection in addition to the last injection given to the female, and the period between two injections is typically 6 hours. The dose ranges from 2-4 mg/kg body weight. Even with the little dose of the initial injection, the females may reproduce if they are in excellent condition. The dosage also relies upon the potency of the glands employed.

- **Preparation of Pituitary extract and Injection (Fig. 1):**

The number of glands needed to inject the spawners is computed after the dosage is chosen. The necessary number of glands is removed, and any extra alcohol is allowed to evaporate. If not weighed previously, the gland is weighed and then homogenized in a homogenizer in a known volume of distilled water or 0.3% saline solution. Following homogenization, the gland is diluted to the required volume at a rate of 0.2 ml/kg of the recipient fish's body weight. After centrifuging the pituitary extract, only the supernatant solution is used for injection.

Pituitary extract can also be made in advance in large quantities, stored, and refrigerated. In this instance, the extract is made using distilled water and kept fresh with glycerine in 1:2 ratio. When a pituitary gland extract is prepared in bulk, it can be used in numerous sets with comparable outcomes because the extract's potency is constant, unlike when it is done individually.

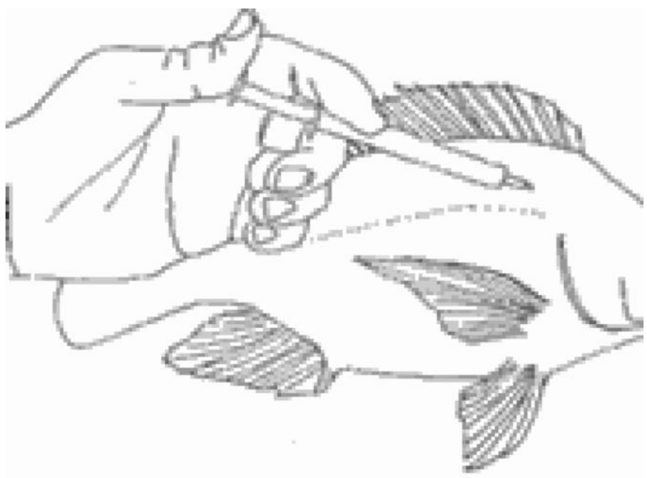

Fig.1.1 Dose administration

- **Breeding:**

One female and two males are released in the breeding hapa after the initial injection. Breeding hapas are rectangular cloth containers with an entrance on one side (the breadth side) that can be used to introduce and remove breeders as well as be secured securely. Hapas that breed are used to the margins of ponds, canals, lakes, and reservoirs. Water bodies with common carp and tilapia are avoided while mending the hapas, as are ponds with recent manure buildup and algae blooms. Breeding takes place within 3–6 hours after final injection to females. Stripping method is not followed, since Indian major carps breed fully after injection with high percentage of fertilization.

Silver Carp and Grass Carp

- **Selection of Breeders:**

Males in good health who easily ooze sperm under light pressure are typically preferred. The pectoral fins of males are rough to the touch, whereas those of females are smooth, like those of Indian big carps. The most common selection criteria for females are a soft, round, protruding abdomen and a slightly enlarged, pinkish vaginal entrance.

- **Selecting female**

Silver and Grass carps can be made easier with the aid of a catheter. By inserting catheter, some oocytes are taken out and examined in the field by keeping them in petridish. Silver carp female with uniform size of eggs, very pale blue in colour, but slightly pinkish in smaller ones are usually selected for breeding. Since well-fed females may appear mature, the use of a catheter is more helpful when choosing Grass carp females to make sure they are pregnant. Because they will be at a more mature stage, females with uniformly sized, brownish or copper coloured eggs are preferable.

Breeding Technique:

Similar to Indian major carps, Silver and Grass carps are bred using the same methods. Pituitary gland extract is administered to females at a dosage of 10–14 mg/kg body weight and to male at a rate of 3–4 mg/kg body weight. As in the case of Indian major carps, males receive one treatment while females receive two injections in escalating amounts. The injected fish are put into the breeding hapas in sets of one female and two males each. Three to four hours after the last injection, the females are checked to see if they are ready for stripping. If the eggs start to leak out immediately after applying a little pressure to the genital hole, the fish is ready to be stripped.

Fish occasionally move quickly, and then some eggs are released. If not, the fish are returned and examined once more after 30 minutes or an hour, depending on the situation. The eggs are stripped into a well-cleaned, dry enamel basin and promptly fertilized with milt when using the dry method of stripping, which involves wiping the fishes with a towel to remove any excess water.

Eggs and milt are vigorously combined for one or two minutes using clean feathers. Water is then added, and the mixture is then washed three to four times to eliminate any remaining milt. Once the eggs have properly swollen and hardened, they are kept in breeding hapas. After receiving pituitary injections, Grass carps can spawn themselves with a high success rate; in contrast, Silver carp rarely produce fertilized eggs, and when they do, the success rate is poor. The amount of milt recovered from Silver carp males is frequently insufficient; therefore additional males are injected, stored apart, and used as needed. Even with a single low dose of 3-

5 mg/kg body weight of pituitary extract, free discharge of eggs has been seen in grass carp and silver carp on chilly rainy days, and the eggs could be fertilized by uninjected males.

- **Multiple Breeding:**

Major Chinese and Indian carps only reproduce annually during the monsoon season. It was believed until a few years ago that females could only be artificially inseminated once each year. Since the majority of these carps were forced to reproduce a second time within the same season, this idea has modified. When fish are properly cared for and start breeding early in the season, they typically have this success. The Silver carp and Grass carp which have bred in February/March can be hypophysed a second time between May-July and the spawners lay more eggs during the second breeding. Chinese carps only spawn once a year in China's natural waters, however carps raised in captivity can spawn multiple times annually. This alteration in reproduction cycle is induced by the change in environmental conditions. Intensified culture of post spawner is carried out when temperature is above 20°C. The brood stock reach maturity again and thus Grass carp could be bred three times in a year from April to August.

- **Breeding Period:**

Major Indian carps naturally reproduce in flooded rivers during the monsoon season. This time frame often falls between April and August/September in various regions of India. The period also coincides with extensive and vigorous induced breeding of Chinese carps in India. Induced breeding experiments on Indian major carps and Chinese carps have found that there are occasions when fishes could be successfully bred for a longer period than generally thought possible. Breeding of *Labeo rohita* was permitted through the end of September, and that of Silver carp through November.

Grass carp can be made to breed in September, but the best time to do it is from July to August. This was most likely caused by the monsoon continuing over a longer period of time and creating favourable meteorological conditions. *Labeo fimbriatus* could reproduce in Kerala from April to August and then again in November. Apart from breeding in July-August, the same species is effectively induced to breed in Tamil Nadu in October. At the Rahara Center of the Central Inland Fisheries Research Institute, silver carp and Mrigal were forced to reproduce in the months of March and April (CIFRI). At the All India Coordinated Research Project on Composite Fish Culture Centers in Jaunpur (Uttar Pradesh) and Karnal (Haryana), Rohu, Mrigal, and Silver carp could be coaxed to spawn 40–50 days before the monsoon under 38°C water temperature. From the latter week of March through September, silver carp, grass carp, and Indian major carps might be effectively reared. By getting the fish to the appropriate maturity by injecting pituitary extracts in the month of November, Mrigal may be bred by hypophysation in the month of December.

3.3 FACTORS RESPONSIBLE FOR INDUCED BREEDING

- **Breeding environment and conducive ecological factors for induced breeding**

Breeders that have been injected are typically released in India in hapas that are fastened to the margins of ponds, lakes, reservoirs, and canals for breeding. With the exception of canal systems, the water will stay still, but in some areas of the nation where it hasn't rained in two or three days, the temperature of the water can soar to 38°C and even up to 35°C. However, improved facilities are now available in some stations where running water or circulation of water with the ability to somewhat adjust water temperature is possible because to the development of hatchery systems.

The weather and water parameters examined during the breeding of Indian major carps in ponds by hypophysation revealed that spawning takes place in clear and turbid water at temperatures ranging from 24-36°C.The ideal conditions are cool, rainy days with water temperatures of 27°C, with the best outcomes being seen between 30 and 33°C. A regulated temperature of 28°C resulted in better spawning than field circumstances, where the temperature was 3.1 to 5.6°C higher. In Kerala, *Labeo fimbriatus* can be bred as early as April 10th at controlled temperatures of 29–30°C.

Indian major carps may reproduce in a wide range of temperatures under hypophysation, however when the water is 30°C or colder, a higher percentage of fertilization and improved hatching are seen. Silver carp and grass carp can spawn in hapas fastened in stagnant pond water when there has been a substantial buildup of rainwater, a sudden rise in water level, and the water temperature is below 30°C. Eggs and brood fish kept in hapas typically have difficulty spawning and hatching when the water temperature is above 33°C.

Almost 100% breeding of Silver carp and Grass carp was accomplished on three consecutive days at water temperature of 24-28°C while performing tests in a pond with stored rain water of the season and with constant slow rise in water level due to the flow of rain water into pond. Silver carp and Mrigal were successfully induced to breed in March and April at the

CIFRI Rahara Center at a controlled temperature of 25 to 26°C. From March through September, a modified version of the Chinese hatchery method was used to mechanically oxygenate the deep tube well water, which had a temperature of 28 to 29°C, in order to breed Chinese carps and Indian major carps. Running water (flow of 0.2–0.4 ml/sec) is effective in encouraging fish to spawn in Chinese carp breeding, and water temperatures between 23–29°C are regarded as ideal.

According to the elements influencing carp reproduction in nature and hypophysation, water/floods play a part in lowering the electrolytic level of water, which results in gonadal hydration and successful spawning. While in natural spawning, a sudden drop in electrolytic level in the water caused by a flood or heavy monsoon rain caused hydration of the fish as a whole, which in turn caused the gonad and those fish that were ripe in condition to start spawning in nature. Gonadal hydration is achieved during induced breeding by additional amounts of exogenous pituitary extract.

It is common knowledge that fish gain water and hence weight as they transition from higher electrolytic level water, such as sea water to fresh water, and that the opposite is true when they transit from lower electrolytic level to higher level water. In rivers and reservoirs, the electrolytic level rises noticeably in the summer and then abruptly falls after monsoon rains. Furthermore, the ovary's overall water content, the presence of fluid between follicular cells, the loss of adhesion between cells and eggs, and the increase in egg diameter all point to the fact that the remarkable absorption of water into the ovary and the ovarian eggs precedes these morphological changes that accompany ovulation.

Investigation is necessary to determine if the conditions in ponds during the spawning season encourage such water absorption or not, especially since these carps mature in ponds but do not spawn there. The pond water may not be as heavily diluted by rain or floodwater as the river where they typically reproduce. It is significant to highlight in this context because while males sperm in ponds, females do not ovulate there. This might be the case because, in contrast to the chorion, which may mechanically oppose or support the admission of ions and water to the egg for its final maturation, sperms do not have a mechanical barrier to water transport.

3.3.1 HYPOPHYSATION

Currently, the method most frequently employed for fish reproduction is hypophysation. It is used in the commercial production of millions of fish in addition to reproduction experiments. Hypophysation is achieved by induced ovulation and spawning are essentially shortcuts to the normal process. In the wild, the pituitary gland of fish produces and stores its own gonadotropin hormone, which regulates and causes ovulation. When all the necessary conditions are met, the hormone that has been stored is released into the circulation. However, the hypophysation approach induces the final ovulation by injecting the breeder with gonadotropic hormone that has been taken from the donor fish's pituitary.

- **Fish pituitary glands and their substitute**

The big Indian carps, Chinese carps, and common carps' glands are frequently used in India for the hypophysation technique. Chinese carps were not given the same treatment as Indian big carps were given. When administered at a rate of 10–16 mg/kg body weight, the glands of freshwater catfishes including *Pangasius pangasius, Silonia siondia, Bagarius bagarius, Mystus seenghala*, and *Wallago attu* stimulate effective spawning. The pituitary glands of *Channa sp.*, *Tilapia mossambica*, and *Notopterus chitala*, when given to females at doses of 8 to 20 mg/kg, had no impact.

HATCHERY SYSTEMS

Pituitary gland extract from *Tachysurus* sp. given at 20–30 mg/kg body weight has been found to affect spawning in Indian major carps, in contrast to pituitary gland extract from *Arius* sp. *Mystus gulio*, and *Tachysurus* sp. at 12–20 mg/kg body weight failed to stimulate spawning. When administered to *L. rohita* at 460–2010 IU/kg body weight, organon did not trigger spawning. However, it has been suggested in a small number of instances that *L. rohita* could be bred by administering organon at a dose of 600 IU/kg body weight. For Silver carp, organon injections alone at 630–660 IU and organon 240 IU plus 12 mg carp pituitary per kg body weight both resulted in effective spawning. Using synahorin and the carp pituitary gland, Rohu was successfully bred.

Hatching:

To improve hatching and survival rates from the earthen hatchery pits and cement hatchery pits at spawn collection centres, the hatching methods for carp eggs have undergone numerous improvements. With or without temperature control, running water systems are replacing the use of twin hatching hapas. To determine the percentage of fertilization, the water-hardened eggs are weighed, their number is calculated, and a sample is analyzed. Under field conditions, the eggs are housed in double-walled hapas with an inner hapa composed of a thin, round-meshed mosquito net and an exterior hapa made of cotton or nylon with a close mesh. Since the inner hapa is smaller, there are gaps of 15 cm between the inner and outer hapa on all sides and at the bottom. A total of 50,000 to 100,000 eggs can be held for hatching in an outside hapa of the dimensions 2 m ×1 m ×1 m and a suitable inner hapa, depending on fertilization. The eggs are evenly distributed throughout the inner hatching hapa. When the water temperature is between 26 and 31 degrees Celsius, the ideal hatching time for Indian main carps is 16 to 18 hours, while it takes about two hours longer for silver and grass carp. The inner hapa is removed as the hatchlings progress from the inner to the outer hapa.

3.3.2 USE OF DIFFERENT SYNTHETIC AND NATURAL HORMONES, THEIR FORMULATION AND MECHANISM OF ACTION

Synthetic Hormones

- **Human Chorionic Gonadotropin (HCG):**

The placenta of a pregnant woman produces the glycoprotein hormone known as HCG. The hormone is detected in substantial amounts in the urine during the early stages of pregnancy. The hormone is known to induce maturation and the release of gametes when it is injected into mature fish. Together, the circulating pituitary hormones and the action of promoting sperm release and ovulation work synergistically. HCG is not as effective when administered alone as it is when combined with pituitary gland extract.

The substance is mixed with distilled water, ground (2 mg in 0.2 ml), and centrifuged. Injection is then performed using the supernatant.

Dose: The female is given the first injection, and then both the male and female receive the second injection at the same time. The initial dose is less. Along with the extract from the pituitary gland, the second dose is administered. Weight affects the dose. A completely ripe breeder and ideal weather conditions are necessary for the greatest outcomes.

- **Synahorin:**

This is another hormone preparation of chorionic gonadotropin and mammalian hypophysial extract.

- **Ovaprim :**Salmon gonadotropin RH and a dopamine antagonist are combined to form "Ovaprim," which is a stable solution. It is made in a certain ratio of glycerin to alcohol. Dr. Richard Peter of the University of Alberta in Canada was the one who initiated this ground-breaking effort. He discovered that the hypothalamic neuromodulator dopamine inhibits the production and release of gonadotropins from the pituitary in fish. Gonadotrophic releasing hormone (GnRH) neurons and dopamine neurons in the hypothalamus share synaptic connections. Thus, synaptic connections allow the inhibitory signal from dopamine neurons to reach the GnRH neurons. Since 1988, this hormone has been commercially available and is widely used. 0.3 to 0.5 mg/kg body weight for females and.01 to 0.3 mg/kg body weight for males are used to introduce them to the fish. In India, Uttar Pradesh, West Bengal, Bihar, Assam, Madhya Pradesh, Andhra Pradesh, Karnataka, Kerala, Odisha, and Maharashtra have seen positive outcomes from using it. It is thought to be superior to pituitary extract. When pituitary extract is used, 1.15 lakh eggs from "rohu" are produced; however, when ovaprim is used, that number rises to 1.41 lakh. Ovaprim can be stored at ambient temperature even in the tropics for more than a year.
- **Pimozide and LH RH-A :**

Pimozide is a dopamine antagonist with LHRH-ovulatory function. When used on Indian big carps, it works fairly well. When it comes to brackish water fish, the LHRH (Luteininsing hormone releasing Hormone) and its counterpart (LHRH-A) are particularly effective (Mugil and Lates). They are inexpensive, but the preparations are currently just temporary. Their use will be held up until preparations with a lengthy shelf life are made.

- **DOCA (II-Desoxycorticosterone – acetate):**

DOCA is another effective drug which has been tried on catfish, *Clarias* and *Heteropneustes*. They are a bit different in the sense that they not only cause ovulation but may also bring about maturation of eggs. Antiestrogen Tamoxifen: (I-CP-(Beta-dimethyl aminoethoxy) phenyl)-1, 2 – transdiphenyl but-1- ene) has given good results on coho salmon.

LH and human chorionic gonadotropin (HCG), two mammalian gonadotropic hormones, are powerful inducers of maturation and ovulation in fish. HCG or a combination of HCG and mammalian pituitary extract has been used to promote spawning in a number of species, although for some recalcitrant breeders, such as Indian and Chinese carps, it is necessary to administer fish pituitary homogenates or extracts. There are instances of even these species being successfully bred using HCG in specific situations. The Chinese carps will respond favourably to injections of HCG after having been successfully bred two or three times using fish pituitary extract.

However, it has been shown that HCG injections may cause a "drug resistance effect" associated with the development of antibodies against foreign proteins. However, it would seem that complete pituitary gland homogenates and extracts, as well as partially purified fish gonadotropins, are more effective than mammalian gonadotropins at causing fish to mature and ovulate, and can be utilized widely in commercial fish production.

3.4 BUNDH BREEDING

Bundh Breeding:

Bundh is a type of perennial and seasonal tank or impoundment where riverine conditions are simulated and where major carps are known to breed. After a heavy shower, the bundhs receive large quantity of rain water with washings from their catchment areas and provide large shallow areas that serve as spawning grounds for the fishes. The first bundh (dry bundh) was set up in Madhya Pradesh at Sonar Talliya in 1958. After this, persistent expansion of bundhs had taken place due to its simplicity of operation and high rate of success.

Types of Bundh:

Bundhs are generally of two types:

(A) Wet Bundhs and

(B) Dry Bundhs.

A. Wet Bundhs (Fig. 2):

1. Wet bundhs are perennial ponds situated in the slope of an undulating terrain. It provides a vast catchment area and facilitates quick filling even with a short spell of rain.

2. It has proper embankments with an inlet tolarvals the high catchment area and an outlet at the opposite lower end.

3. The deeper portion of the bundh during summer, retain water containing major carp breeders.

4. During monsoon, after a heavy shower, water from the catchment area rushes into the bundh.

5. The major portion of the bundh gets submerged and the excess water passes out through the outlet. The shallow areas of the bundh are called moans where the breeders actually spawn.

6. The outlet is protected by a bamboo fencing called chheva.

7. The outflow of the water through the chheva can be controlled by blocking the spaces in it with straw and mud.

8. Fine meshed nylon cloth is placed in the outlet to stop the hatchlings from escaping. Similar nylon cloth is placed i n the inlet to stop the entry of unwanted fishes.

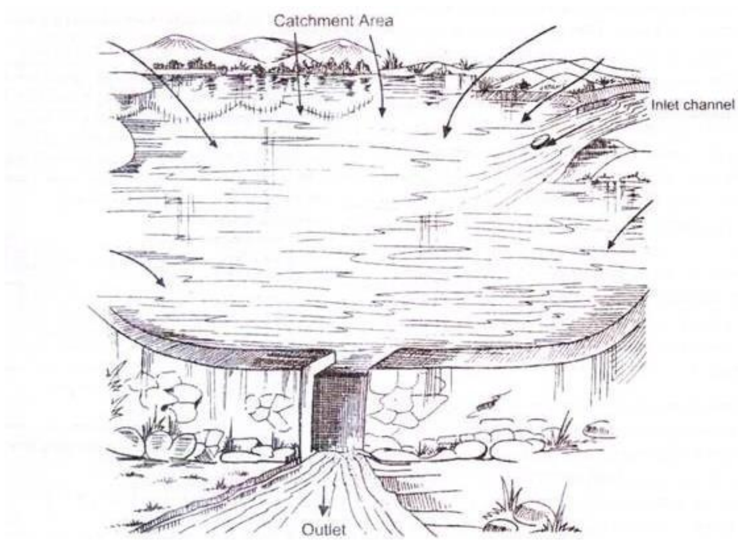

Fig. 1.2 Wet Bundh

B. Dry Bundhs:

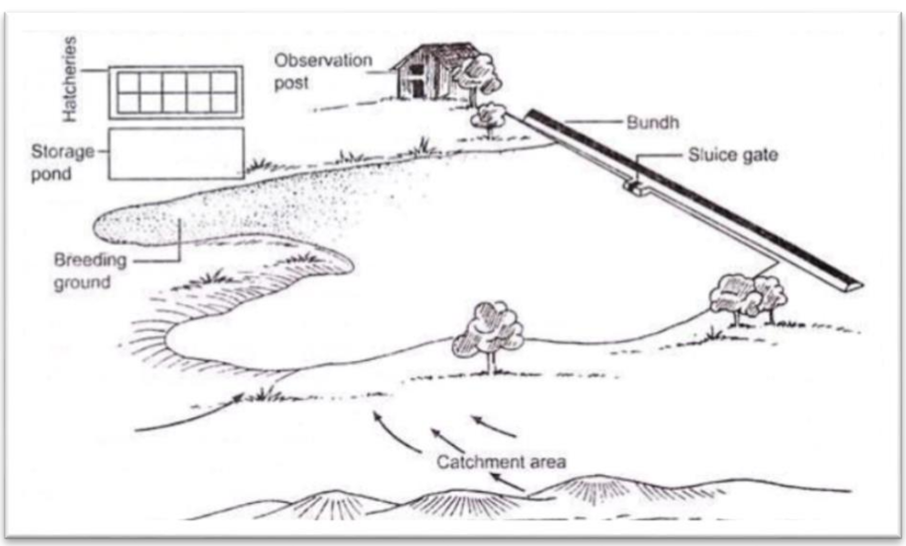

Fig. 1.3 Dry Bundh

1. Dry bundh is a seasonal one, which remains more or less dry during greater part of the year.
2. It is a shallow depression enclosed on three sides by an earthen embankment.
3. During the monsoon season it imports fresh rain-water from the catchment area.
4. In modern constructions, the embankment is a pucca stone masonry with a small sluice gate in the deepest portion of the bundh for complete drainage and one or two waste weirs for overflow of excess water.
5. A dry bundh unit (apart from the bundh) also consists of storage ponds for stocking breeders, an observation post with arrangement for storing necessary equipment and a set of cemented hatcheries (2.4 m x 1.2 m x 0.3 m) along with overhead tank and regular supply of water for handling large number of eggs at a time.
6. In dry bundhs, selected numbers of female and male (in the ratio 1:2) breeders of major carps are introduced. Though major carps breed at any spot in the bundh, it is advantageous to prepare **'spawning grounds'** at different levels which could get flooded at different water levels. It has been stated that the water depth where sex play/courtship behaviour and spawning take place, varies between 8 cm and 1.2 m. In both wet and dry bundhs, spawning usually occurs after a large quantity of rain water fills up the bundh during continuous heavy showers of the monsoon period. It has been seen that at first smaller sized mature fishes (rohu, mrigal) get stimulated to breed and in order to spawn, migrate either to the shallow areas of the bundh or to those adjoining it. Bigger fishes, like catla, spawn next in the same area. Spawning occurs on hard or sandy soil and on rocky embankment. In one year (spawning season of 30-40 days) as much as five crops could be obtained in a dry bundh, whereas only one or two crops possible in wet bundh.

Prerequisites of Bundh Breeding:

For successful bundh breeding the prerequisites are:

(1) Heavy showers during the monsoon season.

(2) Flow of water from up-land to bundhs and then through outlet, makes some sort of water current.

(3) Inlet and outlet of the bundhs are to be kept closed after the water level reaches brim point.

(4) Sudden fall of temperature.

(5) No definite depth for breeding, as breeding can take place even in paddy fields having a depth of 31-35 cm.

(6) Smaller fishes first get inducement to breed and the bigger ones are attracted later.

Drawbacks of Bundh Breeding:

(1) Indiscriminate killing of brood fishes particularly milters during dry months, result in improper sex ratio.

(2) It is not possible to hygienically maintain mud hatching pits.

(3) Large scale mortality of spawn takes place as they are not transported before the 3rd day.

(4) Other limiting factors for successful spawning are:

(a) Presence of excessive numbers of copepods (Cyclops, Diaptomus, etc.) that accumulate in the water of the bundh.

(b) Large scale deposition of alluvium in the breeding grounds.

3.5 HAPA BREEDING

The double-walled hatching hapa

It is one of the traditional and common devices used to hatch carp eggs. A hatching hapa consists of two separate pieces of hapas, the inner and the outer hapa. The inner hapa is smaller and fitted inside the outer hapa. The fertilized are released in the inner hapa. Upon hatching, the newly hatched hatchlings wriggle out through the round meshes of the inner wall and collect themselves in the outer hapa. Remove the inner hapa containing egg shells and dead eggs once the hatching is completed. The hatchlings remain in the outer hapa till the third day when they are ready for stocking in nursery pond. The outer hapa is made of markin cloth or any fine-meshed durable cloth, stitched in the shape of a rectangular trough, without any cover and provided with ropes at its 4 upper and bottom corners. The size of the outer hapa usually is 2 x 1 x 1m. The inner hapa is made of round-meshed mosquito net cloth with the dimension of 1.75 x 0.75 x 0.5 m; rectangular in shape and provided with ropes at its 4 upper and bottom corners. The hapas are tied to bamboo poles and fixed in a pond or river margin or cement cistern or channel with clear, oxygen-rich circulated water, not having algal blooms. About 25-30 cm of the outer hapa should be kept above the surface of water to prevent entry of weed fishes, insects, etc. The haching of eggs takes place 14-20 hours after fertilization at a temperature of 26-31^0 C. About 75,000-100,000 eggs can be hatched in a standard hapa if fertilization rate is over 75%.

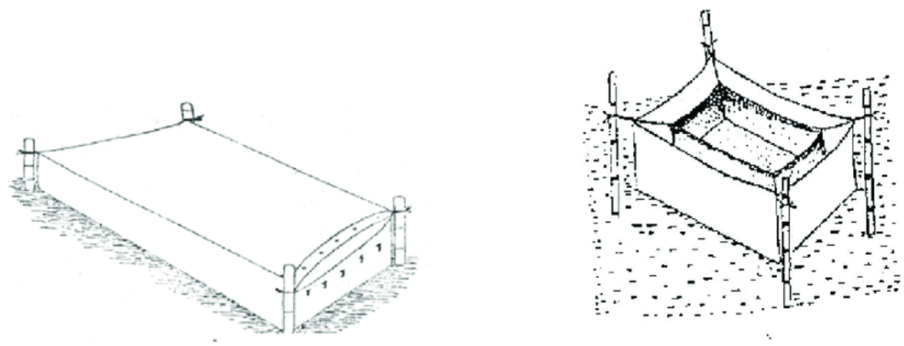

Fig. 1.4 Double-walled Hatching Hapa

Merits :

1. Useful for hatching relatively small number of eggs.
2. Separates egg shells from hatchlings very effectively.

Demerits :

1. Water quality cannot be controlled.
2. Fish from outside can damage eggs and spawn through the hapa wall by sucking.
3. Recurring expenditure is high.

3.6 HATCHERY MANAGEMENT

A fish hatchery is a facility used for the artificial breeding, hatching, and raising of young animals, particularly fish and shellfish. In order to serve the aquaculture sector, hatcheries create larval and young fish, shellfish, and crustaceans that are then transported to on-growing systems, like fish farms, to mature into harvestable sizes. Fin fish hatcheries create larval and young fish that are then moved to aquaculture facilities to be "**on-grown**" until they are ready for harvest. Hatchery production confers three main benefits to the industry.

1. Out of season production,
2. Genetic improvement and
3. Reduced dependence on wild-caught juveniles.

There is, however, little to no assurance that an adequate number can be caught and stored in the time frame required for ideal production circumstances. As a result, the fish farmer is forced to find alternative sources of stock. Fish that can only spawn at first must be stimulated to develop in the proper conditions in order to hatch and grow into fry. A few important elements that must be taken into consideration include the water quality parameters, feed for optimal nutritional composition and particle size, and disease resistance. For optimal fish production, a thorough understanding of each of these components is required.

The farmer can choose for desirable traits through artificial propagation, such as quick growth and disease resistance. The most important element of contemporary fish farming is a hatchery. Hatcheries are enclosures, either natural or man-made, where eggs are bred and hatched. Some authors define a "**hatchery**" in its broadest meaning as a facility that conducts everything from fish spawning to the production of fingerling fish for stocking in grow-out ponds, fish fattening, and brood stock rearing. However, a hatchery is a facility that is indoors and used for fish spawning, egg incubation, hatching, and nurturing the hatchlings to spawn stage.

Need for Hatchery

- Lack of understanding leads to the raising of mixed varieties, which has a lower survival rate.
- The seed that was collected is a mixture of various kinds. For their seed needs, fish growers are limited to natural water bodies.
- The amount of seed harvested from the riverine source is really small.
- Earlier, the only source of fish seed was natural catch during the rainy season from rivers and huge reservoirs, which was accomplished by a number of issues.
- In today's scenario it is attempted to use rearing ponds for raising fry to fingerlings and nursery ponds for rearing larvae to fry stage.
- Modern aquaculture requires brood fish ponds to house adult fish used as pituitary gland spawning donors as well as discarded male and female fishes.

Role of Hatchery

- The importance of the hatchery is evident in the fact that it has increased fish seed production and developed an environment that makes it possible to generate seeds of any grade or quantity.
- State and federal hatcheries are anticipated to play a bigger role in biodiversity preservation through preserving rare, endangered, and threatened genotypes.

- **Essential Components of a Hatchery**

Traditional Hatchery Earthen Hatching Pits:

Carp breeders used earthen hatching pits as the oldest method of hatching carp eggs. There is a 3x2x1 diameter pit that was specifically built. The interior walls of the rows of pits are coated with mud, or red soil. The hatching pits are filled with the fertilized eggs that have been gathered from bund tank types. Each pit may hold between 36,000 and 400,000 eggs, and each egg hatches in around 24 hours. To promote optimum aeration and prevent waste from building up, a steady flow of water is maintained. The accessible spawn is collected with a piece of cloth and moved to nurseries after around 3 days, when the yolksac is absorbed.

a) **Earthen Pot Hatchery:**

This was one of the earliest strategies used to increase hatching rates. The fertilized eggs are removed from the bundh and maintained in a variety of locally constructed earthen pots that have been organized in a specific way. This creates a current of water that is moving and is kept cold by the surface evaporation of the porous earthen pots where the crab eggs were laid. This approach uses baked clay and jars to regulate temperature and pH changes. Even though they are inexpensive, vessels have the drawback of being opaque and are easily changed.

b) **Double Cloth Hatching Hapa:**

In 1976, this technique was uncovered. The outer hapa and the inner hapa are two rectangular shapes. The inner hapa measures 1.75m*0.75m*0.5m, while the outside hapa measures 2m*1m*1m. The inside hapa is constructed of round mesh mosquito netting cloth, while the outer hapa is made of tightly woven cotton fabric. The inner hapa's water is kept at a depth of about 30 cm. Normal egg hatching yields between 75,000 and 100,000 eggs. The inner hatching hapa is removed together with the egg shells and the bad eggs once the hatching has passed through the mesh into the outside hapa. Until the yolk sac is digested, the hatchlings in the outer hapa are retained for a period of 48 hours (2 to 3 days). The hapa is installed on frames that are constructed by combining polyethylene or aluminum pipes, making this method the better one. Floats are included to make floating easier.

I. Plastic Bucket Hatchery:

- A plastic hatchery consists of two components.
- One is an outer plastic bucket with an aluminum bin egg vessel that has perforations in it, and the other is a spawnery made of galvanized iron sheet.
- The plastic bucket is 47 cm in height, 30 cm in diameter, and has three top outlets.
- 45 litres of water is held.

III. Modern Hatcheries Glass Jar Hatchery:

- It is the first ever hatchery in India where it is possible to see the developing eggs through transparent windows.
- It has a spawnery, incubation unit, and breeding tank.
- Water is obtained through a bore well or freshwater pond.
- 5500 litre capacity overhead tanks are situated next to the hatchery.
- This device comprises of a battery of glass jars with conical bottoms and cylindrical shapes that have 6.35 litre capacities.
- One jar can produce the hatching of about 50,000 eggs.

IV. Vertical Hatcheries Modern Carp Hatchery CIFE D-80 Model:

- The CIFE D-80 model modern carp hatchery was created in the year 1980.
- The former director of the Central Institute of Fisheries Education, Dr. S.K. Dwivedi, is honoured in the name of this contemporary carp hatchery.
- In this model, attempts have been made to regulate environmental factors such as temperature, oxygen content, silt content, water flow, and egg-moving area.
- The hatchery is made up of an overhead tank for water storage, a cooling tower, a portion for the eggs, a compressor for aeration, a vertical egg container, PVC pipes, valves, showers, channels, hatchery stands, and hapas.
- The incubation tank and the egg collection tank are the two separate components of this sort of hatchery.
- There are four vertical jar complexes with six funnels each.
- The total capacity of the hatchery complete is 50 lakh eggs at a time.

Chinese Hatchery for Fishes:

Chinese technologies for carp breeding and egg hatching rely on a constant flow of water driven by gravity. Compared to any other design for the same output capacity, a Chinese hatchery is less expensive to build and run. The Chinese hatchery system is currently regarded as being extremely suitable for the production of high-quality fish seed in India. This system is intended for the incubation and breeding of fish. One hatching operation lasts for four days. It may be done again after four days.

General Requirements of Fish Hatcheries

- A crucial component of contemporary fish culture is the fish hatchery, which produces young fish year after year and distributes them to fish producers.
- It is clear that smaller fish farms lack the resources and expertise necessary to meet their own needs for fish seed, particularly for species of fish that are difficult to reproduce or do not ordinarily reproduce in limited waters.
- There are two different kinds of hatcheries: one that can manage only one kind of fish (special hatchery) and another that can handle a variety of fish species.
- In order to fully utilize the pond's food supplies and provide the best potential production, multi-species hatcheries are currently being established in line with the modern trend of mixed culture, or composite culture, of diverse species with distinct eating patterns.
- The number and size of the brood stock, the variety of species to be propagated, the timing of their spawning, the capacity of the larval tanks, incubators, and larva-rearing equipment, the quantity and quality of the water, and the experience of the operators are just a few of the variables that affect a hatchery's production capacity.
- The other crucial elements are the size of the fingerling and fry nursing tanks (or ponds) and the rate at which the young fish are dispersed.
- It is simple to set up sizable central hatcheries and distribution hubs in nations where the transportation of young fish does not present a problem (due to the presence of a good network of roads and dependable low-cost transport infrastructure).
- The research efforts of thes centers can advance and enhance the current technologies.
- Even though large central hatcheries have many benefits, it is advisable to establish a number of medium-sized hatcheries in tropical and subtropical areas, with a capacity to produce about 7–10 million 20–30 day-old fingerlings. This is because long distance transportation is limited by the region's high temperatures.
- If the various species' mating seasons do not coincide, serial propagation of the different species over a longer period of time can significantly boost a hatchery's production capacity with only minimal additional costs.

The requirements and general lay-out of a medium-sized warm-water fish hatchery are as discussed here:

The prerequisites of a fish hatchery are:

• Qualitatively and quantitatively adequate water,

• Adequate land for the ponds, hatchery tanks, buildings, etc.,

• Electricity, if possible,

• Transportation facilities, and

• Manpower.

Description of the Facilities

A hatchery complex consists of four units:

(1) brood fish ponds,

(2) the hatchery with ante ponds and larval basins (tanks),

(3) fry nursing units and

(4) the fingerling rearing cum-production ponds.

I. Brood Fish Ponds:

- Care must be used when handling the brood fish or breeders, which give the sexual products needed to begin new fish generations.
- One thousand square metres, or 0.1 hectares, of pond area can support 20–50 brood fish, which weigh 150–250 kg collectively.
- When propagation techniques are used correctly, 2-3 million and 20–30 day-old fish can be produced from 50–150 brood fish of one species (with 40% females and 60% males).
- This would imply that the 50–75 normal size brood fish (3-6 kg) needed for one species may be maintained in two brood fish ponds, each with a 2000 m^2 surface area.
- Eight to ten of these ponds with a combined surface size of 1.5 to 2.0 ha would be sufficient if the hatchery is working with five kinds of fish.
- Fish broods with various feeding preferences can be stocked in the same pond.
- It is not suggested to reduce the number of ponds and raise the size of individual ponds beyond 2000 m^2, as it is challenging to net the brood fish in large ponds when it becomes required to separate them by sex.
- Ponds for brood fish need to be deep enough (about 1.5 m), and they also need to have a plentiful supply of water. For a pond with a surface size of 1 ha, 100–200 m^3 of water would be needed each day to replace the water that was evaporated during the dry season.

- Ponds for brood fish should be placed in a location where they may be protected from potential theft of the fish and ideally close to the hatchery.
- The need for a separate watch and larval as well as transportation issues may result from a more remote site.
- Given the required space, it is advised to build the brood fish ponds in rectangular shapes.

VI. Hatchery Facilities:

- The hatchery is where most propagation activity is completed.
- Work in the hatchery starts with bringing in ripe breeders for induced spawning and lasts until feeding fry are distributed for stocking elsewhere.
- In the propagation season, staff and commercial hatcheries typically work nonstop.
- Two small ponds, each 200-450 m^2 in size and 1.0-1.5 m deep, are needed to retain the chosen ripe breeders before their hypophysation.
- In these two ponds, all the fish (about 25–50) needed for breeding over the course of a week can be kept (with sexes separated).
- These ponds are sometimes known as storage ponds or ante ponds.
- Brick or concrete tanks or basins with a constant supply of filtered, clean, and well-oxygenated water are required for housing the injected brood fish. Larval basins or tanks are the names for them.
- These basins' bottoms should gradually slope in the direction of the drain so that they can be entirely drained whenever necessary. The turn-down pipe has a 5 cm diameter and controls the water level.
- The turn-down pipe is secured in place with a chain and peg to prevent it from moving and allowing the water in the larval tank to drain.
- When stripping the injected fish, having a 20–25 cm deep and 50 cm wide ditch along the longitudinal axis of the basin is quite helpful since it makes it simple to remove the fish without causing too much disruption.
- In larval tanks with level bottoms, induced spawning can be successfully performed.
- For 4-6 breeders weighing 3-6 kg each, the most practical sizes for these basins are 2.5 x 1.5 x 1.0 m and 4 x 2 x 1 m.

- Extra large breeders, weighing between 12 and 20 kg per piece, are best housed in bigger larval tanks.
- It is not a good idea to have too many fish in one tank, especially if they are going for induced spawning. However, each fish species must be tested in order to identify the ideal stocking density. It is critical to provide the breeders enough air.
- One normal-sized brood fish is thought to require 4 litres of water each minute (3–6 kg).
- Many river spawners, including Silver carp, Grass carp, Catla, Rohu, and Mrigal, can grow disturbed and anxious.
- In order to prevent them from jumping out of the water during treatment, it is best to keep these fish in shallow water (25–30 cm deep).
- In order to stop the injected breeders from jumping out of the basin, it is also advisable to fix a net cover to the top of the basin.
- For the injected brood fish to have a place to hide, a floating shade on the surface of the basin must be of an appropriate size and dark colour.
- The water level in the larval tanks can be increased to 60–70 cm for fish that do not grow anxious during induced breeding.
- If a hapa is installed inside the tank, handling brood fish in the larval tank is made significantly simpler.
- An iron rod frame is fastened around the bottom of the hapa in order to stretch it out and prevent it from disturbing the brooders.
- It is practical to have the hapa's length and width should be 5–10 cm less than the larval basin's.

VII. Nursery Facilities:

The hardest and most important part of fish farming is raising fry successfully on simply feeding until they are about 25 mm in size.

- The primary bottleneck in most hatcheries is a shortage of room for nursing the fry up until they reach the fingerling stage at 3–4 weeks of age.
- Fry nursing is undoubtedly a delicate task needing a high level of expertise.
- By giving them larvae or only feeding fry, fish farmers shouldn't be left with the full responsibility of raising fry.

- Of course, some growers can be taught how to get their ponds ready for the delicate fry.
- However, it is always preferable for professionals to care for nursing infants.
- As a result, nursery ponds should be a crucial component of the hatchery complex.
- Since the different parameters affecting fry survival are now well understood, raising fry is lot easier than it used to be.
- A modern hatchery complex needs specialized nursery tanks and small clay ponds to achieve the greatest results, despite the fact that various varieties of common nursery ponds have been reported.

Special Nursery Tanks:

- A unique nursery tank has dimensions of 20–40 m, 5–6 m, and a surface area of 100–240 m^2.
- A tank of this type may typically hold 2,000–4,000 simply feeding fry.
- Usually, concrete or bricks are used to construct these tanks.
- One successfully reproduced female fish weighing 4-6 kg can lay 0.5–0.7 kilograms of dry eggs, according to previous research.
- This could produce the necessary quantity of fry for filling a dedicated nursery tank.
- It would take 30–40 nursery tanks to raise the offspring for up to 21–28 days if 10 of these female fish were to be reproduced in a single week.

Earthern Nursery Ponds:

- A decent nursery pond should be rectangular in shape with a width of approximately 10–12 m, and it should not be more than 500–1,000 m^2.
- The nursery pond's bottom is shaped so that it runs flat for approximately 2.0–2.5 m from the longitudinal walls before gradually sloping from either side to ward the centre, where it forms a 2-3 m wide ditch that is 0.5 m deeper than the flat part of the bottom.
- The fry can find sanctuary in this ditch.
- The walls dividing the nursery ponds will occupy a substantial portion of the area if they are built of clay materials.
- If the nursery ponds' partitioning walls are constructed of brick, concrete pre-fabricated slabs, or concrete, the wastage of land will not amount to more than 5–7%. If bricks are used, they must be set in good mortar up to a height of 120–130 cm, with half of the bricks positioned above and the other half below the surrounding ground.

- The nursery ponds' bordering walls should be built stronger than the longitudinal walls that divide them.
- Frogs, toads, and snakes are kept out by the brick walls.
- The nursery ponds' drainage system is quite straight forward, and a fish capturing box can be added to it in a brick harvesting hole (for collecting the fry when the pond is drained).

Relative merits of Special nursery tanks and Earthern nursery ponds

The following benefits pertain to the unique nursery tank:

1. The shallow tank, where the fry like to live and eat, is around 70% of the tank.
2. Extra vegetation (grass and other plants) would not be present during the nursing time because the shallow region is partly covered with hard bottom (about 50–60%). It can also be readily dried, cleaned, and disinfected whenever necessary. The fry can also be easily inspected.
3. By netting the central ditch, it is simple to thin out the fry if necessary.
4. Due to its small size, it is easier to provide intensive nursing, and its ability to treat parasites internally means that control and preventative measures may be taken.
5. Maybe the high initial cost of construction is the only drawback.

The main significant drawbacks of earthen nursery ponds, particularly if they are square rather than rectangular, are listed below.

a. The shallow area is smaller, only comprising 40–60%.
b. Too much grass and other plants could prevent the growth of food producing creatures.
c. The prevention of silting in the deeper areas makes cleaning and disinfection activities more challenging.
d. The thick foliage makes net operations difficult.

IV. Fingerling rearing-cum-production Units:

The objectives of the fingerling rearing-cum-production unit are basically for:

- Raising potential brood fish, rearing the donor fish for the pituitary gland (often common carp), rearing large-sized fingerlings and young fish for delivery to fish farmers, and, if necessary, producing marketable fish.
- Polyculture is typically practiced in the production ponds and fingerling raising ponds.

- The fingerling rearing-cum-production facility operates year-round, but the propagation activity of the hatchery and nursery typically lasts no longer than 5 to 6 months.
- If the hatchery also raises marketable fish in addition to producing its own pituitary glands from donor fish, the expense of producing fingerlings can be kept to a minimum.
- The fingerling rearing-cum-producing unit ponds are often built as production ponds, with sizes ranging from 0.5 to 1.0 hectares and an overall area of 2-3 ha.
- In general, 10-15 ha of suitable terrain are required to build a medium-sized hatchery-cum-seed distribution facility.

Manpower Requirements:

Work in a hatchery is delicate and demands careful attention, punctuality, accuracy, and ability. The safety of the brood fish, eggs, and different stages of seed must be regularly maintained in the hatchery. Throughout the propagation season, the hatchery's personnel must put in 8 to 10 hours every day. Fish eggs must be transported and sorted by three to four people.

3.6 FLOW THROUGH HATCHERY FOR MAHSEER AND TROUT

The most valuable sport fish found in all Himalayan waters is the golden mahseer. Due to illicit fishing practices, habitat degradation, and the introduction of foreign species, this species is currently regarded as one that is endangered. As a result, a drop in its captures is observed in practically all natural resources. Artificial reproduction is a crucial component of this species' rehabilitation. It has been built and produced a specialized hatchery that can control the volume and flow of water to incubate and hatch eggs.

The designed hatchery system included nursery tanks, raising tanks with continuous water flow, and a series of troughs under which trays of a particular size and mesh could be found. For a constant supply of water to the hatchery, a 1000 L overhead tank is made at a height of 5 m. The trays containing fertilized eggs are kept in a rectangular trough that measures 220 cm × 50 cm x 40 cm. 50 cm x 30 cm x 10 cm trays are used to incubate 5000–6000 eggs each tray. For the purpose of raising fry, tanks of 200x60x30cm are made of fibre glass or galvanized iron sheets. For 2000 eggs to be incubated at a water temperature of 20–28 °C, 1 LPM of water flow is necessary. For the rearing of 2000 fry at a water temperature of 20–28°C, a water flow of 3–4

LPM is necessary. In coldwater environments, the structure is suitable for the generation of spawn and fingerlings. Mahseer fish seed can be grown in controlled conditions and is of high quality. For the bulk seed production of this fish species, a flow-through Mahseer hatchery has been created. For breeding, egg incubation, and larval rearing with continuous water flow, the system is straight forward and farmer-friendly. This species' artificial mass seed production might be useful for both increasing aquaculture output and rehabilitating this species through ranching in upland water bodies.

3.6.2 PLOIDY INDUCTION

Induction of triploidy

Several physical shocks and chemical treatments are used to directly induce triploidy during the second meiotic division shortly after fish eggs have been fertilized. An alternate way to create hybrid triploid fish is by marrying conventional diploid and tetraploid fish. Many researchers have successfully employed pressure stocks as well as temperature (cold and heat) as efficient factors to induce triploidy in a variety of fish. Although there was less inter-individual variance in response to heat shock than was shown for cold, pressure was generally more effective in maximizing triploid yields. There have been reports of a similar circumstance where pressure shock was chosen over temperature shock for triploidization of Atlantic salmon eggs because to the great variety in how the eggs from various females responded to the identical heat shock treatment.

3.6.3 PRODUCTION OF MONOSEX POPULATION

As some fish have superior sex specific growth rates, where one sex of fish grows quicker than the other, sex control is desirable for the development of aquaculture. The crucial instance is tilapia, where males grow more quickly than females. The females also appear to grow more quickly than the males in Himalayan golden Mahseer. Sex control is essential for population control, especially in fish species that reproduce a lot and negatively impact production because of stunting brought on by overcrowding. Aquaculturists may also be drawn to sex-specific attractive colorations and body shapes if they plan to use sex manipulation technologies in the aquarium commerce. Many foreign fish species are also viable candidates for aquaculture, but they have certain negative ecological effects, such as invasiveness. The use of monosex/sterile fish production methods will thereby ensure ecological protection by preventing introduced fish species from reproducing in the wild, even if they escape from farm facilities.

Certain species of fish are better suited for monosex and sterile culture than for indiscriminate culture of both sexes and fertile forms. Such fish seed types are cultivated in the typical way. Getting pure monosex or sterile seedlings is the main challenge. Certain steroids, such as methyl testosterone and estradial-17B in large dosages, inhibit spermatogenesis in *Salmo gairdneri* trout. However, it is not recommended for commercial production to employ exogenous (hormone) steroids to limit gametogenesis because the resulting fish might not be safe for human consumption. The chemosterilants lessen the synthesis of gonadotropin , reduce androgen production without stopping gonad maturation. They will also need to be given to the young for inclusion in their diet, making their usefulness for business purposes questionable.

(i) Radiation treatment to induce in embryonic or fry stage.

(ii) Many fish hybridize successfully to produce sterile offspring.

(iii) Modifying the chromosomes to produce polyploidy

They lack meiosis normally, hence they are sterile. Only auto diploids and closely related types are viable.

Importance:

(1) Fishes' growth slows down as they reach sexual maturity. Because the energy resources used for reproduction are gradually redirected for growth, sterile fish exhibit improved and faster growth as well as greater vigour than they would normally. Fish flesh is produced more efficiently from food.

(2) Sexually mature fish, such as salmon, lose flavour because their meat becomes watery and unhealthy because it is more prone to microbial (fungal) illness.

Production of monosex

Through mechanical sexing and individual stock sorting in fish that exhibit sexual dimorphism, such as tilapia. The approach is not commercially viable since it is very time-consuming and labor-intensive. By sex reversal, in which the gonads differentiate in a different way from how they normally do. biological makeup.

Fish have the ability to reverse their phenotype both from male to female genetically (feminization) and from female to male phenotypically (masculinization). An important method of sex reversal is the introduction of exogenous sex hormones that over ride the endogenous hormones to the early developing masculinization or feminization. Such hormones are administered through breeding of hormone incorporated diet to the early developing masculinization or feminization. Production of sex reversal male is simple. Males who have had hormone treatment are unfit for human consumption, but because F progeny are genetically xx safe, they only create x-bearing sperm after fertilization, which only produces female offspring when fertilized with x-ovum (undesirable). The conversion of such fertilized eggs into triploid females, which are desired since they are sterile, is attempted in trout farming. Hormonal sex-reversal therapy is a reliable treatment as long as the right doses are administered at the right time (early life) and for the requisite amount of time.

3.6.4 HYBRIDIZATION

Hybridization is a conventional technique commonly used in fish breeding. Hybrids are defined as the products of crossing distinct species. A considerable number of hybrids have been produced between different fish species. The occurrence of natural hybridization in fishes is known since long. It is more common in freshwater fishes than in marine. By crossing fish with various phenotypes and genotypes, hybridization aims to bring out or combine valuable features.

• The F1 hybrids frequently display heterosis and will have novel genotypes and traits.

• Fish breeding as well as commercial fish production can both use hybrids with clear heterosis in the first generation.

• Hybridization can be used in one of several ways to improve productivity. This can be incorporated into a selection programme as a final cross to produce animals for grow-out. In this case, the fishes are selected in two lines that have been shown to produce good hybrids; after the selection programmes, the selected lines are hybridized.

• Interspecific hybridization has been successful in improving production traits (such as growth rate, survival, disease resistance) as well as manipulating sex ratios in many fish and shellfish genera and/or families (carps, catfishes, cichlids, moronids, salmonids, sparids, sunfishes, oysters, crayfish).

• Sometimes an interspecific hybrid shows a nice blend of advantageous features from both parent species even when it does not show heterosis for any trait.

• The majority of the hybrids tested showed no promise for aquaculture.

• A few desirable hybrids are, nevertheless, used economically.

3.6.5 CRYO-PRESERVATION OF GAMETES AND EMBRYO

The cryopreservation is a storage technique with practically no time limits. Preservation of fish gametes has been tried with this technique. The cryopreservation of sperms is a well-established procedure in animal husbandry. Now, cryopreserved sperms are used successfully in insemination of cattle, horse, pig, sheep and poultry breeding. It is interesting to note that great efforts have been put to transfer this technology to the preservation of sperms, ova and embryos of fish.

This technique will help the fish breeders in the following ways:

(1) The problem of non-coincidence maturation of male and female can overcome, if sperms or ova are held in storage.

(2) The programme of selective breeding can be undertaken which will improve the indigenous stock and will help the third world to breed their indigenous species and to produce special strains of superior stalk.

(3) The technique of cryopreservation of gametes will play an important role in conservation of indigenous germplasm as many of indigenous Indian fish cannot compete with exotic fishes. By this technique the gametes from threatened species are banked as a hedge against dwindling genetic variability caused by environmental disturbances.

(4) It can help in production of mono-sex culture.

(5) If gametes can be successfully preserved we can develop fish throughout the year as per our requirement and can help to establish gene bank to preserve genetic originality of population and keep them available for re-introduction when general conditions for survival have improved.

The sperms, eggs and embryos can be cryopreserved, but the preservation of egg and embryos are difficult because of unavailability of cryoprotectant to be absorbed sufficiently in these cells because of their large size in comparison to spermatozoa.

The cryopreservation of spermatozoa in fishes is successful in man; species These species are *Oncorhynchus, Salmo, Salvilinus fontinalis, Hucho hucho, Thymallus thymallus, Esox lucius* and *Cyprinus carpio, Serothodon mossambicus*; *Labeo rohita, Catla catla* and *Cirrhinus mrigala*.

The following steps are to be followed in preserving spermatozoa:

(1) Collection of milt (semen).

(2) Preparation of extender solution.

(3) Selection of cryoprotectant.

(4) Freezing.

(5) Success at fertilization.

Collection of Milt:

The first step is to collect sperms. Normally the sperms are collected from healthy fishes by stripping method. The catheter may be used, which is better alternative to stripping. The male brooders with best characteristic traits were selected and washed with Ringers solution and genital papillae region is made dried.

The brooder may be anaesthetized or not anaesthetized. The anaesthesia generally used is 0.3 ml/l of phenoxyethanol. The milt is collected in syringes or haemolysis tubes and later preserved in glass ampules (sealed or unsealed), plastic straws and often in plastic bags. The colour, volume, density, pH and motility of sperms are to be noticed.

The sample should be free from urinary and faecal matter. A smear of the sample is to be examined under microscope to notice abnormalities in sperms. If sample is OK, then put for further processing, otherwise fresh sample from new brooders may be taken.

During the period of collection and preservation of spermatozoa, the syringe/ampules/ straw may be kept in pond water to maintain constant temperature. The preparation and selection of extender, a solution in which milt is collected, is most critical for cryopreservation. The extender prevents depletion of sperm energy and maintain sperm in quiscent condition but alive.

There are two basic extenders. They are called Mounibs medium (M) and Menezo medium (Me). In these two media bovine serun albumin (BSA) and tellurite egg yolk are added. For Indian fishes, several extenders were tried by modifying in their following constituents.

The common constituents are sodium chloride, KCI, $CaCl_2$, $NaHCO_3$, Na_2HPO_4, and $MgSO_4$. In addition to these, nutrients and glycine are also added to improve cryopreservation. Antibiotics such as gentomycin or streptomycin are also added to the extender solution if needed.

Cryoprotectant:

The cryoprotectant's main function is to penetrate in the cell and may help spermatozoa to tolerate freezing temperature. The most important and used widely is DSMO (Dimethyl sulfoxide) and glycerol. Cryoprotectant and extender solution in a fixed ratio, generally one part of cryoprotectant and nine parts of extender solution is known as diluent. In this diluent the sperms are collected for further processing for freezing.

The diluent (cryoprotectant + extender + sperms) are taken in polyvinyl straws and both ends of straws are sealed and now they are ready for freezing or chilling. The milt can be chilled; the temperature is maintained between 0-5oC. While in freezing, CO2 and liquid nitrogen are used Chilled storage of teleost milt (0-50^{o}C) has been studied extensively in Salmonids.

In freezing procedure many problems such as cold shock, formation of intracellular ice and osmotic shock should be controlled. Cryopreservation generally means storage of cells or tissue at -196^{o}C, the temperature of liquid nitrogen.

Cell injury should be controlled. Three types of cell injury generally occur. The first is cold shock, which is caused by cooling above freezing temperatures. This is more important for ova, not very much important for sperms.

This occurs up to 0°C. When the temperature goes from 0°C and-80°C the osmotic shock and formation of intracellular ice in ova and sperm takes place. For successful cryopreservation these things are controlled.

In short, the straws containing diluent, are transferred into cannisters. The cannisters holding straws after allowing varying equilibration period are dipped first into liquid nitrogen vapours and then into liquid nitrogen at the temperature -196°C.

In a number of fresh water species freezing has been carried out by pelleting suspend sperms into dry ice. The transition from 0°C to -70°C lasts approximately 2 minutes resulting in a rate of 35oC/min. Since the rate decreases above – 60°C. The best results are obtained in liquid nitrogen.

Thawing:

The thawing is reverse event of freezing. Thawing is done in water bath at temperatures ranging 10°C to 60°C. The success of whole procedure depends upon the motility of spermatozoa and capability of fertilizing ova. The eggs of *Salmo gairdeneri*, *Onchorhynchus kisutch* and *O.keta* were fixed by removing through the process of stripping and sealed in plastic bags together with coelomic fluid and kept under oxygen at 1°C. The eggs are then allowed to spread to form a layer one or two eggs deep. The eggs then mixed with extender solution and cryoprotectant almost in similar way as described earlier for sperms. Unfrozen (chilled) storage of ova has been moderately successful in salmonids, with storage times in order of a few weeks obtained through refrigeration of oxygenated eggs in coelomic fluid.

3.6.6 TRANSGENIC FISH

The ground-breaking technology of transgenesis allows for the creation of genetically altered organisms. It's interesting to note that fish are easier to manipulate genetically than their mammalian counterparts since they breed more quickly, produce more eggs per female (greater fecundity), and have autonomous embryonic biology. The main objectives of genetically modifying fish species used in aquaculture are to:

a) Boost the growth and effectiveness of food conservation,

b) Develop a higher tolerance for environmental factors like temperature and salinity,

b) Release ornamental fish in new colour varieties, and

c) Create pathogen-resistant strains.

The various methods for producing transgenic fish have been used, and each has benefits and drawbacks that call for further development. While selective breeding technology has shown its influence on fish output, it takes a long time; in contrast, genetic improvement through direct gene manipulation or a transgenic technique might be completed in a matter of years. Therefore, to supplement drastically increased future food requirements brought on by the development in the human population, both the conventional selective breeding and transgenic techniques are necessary. With the enormous variety of fishes, transgenesis could be helpful for developing a new colour form of attractive species as well as to modify sexual phenotype or reproductive performance. A foreign DNA sequence has been incorporated into the chromosomal DNA of the transgenic fish.

ISSUES OR CONCERNS RELATED TO TRANSGENIC FISH

Due to the higher rate of differentiation compared to laboratory or farmed animals, the failure of ubiquitous expression, which resulted in mosaicism, was the main issue in the development of transgenic fish. This resulted from the transgene's delayed integration at the one-cell stage, random transgene integration into host DNA, host enzyme destruction of foreign DNA, end-to-end ligation of the injected DNA before to integration, and the inability of foreign DNA to pass down. It was possible for the transgenes to integrate at one or more chromosomal sites. Several transgenic food fish have been created, however they have not been commercialized (with the exception of AquAdvantage salmon) due to societal and ecological concerns. As a result, it's crucial to comprehend the use of transgenic fish that pose serious threats to both human health and biodiversity. The development of transgenic fish via viral vectors may be harmful to human health. The extinction of biodiversity and genetic diversity are the ecological issues with the adoption of transgenic fish. Since fish have the intrinsic ability to escape captivity and potentially enter native or wild environments, their transgenic production creates ecological problems. Generally speaking, it is accepted that fertility and viability are the most important fitness traits for determining the ecological safety of transgenic fish. Evidence suggested that transgenic fish displayed numerous behavioural and phenotypic alterations, including altered predation, migratory, and incentive to feed.

3.7 SUMMARY

Fish breeding is a natural process. However, in certain conditions (environmental, physiological, captive) artificial breeding is done and that procedure is called as hypophysation or induced breeding. There are multiple factors associated with it. Induced breeding is the process of artificially inducing fish to reproduce when it does not occur naturally. It is mainly done on Indian Major Carps and other finfishes of food values. Multiple steps are followed up like selection of breeders, preparation of pituitary extract. Bundh breeding and hapa breeding are few types of fish breeding techniques. Bundh breeding is divided into two types – dry and wet. In hapa we use a fine meshed cloth. There are different types of finfish hatcheries. Fishes are placed in these hatcheries according to their need.

Proper management of these hatcheries is a tedious task. Ploidy induction is another important technique where we can change the ploidy level of fish. Through this method even monosex populations could be produced. In cryopreservation we use cryoprotectant to store fish gametes. Through transgenic mechanism genetically modified fishes are produced. They help in boosting the growth and effectiveness of food conservation, develop a higher tolerance for environmental factors like temperature and salinity, release ornamental fish in new colour varieties, and create pathogen-resistant strains.

3.8 TERMINAL QUESTIONS AND ANSWERS

Question No.1 Explain the various factors responsible for induced breeding.

Question No.2 What is the process of hypophysation? Explain in detail the se of different synthetic and natural hormones, their formulation and mechanism of action.

Question No.3 Explain the difference between Bundh and Hapa breeding.

Question No.4 Explain the steps of Hatchery management.

Question No.5 Explain the terms Ploidy induction, monosex population, hybridization and transgenic fish.

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UNIT-4: FISH CULTURE SYSTEMS AND MANAGEMENT

CONTENTS

4.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

xi. Basic concept of pond and its ecology
xii. Learn about fish farm and its construction
xiii. Have knowledge about different culture systems.
xiv. Learn methods of pond management
xv. Basic concept of Composite fish farming and polyculture

4.2 INTRODUCTION

Many fish in the wild die from disease or a lack of oxygen or are devoured by other creatures or predators before they can grow to adult size. Pond fish farming makes an effort to maintain the situation in order to increase fish production. In ponds, predators can be managed to increase the pond's fish production above natural waterways. Fish in ponds thrive mostly because they cannot escape and because feeding, breeding, growing, and harvesting the fish are done in a systematic manner. In ponds, fish culture is practiced. These are tiny, shallow bodies of water that are totally drainable in their natural settings and are typically man-made. The natural ponds are different from the lakes in having a relatively large littoral zone and a small profundal zone. Their source of water is varied.

History

Pond fish farming is a very old activity. Fish have been cultivated since 2698 B.C. Every time civilization was established for a long time, fish culture appeared. Ancient Egypt and China, which has maintained a continuous civilization for more than 4,000 years, both practiced fish culture. Chinese fish farmer Fan Lai wrote the first account of fish cultivation in ponds around 475 B.C. Asiatic carp was brought to Greece and Italy by the ancient Romans. In Europe wide carp culture was practiced by the seventeenth century.

Why fish grow in ponds

Pond fish culture is a more favourable approach. Fishing from a pond is simpler than fishing from an abundant natural resource. It is possible to manage fish growth. To increase the market value of fish, more food can be provided to them. Fish in ponds can be protected from natural predators. Diseases can be prevented in fish. With proper management, fish productivity in ponds can be enhanced and more money can be made. A farmer can maximize the utilization of their land by engaging in fish farming. Additionally, fish farming will generate extra income.

4.3 PONDS AND POND ECOLOGY

Pond Ecosystem (Fig. 1):

A biological community made up of various species of creatures is referred to as an ecosystem. To adapt to changing environmental conditions, these organisms communicate with one another. Around us, there are various ecological types. The existence of nearby environmental factors may also be used to define an ecosystem. Pond ecosystems, forest ecosystems, ocean ecosystems, and others are some of the best examples of ecosystems. The pond serves as an illustration of an ecosystem created in a region where water overflows and contains aquatic plants and animals. An ecosystem is created when the many kinds of plants and animals in a pond ecosystem interact with one another and their surroundings.

Pond Ecosystem: Definition

Pond ecology is a type of freshwater ecosystem that can be temporary or permanently made up of a range of aquatic organisms interacting with one another and the aquatic environment around them. The longer amount of time that the water is stagnant makes the pond environment a lentic ecosystem.

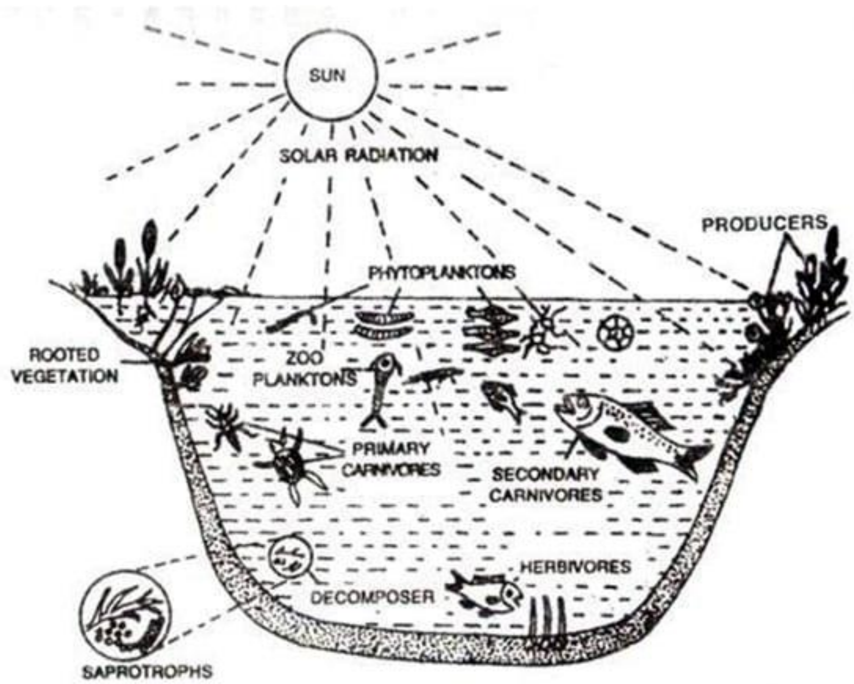

Fig4.1: Pond Ecosystem

Types of Pond Ecosystem

There are the following types of pond ecosystems:

- **Garden pond ecosystems:**

These are artificial ponds that were created by humans and contain decorative plant and animal species imported from all over the world.

- **Salt pond environments:**

These ecosystems, which contain brackish water, are generated naturally by the sea. These result from water logging. These can also be found in rock pools, which are rocky regions on the beach. Because it contains brackish water, it can support marine life.

- **Freshwater pond ecosystems :**

Freshwater pond ecosystems are created naturally as a result of rainfall or soil saturation brought on by on-going rain. They may also develop as a result of river water flowing into a significant depression. Freshwater fish, amphibians, crabs, and many other species of wildlife all call these habitats home.

- **Venereal pond ecosystems:**

These are temporary ponds that occur during periods of heavy rain as a result of the buildup of water in the ground depressions. They frequently become desert terrain as the seasons change.

- **Mountain pond ecosystems:**

Ponds that have naturally formed might be found in mountainous areas. These are the result of rock movement and snow melting. They provide habitat for rare or threatened aquatic species.

Characteristics of Pond Ecosystem:

The following are the main characteristics of the pond ecosystem:

1. The pond environment is surrounded by either natural or man-made barriers; the water in the pond is stagnant.
2. The littoral zone, limnetic zone, profundal zone, and benthic zone are the three separate zones that make up the pond ecosystem.
3. The biotic elements of the pond ecosystem are located at various levels, which prevents them from competing with one another for life.
4. Scavengers and decomposers occupy the bottom level, and fish occupy the middle level.
5. Pond ecosystems demonstrate a wide range of variability in their size. The plants enclose the pond's edges and offer protection to little creatures and insects.
6. Pond ecosystems show a wide range of variety in their size.

Stratification in the Pond Ecosystem (Fig. 2)

The following zones are found in the pond ecosystem, and they are determined by various characteristics including proximity to the shore, light penetration, water depth, plant and animal species, etc.

- **Littoral zone** : The zone closest to the shore is known as the **littoral zone**. Shallow water is present, and light can easily enter. It is home to rooted plant species. Reeds, crawfish, snails, insects, etc. are examples of different animal species.
- **Limnetic zone**: The open water of a pond in which light can effectively penetrate is referred to as the **limnetic zone**. Phytoplankton dominates this region. Small fish and insects are the two predominant animal species.

- **Profundal zone**: An area of a pond below the limnetic zone is referred to as a profound zone since it is completely dark. It is home to certain turtles and amphibians.
- **Benthic zone**: The bottom zone of a pond is benthic and is occupied by a community of decomposers. The decomposers are called benthos.

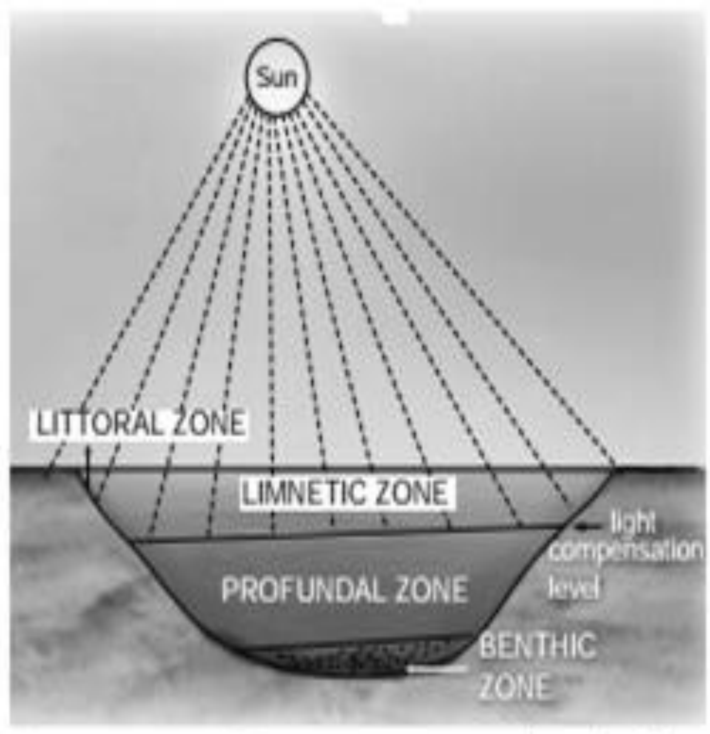

Fig 4.2: Stratification of the Pond Ecosystem

Abiotic Components of the Pond Ecosystem

The non-living elements of an ecosystem known as abiotic components are crucial for the survival of aquatic life. The following are the pond ecosystem's primary abiotic elements:

1. **Light:** Light is a key abiotic element needed for phytoplankton to engage in photosynthetic activity. Light penetrates most deeply in the littoral zone and least deeply in the profound zone.
2. **Temperature:** The progressive reduction in light penetration causes the temperature of the water to gradually drop as the depth of the pond increases.
3. **Dissolved oxygen:** As you move from the pond's surface to its depth, the amount of dissolved oxygen steadily drops. It is highest in the shallow water.

Biotic Components of the Pond Ecosystem (Fig. 3)

Living things make up biological components. The following list of living organisms that make up the pond ecosystem can be discussed:

1. **Producers:** These comprise a variety of rooted, submerged, emergent, floating, and algal species. *Spirogyra* is the most prevalent type of filamentous algae found in ponds. Other algae in the pond include *Mougeotia* and *Zygnema.* In the pond ecosystem, green plants like *Azolla, Hydrilla, Pistia, Wolffia, Lemna, Eichhornia, Nymphaea, Potamogeton, Jussiaea, etc*. can be found.
2. **Primary consumers:** The principal primary consumers are a sizable population of zooplanktons. The main consumers typically found in the pond are small herbivores like snails, insects, small fish, tadpoles, and larvae of aquatic creatures. Large animal species like frogs, large fish, water snakes, crabs, etc. are examples of secondary consumers. Mammals such as water shrews and water voles, as well as herons, ducks, kingfishers, and other birds, may be among the highest order of consumers.
3. **Decomposers:** These are the various bacterial and fungal species that consume the dead and decomposing components of aquatic species.

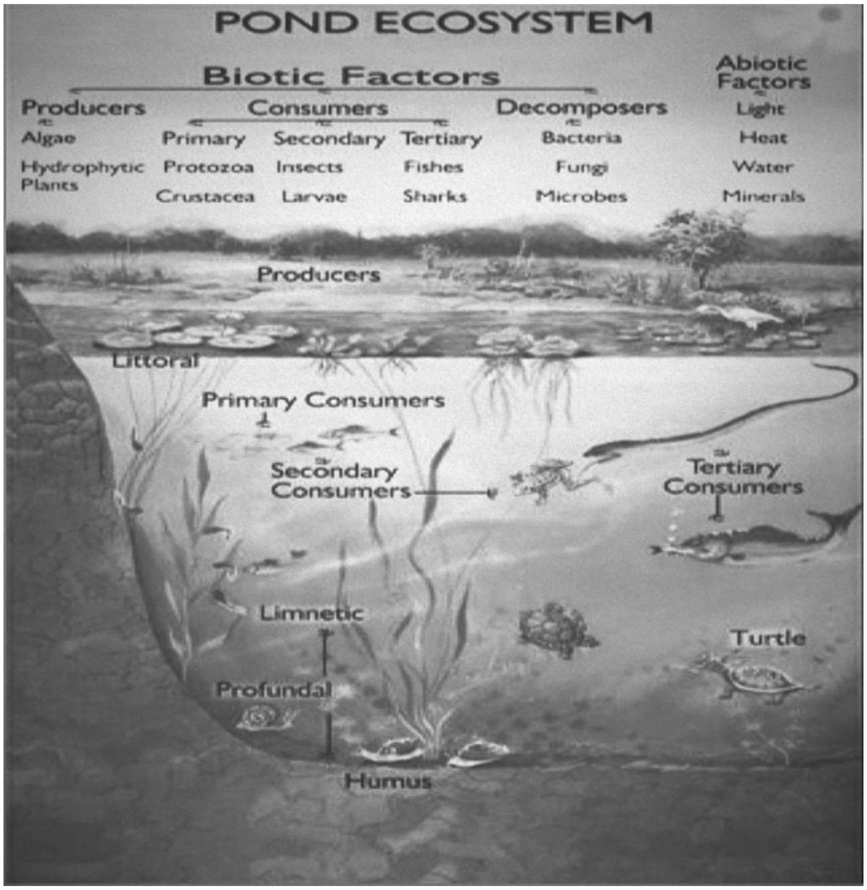

Fig.4.3 : Biotic and Abiotic Factors of the Pond Ecosystem

Food Chain in the Pond Ecosystem

The food chain is a group of animals in which each one consumes the lower member before being consumed by the species above it. Algae and phytoplankton act as producers, converting solar energy into chemical energy. Zooplankton is consuming phytoplankton (primary consumers). Small pond creatures that eat zooplankton continue the food chain's progression. Large pond species consume little pond species. Some bacteria and fungi are known as decomposers because they consume dead and rotting animal species' components.

Decomposers break down organic materials (dead plants and animals) into their inorganic constituents, which are then used again by producers. This maintains a constant flow of energy.

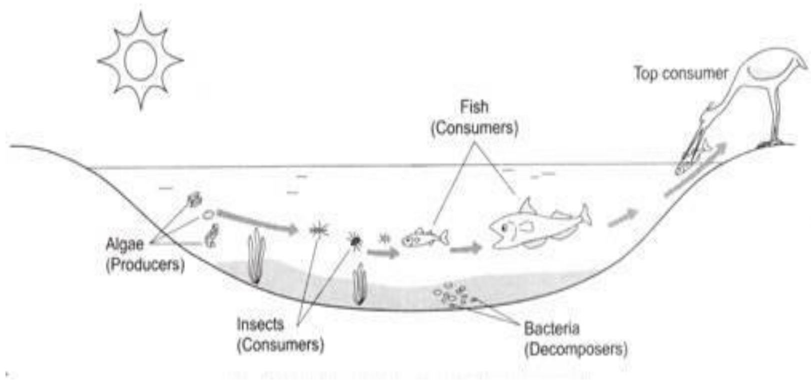

Fig. 4.4: Food Chain in the Pond Ecosystem

Importance of Pond Ecosystem

The following points can be made regarding the significance of pond ecosystems:

- Some aquatic plants contribute to better water quality by removing heavy metals and pollutants from the water.
- Shoreline plants absorb nitrogen and phosphorus, which helps to prevent algal blooms and maintains the pond's oxygen level.
- The pond ecosystem is one of the sites for the conservation of biodiversity as different types of plants and consumers occupy different strata in the pond and live together by interacting with each other. In addition, aquatic plants absorb animal wastes to reduce the nutrient availability for plants and thereby prevent the growth of algae. Mountainous ponds protect the endangered species.
- Pond ecosystems add to the beauty of nature by supporting a range of decorative flowering plants, as well as acting as a supply of water for species that do not dwell in the pond.
- The distribution of animal species within the pond is governed by stratification in the pond ecosystem. It somewhat lessens competition between the species.
- Pond ecology is best defined as the relationship between the life in your pond and its surroundings.
- Algae and aquatic plants will flourish in a shallow, nutrient-rich pond that is exposed to sunshine and has little water running through it. Due to the low oxygen levels, there may not be much animal life there.

- A newly constructed, deep, spring-fed pond, on the other hand, might not have any life in it at all due to the cold temperatures and scarcity of food.
- Every pond ages. A pond's initial components are mainly water, few nutrients, and not much aquatic life. The pond builds up nutrients over time. The term "**eutrophication**" refers to this enrichment process. Aquatic life grows as a result of the supply of nutrients. These organisms are alive, develop, and pass away.
- Their remnants decompose in the pond, releasing the nutrients needed to grow them back into the water to continue the cycle. However, eventually there will be a buildup of material that is resistant to degradation, and the pond will overflow. It will eventually turn into a bog and resemble dry terrain.

Returning to dry land can take a decade or it can take generations. It is your responsibility as the pond owner to delay the process as much as you can. The guidelines you can use are described below.

- **Exclude Nutrients**

Aquatic organisms are created from four fundamental components. They are phosphorus, nitrogen, oxygen, and carbon. Of course, more than these are needed to create even the most basic organism, but these are the widely available ingredients. Aim to avoid the rapid introduction of substances, especially nitrogen and phosphorus, to avoid the rapid ageing of a pond (eutrophication). In order to reduce inputs of nitrogen and phosphorus from animal waste, animal access to ponds or streams that feed ponds should be restricted.

- **Buffers**

The pond benefits greatly from maintaining vegetation in all locations where water must pass in order to reach the pond. These buffers filter and slow down the flow of water. Sediment can fall out of water that is moving slowly. Since phosphorus is heavily bound to soil particles, sedimentation is an efficient way to keep it out of ponds. The pond won't get shallow by being filled with sediment if sediment is kept out of it. This immediately adds to our main goal of preventing the pond from reverting to dry ground. Ponds that are deeper will also be colder. The growth of organisms is slowed down by colder temperatures, which is a general biological principle. So once more, the buffer zone influences the conditions that help slow the aging process for the pond.

- **Sedimentation**

Creating a small pool at the pond's entrance is another way to prevent sediment from entering ponds. Water will have the chance to deposit its sediment load in the pool as it passes through it on its way to the pond. The size of the pool should be such that a backhoe can readily clean it from the pool's shore. Similar to how silt removal via buffer strips benefits the pond, a sedimentation pool accomplishes the same.

- **Limit Fertilization**

The pond will profit when it is possible to reduce the usage of fertilizer on turf or crops cultivated in the pond's watershed. This is due, in part, to the fact that plants never utilize fertilizer components with 100% efficiency. Therefore, even when fertilizers are applied at the proper rates, some elements, especially nitrogen, are not utilized and end up moving off the site. The quantity leaving the site will be lessened by lowering fertilizer rates.

- **Maintain Ecological Balance**

Ponds perform best when a complete and balanced food web is present. This indicates that there are enough planktonic algae present, starting at the top, to feed some zooplankton. The smallest fish and aquatic insects eat the zooplankton, which in turn provide food for them. Larger fish then prey on these, which may then be caught by raccoons, bears, or fishermen.

The higher plant community is involved in ecological balance in another way. The pond owner is discouraged by too many plants, and the food side of the ecology we just discussed suffers as a result. From the perspective of the pond owner, a pond covered in vegetation gives a terrible aspect and hinders boating, swimming, and fishing. There are issues from the perspective of aquatic life as well. Some aquatic plants are useful for shadiness, hiding places for little fish, habitat for some aquatic insects and animals, and as a source of food for some fish and animals. In addition to the angler's hook becoming tangled in too much vegetation, the bait is hidden from that magnificent bass. The greenery concealing the bait and his prey renders the pursuit fruitless. A pond of this type has a reduction in fish production.

No other vegetation will grow beneath the water in a pond that is entirely surrounded by lotus or water lilies. In addition, there won't be enough light for planktonic algae to flourish. For plants other than lilies, this pond won't be very useful. The other instance is the overgrowth of watermeal or duck weed. When these plants completely cover the pond's surface, the light is once more turned off and there isn't much life beneath the water.

By maintaining a full isolation of the water surface from the atmosphere, these plants also nearly eliminate oxygenation of the water. The possibility of eradicating excessive amounts of vegetation or eradicating beneficial plants alongside the intended weeds is a rarely mentioned issue in the management of aquatic vegetation. When thinking about weed control in ponds, keep this in mind. Some solutions include treating the pond in sections over time, using mechanical techniques, or even using the right number of grass carp to keep things "pruned up" rather than wiped out. As a result such a pond becomes oxygen deficient to such an extent that any fish present are killed from lack of oxygen.

- **Maintain Water Flow**

When a new pond is being designed, the water source for the pond is a topic of discussion. A pond with a consistent water supply will almost always be more satisfying than one with a variable water supply. Ponds lose a lot of water through evaporation in the summer. Ponds with enough input remain full, but as the water level drops in others, a muddy beach forms at the edge, which is unsightly. Because surplus nutrients will be carried away by the overflow water, the nutrient conditions in a pond with a continuous overflow are probably superior. In contrast, the intermittent flow pond only has the opportunity to remove extra nutrients during storm occurrences. These ponds are more likely than their overflowing relatives to acquire nutrients considerably more quickly. As was said above, an overabundance of nutrients causes excessive vegetative growth of all kinds.

- **Encourage Aeration**

The presence of oxygen in pond water is particularly advantageous to the pond's general health. It is clear why fish are valuable. The pond's capacity to remove waste is less evident but very significant. The garbage that accumulates in the pond consists of "deposits" from the fish and geese that inhabit it, waste materials that are carried in by storm water runoff, as well as dead plants and animals. Aerobic bacteria work about 20 times faster than anaerobic bacteria in breaking this waste down and putting it into solution. Once in solution, it can be removed or used to create new life. Pond oxygenation is a fascinating process. There are two main ways that it occurs.

During the day, plants and algae synthesize oxygen, while at night, wind contributes oxygen. The oxygen that plants create is discharged into the pond's water and keeps the oxygen level there high. Therefore, it is important to keep an eye on the factors preventing light from entering the pond, or else a catastrophe like the one caused by watermeal's total cover may occur. Instead of being discharged into the pond water, all of the oxygen produced by the watermeal is released into the atmosphere. Unless the pond is being mixed from top to bottom, any area of the pond that is too dark for photosynthesis to take place is likely to lack oxygen. To determine visibility, a Secchi disc can be lowered into the water. It is observed the extent of disappearance. Photosynthesis will oxygenate surface water above this disappearance depth, whereas water below that depth needs to be mixed to get oxygen.

The second way to provide oxygen to pond water is by oxygen exchange with the atmosphere at the pond's surface. The rate of exchange increases with surface roughness. Furthermore, the exchange happens more quickly the more oxygen-deficient the water is. This procedure is crucial for the pond, which has a significant burden of plants and animals, and especially necessary at night. Similar to animals, plants respire at night rather than photosynthesis. By dawn, the pond water may be oxygen deficient if atmospheric aeration is impeded by lack of wind or especially by a covered surface.

Winter Pond Ecology

The water in the pond may become significantly colder in the winter and become completely covered in ice at times. What effects do these elements have on the pond's animal inhabitants?

Amphibians like fish, frogs, and turtles have evolved special adaptations to survive in this hostile environment. As the water gets warmer, their body temperature drops along with their requirement for energy and respiration. At the pond's bottom, frogs and turtles dig burrows and spend the winter there. They can accomplish this because they breathe via their skin. You might be curious as to how even the minimal amount of oxygen required during this period is supplied as ice prevents oxygen from entering the pond water through the surface. The ice lets in enough light for some aquatic plants to begin photosynthesis. Fish, frogs, and turtles may die from "winter kill" in a pond that is entirely covered in snow. However, that is avoided by manually clearing snow off about half of the ice in routes across a pond. It is important to keep roughly 30% of the ice free of lengthy snow cover during the winter. Make that the intended snow removal method is secure on the ice. Use a diffuser-style aerator as an alternative to keep a small area free of ice while supplying oxygen.

4.4 FISH FARM: CONSTRUCTION AND LAY OUT OF DIFFERENT TYPES OF PONDS

Site selection

One of the most crucial elements that affect the success of the fish farm is choosing the right location. Prior to building the pond, it is important to consider the soil's ability to retain water and its fertility because these aspects affect how the organic and inorganic fertilization in the farm pond will affect plant growth. The chosen location should have year-round access to sufficient water supplies for uses such as filling ponds. The topography area must be taken into consideration when building the pond. To construct a pond of a suitable size in swampy and marshy locations, bundhs should have a bigger accumulation of dirt. Higher elevation sites are best suited for self-draining ponds. For convenient fish removal, the site should be easily reachable by road or any other mode of transportation. Additionally, it should be possible to get inputs like feed, seed, fertilizer, and building supplies close to the project site. Pollution, residential, industrial, and other detrimental activities should not occur on the site.

The following ecological, biological, and social elements need to be taken into account while choosing a site.

- **Ecological factors**

While site selection for a pond, the ecological factors to be considered are soil, water, topography and climate.

- **Soil**

The pond's productivity, water quality, and dyke building are all impacted by the soil quality. The appropriateness of a location is evaluated by the characteristics of soil texture and soil permeability. The water should be able to hold in the pond bottom. The best soil types for building ponds are loamy, clay loamy, and silt clay. Good gravel shouldn't include more than 10%. Soil types such as limestone, gravel, sand, and rocks should be avoided.

Evaluation of soil suitability

Soil suitability can be evaluated by three methods -

1. To use the squeeze method, place the soil in your damp hand and tightly close your fist. Soil is appropriate for pond construction if it maintains its shape even after you open your hand.
2. The best way to assess the appropriateness of the soil is through a ground water test. One metre deep pit should be dug, and then covered with leaves for the night. A pond could be constructed if the pit is filled with ground water the next morning. However, because there is enough groundwater available in such soils, drainage may take longer. The site is appropriate for pond building if the pit is empty the following morning, but the water permeability needs to be verified first.
3. The water permeability test is the third technique. Fill the pit with water, and then cover it with leaves. The next morning, if there is no water in the pit, seepage has occurred. Pour the water into the pit once more and cover it with leaves to verify this. The land is appropriate for building if water is readily available. However, if the water is drained, the location is unsuitable for building a pond. However, the property can be utilized by covering the pond's bottom with plastic or dense clay.

Water

The fish farm must be constructed in an area with enough water since the water depth must be altered periodically. When compared to borewell and well water, natural water bodies including reservoirs, rivers, and lakes exhibit steady water quality parameters (water temperature, dissolved oxygen, pH, alkalinity, and water hardness). The location ought to be far from a flood plain. If water is determined to be either acidic or alkaline, the appropriate correction should be made by adding lime or organic manure, respectively. For a fish farm, the recommended water temperature range is 20–300°C. The quantity of salt dissolved in water is known as salinity. Freshwater fishes such as Tilapia and catfishes grow even in salt water, but the carps can withstand only in freshwater.

Topography

The geography of the terrain influences the type of pond building. Normally, it is best to steer clear of locations with frequent floods and little rain. It is also not advised to build ponds in places like industrial zones, fields with underground oil pipelines, uneven soil, fields with tall power poles and radio towers, and areas with deeply rooted vegetation.

Biological factors

Biological factors include the species which are to be cultured, seed source and culture type and they need to be considered before site selection of fish farm.

Social and economic factors

Good site selection and management procedures for aquaculture are dependent on ecological and biological considerations. Knowing the area's social and economic history as well as its culture and traditions in particular, those that are regionally related with aquaculture practices is crucial. It is important to take into account the social fabric, the market and its structure, and any services directly or indirectly related to the aquaculture industry. Examples include issues of transportation, storage, and wholesale markets. Legal concerns should not exist on the property chosen for farming, and locals should support fish farming. The availability of labour, electricity, medical services, and transportation are other considerations.

Pond Construction

An effective pond construction requires a thoughtful design and layout. The earth from the excavation should be used to build the dyke, which should have a sloping slope leading to the outflow for the right drainage facility. The construction of the pond should ideally be finished in the summer so that it may be stocked.

Steps in pond construction

Normally, the pond construction includes the following steps:

Step 1: Prepare the location by clearing it of undesired objects like rocks, bushes, and trees.

Step 2: Using the clay core to build a secure, seepage-free dyke.

Step 3: Excavating a pond and building a dike over the clay core.

Construction of the inlet and outlet is completed in steps four and five. The pond should be guarded to prevent theft and the entry of predatory animals. Avoid using long-rooted plants like Rhodes grass and star grass.

Site preparation

Ropes, wires, and other objects have been removed from the area. Removal of trees, bushes, and other obstructions that prevent heavy equipment from moving about the site must be done manually, with the assistance of animals, or with the use of machines. In the area, all vegetation, including timber, must be removed (inclusive of 2 to 3 m beyond the dyke for workspace). Large stones, tree slumps, and trees within a 10-meter radius must all be removed. Pond construction is not appropriate for the surface soil with the maximum concentration of roots and organic substances. As a result, approximately 30 cm of surface dirt must be removed.

Construction of dyke

Dykes ought to be tightly packed, sturdy, and leak-free. 15 to 30 percent silt, 45 to 55 percent sand, and 30 to 35 percent clay are used to build a good dyke. For loamy silt or sandy soils, the embankment slope should be 3:1 and for good quality clay soils, it should be 2:1. The clay buddle (1:2 sand and clay) is deposited as a 10–15 cm thick layer at the centre or inside the pond's waterside in order to raise the dyke. The top of the embankment should be higher than 1 m, and the crest of the dike should be sufficient to aid linked agricultural activities. Extra outlet is essential on the embankment as a safety measure to avoid damage due to excess raise in the water level.

- **Digging the pond and construction of dyke**

Types of pond

For the development of fish at different life stages, specific pond types are needed, such as ponds for broodstock, nursery, rearing, stocking, and treatment. Because it prevents fish from escaping during harvest, rectangular ponds are preferred to those with round corners. The pond's ideal length to breadth ratio is 3:1, with a maximum breadth of 30 to 50 metres. The nursery takes up 5% of the total farm area, the raising pond takes up 20%, the stocking pond takes up 70%, and the bio pond or treatment pond takes up 5% of the total farm area.

Nursery pond:

1. The nursery pond measures 0.01 to 0.05 hectares in size and has a depth of 1.0 to 1.5 m.
2. The nursery pond receives the spawn, which is raised there for a maximum of 30 days (to attain 2 – 3 cm length).

Rearing tank:

1. A tank where fingerlings (fish that are 10 to 15 cm long) are grown from fry over the course of two to three months.
2. The pond's size ranges from 0.05 to 0.1 ha, and its depth is 1.5 to 2.0 m.

Stocking pond

1. Here, fingerlings (TL 10 to 15 cm) are raised until they are of marketable size.
2. The culture lasts between 8 and 10 months.
3. The intended fish production determines the stocking density.
4. Depending on the situation, the stocking pond serves as a breeding and broodstock pond. The pond's size is between 1 and 2 ha, with a deeper water depth of 2.5 to 3.0m.
5. Regarding the size of the ponds, there are no strict guidelines.

Bio ponds or treatment ponds are sizable settling tanks where fishpond water is biologically cleansed. They could also be utilized as ponds for stocking. For simple netting operation, a flat even bottom is advised. A fruitful farm should build a nursery pond first, then a rearing pond, at its higher altitude area. The stocking pond should be constructed in the lowest part of the farm, which will lower construction costs and make farm management easier.

Pond construction types

The two types of ponds used for construction are dug out ponds and embankment ponds. The dug out pond is best suited for building ponds in plain settings and is made by digging the earth. It must be built scientifically while keeping in mind elements like shape, size, depth, and others. For steep regions, an embankment pond is more ideal. Depending on the need, dykes may be built on one or both sides. Due to the inability to adjust the pond's size, shape, and depth to meet the requirements of scientific fish culture, it is economically feasible but not optimal for fish culture.

Inlet and outlet construction

Except for ponds that are fed by rainwater, feeder canals are built to supply the ponds with an adequate volume of high-quality water. To prevent the introduction of undesired particles into the culture system, inlets are placed at the top of the pond and screens are utilized to filter the pumped water. The intake pipe size needs to be planned so that it should fill the pond in no more than one or two days. The exit pipe is installed at the pond's bottom. In order to maintain the pond's water quality during the culture period, it is utilized to partially drain the pond during harvest and dewater it completely. Before building the pond dyke, the outlet is built.

Soil and vegetation coverage of Dyke

Creeping grass can be cultivated on the top and sides of the dike to lessen soil erosion. You can grow coconut and banana trees in the embankment. To provide food for the grass carps raised in the ponds, the slope of the embankment can be planted with grasses including Hybrid Napier, gunny grass, and elephant grass.

Pond fencing

To prevent theft, the ponds are enclosed. Live fences also act as a windbreak, broaden the variety of the farm, provide the farm seclusion, and enhance the fish farm's attractiveness. Fences can be constructed in a variety of ways. These include stone walls, wire fences, post and rail fences, weaving fences, live fences, pile fences, and wire fences. There are benefits and drawbacks to each kind of fence. Fish farms frequently employ wired net fencing to deter trespassers and safeguard the fish population.

4.5 DIFFERENT TYPES OF CULTURE SYSTEM

Fish culture is classified into two based on the number of fish species as monoculture and polyculture.

Monoculture

The culture of a single species of fish in a pond or tank is what this is. Monoculture examples include the cultures of *Clarias* alone, *Oreochromis niloticus*, *Heterotis*, and *Gymnarchus*. The benefit of this kind of culture is that, especially in the intense culture system, it enables the farmer to produce the feed that will suit the needs of a specific fish. It is possible to stock fish of various ages, which improves selective harvesting.

- Common carp culture in East Germany
- Common carp culture in Japan
- *Tilapia nilotica* culture in several countries of Africa
- Rainbow trout (*Salmon gairdneri*) culture in many countries.
- Channel catfish (*Ictalurus punctatus*) culture in U.S.A.
- Catfish, *Clarias gariepinnus* culture in Africa.

Polyculture

The process of cultivating multiple types of aquatic organisms in the same pond is known as **polyculture**. The guiding assumption is that raising a variety of species with various feeding preferences will maximize fish production in ponds. The variety of fish allows for better use of the natural food produced in a pond. Chinese polyculture dates back more than a thousand years. Southeast Asia and other parts of the world have seen a proliferation of the practice. Natural fish food species are in great abundance in ponds that have undergone chemical fertilization, manuring, or feeding procedures. These organisms can be found living at various depths and places throughout the water column. The majority of fish primarily consume particular populations of these creatures. Fish raised in polyculture should be mixed in numbers that effectively use these natural sources and have a variety of eating patterns. Higher yields are as a result obtained. In tropical climes, productive polyculture systems can yield up to 8000 kg of fish per ha per year.

Fishes used in polyculture

In polyculture, the three Chinese carps (bighead, silver, and grass carp) are most frequently combined with the common carp. It is also possible to employ other species. While fish can be divided into broad categories according on how they feed, there is some overlap. The categories of feeding habits are described, along with examples of fish from each category.

• **Plankton Feeders** - Since plankton is typically the most abundant food in a pond, a polyculture system must contain fish that feed on it. This particular kind of fish eats the microscopic, freely floating plants (phytoplankton) and animals (zooplankton) that proliferate in large numbers in fertilized ponds. The silver carp, *Hypophthalmichthys moltrix*, and the bighead carp, *Aristichthys nobilis*, are two species that belong to this group.

• **Herbivores** – This class of fish consumes aquatic plants. Most famous for this behaviour is the grass carp, *Ctenopharyngodon idella*, which is stocked in ponds to reduce weeds. Fish in this group, known as bottom feeders, eat mostly at the pond's bottom. They eat a range of organic waste that has decomposed, aquatic organisms like clams, insects, worms, and snails, as well as bacteria that are present in or on the sediments. It is commonly known that the common carp, *Cyprinus carpio*, exhibits this behaviour.

- **Piscivorous Fish-** These fish are predators that feed on other fish, requiring 5–7 g of prey to produce 1 g of growth. They are frequently introduced to ponds as stockings to prevent unintended reproduction, especially in Tilapia and other fish that enter the body of water and compete with the stocked fish for food.

Predator fish that are frequently utilized include the sea bass (*Latius spp*.), catfish (*Clarius spp*. and *Silurus spp*.), snakeheads (*Ophiocephalus spp*.), cichlids (*Cichla spp*.), knife fish (*Notopterus spp*.), and largemouth bass (*Micropierus saimoides*). The average weight of prey species rises in a polyculture system where predator fish are present. Utilizing a fish predator that eats little prey is the most effective strategy. As a result, the prey cannot get big enough to compete for food with other fish of its species that are bigger. In the majority of the world, the use of predator fish in polyculture systems is experimental. It is nearly impossible to fill tiny ponds with the precise number of predator fish needed to mimic the predator/prey ratio found in nature. To totally regulate the reproduction of the prey species, predator fish are typically supplied at rates of 5 to 20 fish per 100 m2 of pond surface area in small-scale aquaculture. Typically, the stocking rate for *Catla* is 19 fish per 100 m2, and 6 fish/100m2 for mrigal.

Issues in polyculture

To get the most out of the natural food that is present in a pond, polyculture is an effective strategy. Pond management becomes more challenging, however, when multiple fish species with distinct feeding preferences are stocked in the same body of water. This is because proper fertilization and feeding procedures must be followed. If the availability of species for polyculture is severely restricted by a lack of fingerling supply, at least one species should exhibit broad rather than specialized eating behaviour. This will make it possible to use more of the natural food that is accessible.

4.6 CULTIVABLE INDIGENOUS AND EXOTIC FISHES

Characters of cultivable fish

Before choosing a fish for agricultural purposes, you should take into account the following factors. There are primarily three distinct types of pisciculture. These are:

• **Monoculture:** This method permits the rearing of just one species of fish. High productivity and quality are offered. Consumers enjoy eating these fish. Shrimp is frequently used in India as an illustration of monoculture fish.

• **Polyculture:** This practice is also known as mixed or composite fish farming. In a communal pond, polyculture enables the growing of various species of fish that get along. To enable each species to subsist on a varied diet sourced from a single resource, their feeding habits must differ. It is an advantageous form of pisciculture.

- **Monosex Culture:** Typically, in this culture, either female or male fish of a species may be grown. This is the method used to produce fish in this culture. *Tilapia* is one such kind of fish.
    1. **Growth rate:** Fish that reach a larger size in a shorter amount of time are excellent for culture like carps.
    2. **Climate adaptation:** Cultured fish species should be able to adjust to the farm's specific climatic circumstances.
    3. **Tolerance:** Fish should be able to withstand significant changes in the physicochemical properties of the water, such as oxygen content, salinity, and temperature.
    4. **Acceptance of artificial feed:** When there is a requirement to accommodate more fish in a small area, compounded diets must be supplemented fed. These foods should be quickly preferred by the fish.
    5. **Resistance:** It is preferable that cultured fish have little to no ability to fend against parasite and common illness attacks.
    6. **Amiability and compatibility:** The fish species that are to be cultivated together (in a "poly culture") must get along well and not attack or interfere with one another.

7. **Conversion efficiency:** Fish species are chosen if they produce more edible meat per unit of food eaten.
8. **Consumer preferences:** People's food preferences vary according to where they live.

As a result, the species raised should be simple to sell locally or to the intended consumers.

Culturable Fishes of India

Carps, Catfishes, Murrels, Tilapia *etc.* are the main culturable fishes.

- **Indian major carps:**

Catla catla (Catla)

Labeo rohita (Rohu)

Cirrhinus mrigala (Mrigal)

- **Exotic (Chinese) carps**

Cyprinus carpio (Common carp)

- **Minor Carps**

Labeo bata (Bata)

Catfishes

Wallago attu

Mystus aor (Cat fish)

Clarias batrachus (Magur)

Murrels or snake heads

Channa striatus (Striped snake - head)

Tilapia

Oreochromis mossambicus

- **Sport fishes (Cold - water fishes)**

Salmo gairdneri (Rainbow trout)

- **Marine fishes**

Lates calcarifer

Chanos chanos

Besides these food fishes, there is an enormous potential for the mass culture of a variety of ornamental fishes, which can bring in high profit, also from overseas markets.

4.7 *POND MANAGEMENT: WATER, SOIL, MANURING AND LIMING*

Liming and Watering in Stocking Ponds

Liming

Aquaculture methods commonly use lime to enhance the quality of the water. The pond should be lime-conditioned after being ploughed, cleansed, and smoothed. Liming boosts a pond's output and enhances hygiene, both preventative and therapeutic. Prior to adding water, new ponds can be limed. In ponds without water, it is preferable to sprinkle the limestone uniformly on the water's top rather than the bottom. Whether the pond is new or old, the bottom should be covered with a layer of lime. Two weeks before the water is pumped into the pond, lime should be added to it. After fertilization has been discontinued is the ideal time to apply lime. While the pond is being fertilized, lime should not be used.

The main uses of lime are:

• Liming is absolutely necessary to keep the pH of water stable.

• The water should have a modest alkaline pH since this helps to keep the pond's water clean and helps to eliminate bacteria.

• Lime can be used to balance the acidic environment that would develop during manuring. 250 kg of lime per hectare is applied. In extremely acidic soils, the dose must be increased to 1000 kg/ha.

• To bring acidic water's pH level up to a neutral or slightly alkaline level. To boost the alkaline reserve in the mud and water, this prevents a sharp change in pH.

• To increase biological production by enhancing the bacterial decomposition of organic materials, this increases the reserves of oxygen and carbon.

• To precipitate organic compounds those are soluble or suspended.

• To reduce the need for biological oxygen (BOD).

• To improve light filtration.

• To improve nitrification since nitrifying organisms need calcium to function.

• To counteract the negative effects of some chemicals, such as acid and sulphide.

• To obliquely enhance fine-textured bottom soil that contains organic materials.

• Liming makes water more alkaline, which makes more carbon dioxide available for photosynthesis.

• By adding alkaline earths (calcium and magnesium), liming increases the overall hardness. It can also clear water of humic stains of vegetal origin that obstruct light penetration.

• The overall result of changes in water quality after liming is an increase in phytoplankton productivity, which then results in an increase in the output of fish, shrimp, and prawns.

Types of Liming Material

The chemical utilized for the liming of soil and water is the oxides, hydroxides, and silicates of calcium or magnesium. A variety of different compounds are employed as liming materials. The following are examples of common liming substances:

1. Calcium ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$] are both carbonates of magnesium and calcium. Calcium oxide (CaO) and Calcium hydroxide [$Ca(OH)_2$] are also used.

Applying of lime in the stocking pond

Watering

• The water should be introduced gradually after the lime has been placed to the pond bottom for at least two weeks.

• The water should descend into the pond from the water inlet such that when it does, it combines with oxygen from the surrounding air.

• The pond's water should not fill up too soon. The pond bottom will be churned up if the water enters too quickly, making the water muddy.

• After the pond has been filled, it should be left free for a few days to allow undesired fish and other organisms to avoid entering the pond by using screens at the inlets.

• Water quality in the pond should be checked before the fish is released into it.

4.8 MANURING (ORGANIC AND INORGANIC) AND LIMING

Manuring:

To encourage the growth of fish food organisms, manuring or fertilization is carried out after 15 days following liming. Manure may be chemical or organic in origin. 2-3 tonnes/ha of raw cow dung are applied at a rate for stocking ponds. 5000 kg of poultry manure per hectare is applied. The amount of chemical fertilizer used varies depending on the amount of phosphate and nitrogen in the soil. The typical NPK ratio for freshwater ponds is 18:10:4.

Conditioning the pond:

- For conditioning, a layer of lime or calcium hydroxide is applied and left on the pond's bottom for two weeks.
- It is typically administered at or following the stage of pond drying.
- By doing so, the soil's acidity is reduced, biogeochemical cycles are facilitated, and undesirable species are avoided.

There are three methods for liming:

By spreading it over a dried pond, including the dike walls, by combining it with water and spraying it over the pond, by liming the water entering the pond, and by any other method.

4.9 CONCEPT OF COMPOSITE FISH FARMING AND POLYCULTURE

Multi-Fish Culture

Fish culture in which different feeding zones are used to cultivate both compatible and non-competing fish simultaneously.

Primary objective:

- Utilization of all available resources
- To increase the total production per unit area

Steps in Composite Fish Culture:

1. Site selection:

Factors to be considered:

a) Environmental factors, such as geography, water quality and quantity, etc.

b) Biological: species evolution, sickness, and so on.

c) Economical and social factors: amenities offered marketing, security, social factors, etc.

2. Pond Administration

i. Pre-stocking includes removing weeds using mechanical or manual means. The introduction of several species, such as Grass carp, Tilapia, Common carp, etc.

ii. By repeatedly netting or utilizing mahua oil cake, undesired and predatory fish can be eliminated. To raise the pH to the required level, use liming.

iii. Liming also has the following additional effects:

a) Prevents pH swings;

b) Makes soil more parasite-resistant; and

c) Acts as a buffer.

d) Eliminates parasites

e) Speeds up organic decay

iii. Pond Fertilization - The goal of pond fertilization is to boost fish productivity by enhancing the natural productivity of the pond. The dosage of lime must be calculated depending on the pH of the soil and water. Fertilizers made from both organic and inorganic materials can also be employed.

- **Inorganic**: It comprises several inorganic components like nitrogen, phosphorus, etc. in the form of nitrogenous and phosphate fertilizers.
- **Organic:** It includes farm yard manure (FYM)- Cowdung @ 5000 kg/ha, Poultry, sheep manure, and crop byproducts like cotton seed meal, mustard oil cake, etc.

3) **Stocking**: Completed 15 days after fertilizer application.

Fish fingerlings should be between 5000 and 8000 in number and between 50 and 100 gram in size. It can be used for stocking. Stocking can consist of a combination of 3, 4, or 6 species, depending on the environmental conditions.

• Depending on the compatibility and diversity of the fish species used in composite fish culture,

• Indian and exotic kinds of fish's feeding patterns have been found and suggested for culture.

• In the composite fish farming technology, the feeding zones and behaviours of the various species must be monitored.

In order to maximize production per hectare of water body, fast-growing compatible fish species of different feeding habits (or different weight classes of the same species) are cultured in the same pond. This practice is known as polyculture, mixed fish farming, or composite fish culture.

A pond can be divided into three distinct zones based on its depth: **the top surface zone, middle column zone, and bottom zone.** A certain species takes advantage of the food in a certain zone. For instance, *Cirrhinus mrigala* is a bottom feeder, *Labeo rohita* is a column feeder, and *Catla catla* is a surface feeder. Only one zone will be used or exploited in the case of a single species, monospecies, or monoculture, leaving the other zones untapped. The yield or fish output would be lower as a result of not using the complete ecological area.

Principle of Polyculture:

The most effective way to use all the food sources in the pond for fish production is to cultivate different kinds of fast-growing suitable fishes that fill diverse biological niches of a pond or any other water body without damaging one another.

Objectives of Polyculture:

(1) To produce the most fish possible.

(2) To utilize all the available niches.

(3) The fish that are raised should not upset the ecological balance.

(4) The fish species being raised should not be in direct conflict with one another, but each species may positively affect the development and output of the others. For instance, grass carp transforms plant tissue into fish flesh by ingesting aquatic vegetation, while their excrement fertilizes the pond, helping all other species.

(5) Some fish species are raised for their ability to consume wastes generated in ponds to preserve the water's quality. For instance, grass carp and silver carp excrete enormous amounts of uneaten plant material, which common carp and mrigal eat.

(6) A recent fish species combination is centered on one or two species as the primary ones and the rest as auxiliary compatible species that use the food resources that would otherwise be wasted.

Origin of Polyculture:

Chinese and Indian history provides the foundation for composite fish farming. Based on varied seed stocks that were gathered from natural sources, polyculture was used in the carp farming industries in both of these countries. Sorting out stocks of various species in their infancy was not feasible. Therefore, the farmers were compelled to raise the various carp species in close proximity until they reached the fingerling stage. The farmers noticed that there were variations in feeding practices and preferences for natural food sources. This inspired the idea to modify stocking levels in accordance with the availability of natural food and the niches filled by each species in the ponds. As a result, it can be advantageous in conventional production methods by cultivating the right species combinations. The use of considerably more food resources and the emergence of a symbiotic interaction between the cultivated species in the system could both result from such a technique.

As a result, it would be possible to maintain the farm environment at the necessary standards while increasing productivity at a cheaper cost.

The variety of species raised in China's polyculture system includes:

(1) Grass carp (*Ctenopharyngodon idella*) which feeds on macro-vegetation.

(2) Silver carp (*Hypophthalmichthys molitrix*) which feeds on plankton (mainly phytoplankton).

(3) Big head (*Aristichthys nobilis*) which feeds on microplankton.

(4) Black carp (*Mylopharyngodon piceus*) which feeds mainly on snails and other mollucs at the bottom.

(5) Mud carp (*Cirrhinus molitorella*) which feeds primarily on detritus.

(6) Additionally, occasionally the omnivorous common carp (*Cyprinus carpio*), which essentially acts as a scavenger in farm ponds, is added.

(7) A variety of new species, including Tilapia, Wuchang Fish, Crucian Carp, Red Eye, White Amur bream, Snake Head have been added to the aforementioned traditional mix.

The following combinations are used in the Indian polyculture system:

(1) The zooplankton-eating surface feeder catla (*Catla catla*), which eats planktonic creatures in general. Young fry and larvae consume planktonic unicellular algae.

(2) The rohu (*Labeo rohita*), a column feeder that eats decaying aquatic plants, algae, and other vegetable detritus. Zooplanktonic and unicellular algae are the primary food sources for larvae and fry.

(3) The mrigal (*Cirrhinus mrigala*), a bottom feeder, prefers algae, detritus, organic debris, and other decomposed plant and animal materials. The larvae and fry eat zooplankton and planktonic unicellular algae.

(4) The bottom feeder, the calbasu (*Labeo calbasu*), specifically consumes organic waste and benthic and epiphytic species.

(5) By including exotic carps like grass carp, silver carp, and common carp, modern culturists and scientists have created composite carp cultures.

(6) The introduction of grey mullets that feed on benthic organisms has led to the development of new species combinations for polyculture (*Mugil cephalus*). To get rid of weed fishes, carnivorous fish called chitals (*Notopterus chitala*) have been introduced.

Drawbacks in Polyculture System:

1. In general, it is largely believed that there are fewer species pairings with distinct roles that are well understood. The utility of some of the species in these pairings has come into doubt, though, when there are more species involved.
2. Although there are distinct differences between food preferences under natural circumstances, it is still too early to determine the relevance of these feeding differences when the stocks are fed with formulated feeds.
3. Adopting supplementary feeding in an economical manner is not very simple.
4. To preserve the best possible balance of the species, farmers must use special knowledge, skills, and efforts to generate or buy the right quantity of seed stocks of the different species chosen.
5. Sorting out the various species after harvest requires more labour.
6. Consumer acceptance of the various species differs in many cases and in most places.

Additionally, finding markets for some species, like the silver carp, has proven challenging.

Modern monoculture with correct feeding has been found and demonstrated to be more productive than polyculture. Therefore, it is suggested that the value of polyculture greatly depends on the circumstances and requirements in a particular place. Most likely, polyculture is not as broadly applicable as previously thought.

4.10 SUMMARY

There are different types of fish culture systems in India. The fishery sector offers immense possibilities in these culture systems. Pond is a type of freshwater ecosystem having its own chain and food web. It comprises of both biotic and abiotic factors together making it habitat for aquatic animals to survive therein. The fish farms are of various types. The ponds are small types of culture ponds where the fishes mature out. There are different types of fish farms where the culture of indigenous and exotic fishes is done. There are various steps for the management of pond water. As a prerequisite for the health of fishes, proper maintenance of water quality, their timely monitoring, manuring and liming is required. Various methods are adopted to perform all these steps in a scientific manner. There are various fish culture techniques like monoculture and polyculture.

4.11 TERMINAL QUESTIONS AND ANSWERS

Question No.1 Explain in detail about the pond and its ecology.

Question No.2 What are the basic steps for fish farm construction? Give layout of different types of ponds?

Question No.3 What are different types of culture systems?

Question No.4 Explain the basic steps of pond water management.

Question No.5 Explain the difference between composite fish farming and polyculture.

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UNIT 5: INLAND FISHING GEARS AND FISHING METHODS

Contents

5.1 OBJECTIVES

After studying this module, you shall be able to learn and understand:

- Inland fishing gears and fishing methods
- Biological factors in fishing
- Types of fishing gears
- Natural and synthetic fibers
- Preparation and maintenance of fishing nets
- Different fishing method

5.2 INTRODUCTION

Inland fisheries are any activity conducted to extract fish and other aquatic organisms from "inland waters". The term "inland waters" is used to refer to lakes, rivers, streams, ponds, inland canals, dams, and other land-locked (usually freshwater) waters (FAO, 2014). While most inland waters are freshwater, there are many areas that are classified nationally as inland waters which have daily or seasonal fluctuations in salinity (eg. estuaries, deltas, some coastal lagoons). Fisheries in inland waters have long provided an important source of food for mankind. Individuals can relatively easily begin fishing in inland waters because basic equipment needs (e.g., nets, hooks, traps) are generally inexpensive and do not require substantial skill to operate or maintain. Fishing nets and gears are refers to those devices having different shape and sizes and used in the water body to capture different sizes of fishes. There are two main types of devices used to capture fishes in both marine and inland fisheries:

(1) Crafts or Boats - Used in fishing operations, for carrying the crew and fishing gears.

(2) Nets or gear - For catching fish these equipments are required. There are various types of gears and crafts used in different parts depending upon the nature of water bodies, the age of fish and their species. Some nets are used without craft; however, others are used with the help of crafts. Selection of appropriate gear for catching fish is of utmost importance in order to increase catch. Choice and design of fishing gear is greatly influenced by biological characteristics such as body size and shape, feeding habits and swimming speed; behaviour in the vicinity of fishing gear and during capture process; spatial distribution and aggregation behaviour of the target species.

Fishing gears whether primitive or sophisticated use five methods in the capture process viz., gilling and tangling (e.g. gill nets and trammel nets), trapping (e.g. traps, pound nets), filtering (e.g. trawls, seines and other net fishing systems), hooking and spearing (e.g. hook and line, harpoons) and pumping (e.g. fish pumps). Netting materials for making of fishing gear are either of textile or non-textile origin. Textile materials comprise of netting, twine and rope while floats, sinkers, hooks etc constitute non-textile origin materials. The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and synthetic fibres. Earlier, nettings used to be fabricated manually, which is laborious and time consuming while the introduction of synthetic fibres used in machine made nettings make revolution in fishing sector.

5.3 BIOLOGICAL FACTORS IN FISHING

Phytoplanktons - Biological factors of water which influence fish production are tied up with the capacity of the surrounding environment to supply essential food to cultured species. They are therefore concerned only with rearing operations where no supplementary food is given and the energy requirements are met through the phytoplanktonic primary production. The biomass of phytoplankton varies seasonally in general reaching its highest levels in spring and summer. The density is highest in superficial layers of water and decreases with depth. The appearance of different populations is linked in part to the characteristics of the surrounding water temperature, turbidity and depletion of nutrient.

Diseases - The diseases in fishes and prawns are caused by bacteria, virus, fungi, protozoa and crustacean parasites. These parasites enter into the pond along with water, fish or prawn seed and nets from other infected ponds.

Weeds - Excess growth of aquatic weeds in fish pond is not a good sign in aquaculture systems. Weeds utilize the nutrients and compete with desirable organisms.

The biological prerequisites of fish for aquaculture are

Established hatchery techniques- Large numbers of larvae, fry or juveniles must be available for grow-out operations. Broodfish must be available to establish successful hatchery techniques; the species should be fecund and capable of spawning in captivity.

Crowding- Cultivated species must thrive in captivity and be amenable to crowding. The more fish that can be stocked into a given space, the greater the potential production.

Suitable behavior- Regular observation and sampling of fish are essential for successful culture; fish that are readily seen and/or easily captured are desirable. Species that school and swim near the surface or edges are ideal, as are species that can be readily trained to feed at a particular area. Species that are very flighty or secretive are usually less suitable for aquaculture.

Rapid and uniform growth- Species must be capable of rapid growth to ensure efficient use of facilities and food. Most species of finfish that are farmed successfully throughout the world grow rapidly under culture conditions and reach minimum market size (500grams) in 18 months or less.Variable growth amongst fish within a rearing unit is undesirable as it necessitates culling or grading, which increases stress and susceptibility to disease, damage to the fish, and requires extra labour and facilities.

Amenable to artificial feeding- Semi-intensive and intensive fish culture is based on the use of medium to high stocking densities, prepared feeds (usually specially formulated pellets) and with some species, fertilisation of pond water. Very high production rates can only be achieved with species that accept prepared feed.

Appropriate dietary requirements- In general, fish that feed lower in the food chain are most efficient in the use of food under pond culture conditions. Although some carnivorous species accept artificial feeds, they require relatively high levels of protein (including animal proteins) and are unable to use most of the natural food available in ponds.

Non-cannibalistic- Cannibalism reduces survival rate and production .The greater the degree of cannibalism, the greater the losses.

Disease resistance- Although all species are susceptible to diseases under culture conditions, some are more so than others. This factor should be considered when selecting a species for aquaculture

Hardiness- Species that can tolerate sub-optimal conditions (for example, high or low temperatures, low dissolved oxygen, high pH) for short periods are more suitable than less tolerant species.

High meat recovery- Species that have high meat to total body weight ratio are desirable because of their more efficient conversion of feed into edible flesh. This is particularly important if the end product is to be processed.

Marketability- In addition to these biological factors, a species must have high market acceptance

5.4 TYPES OF FISHING GEARS

The use of crafts and gears in fishing technology plays very important role and help enhancing the production in commercial bases. The success of fishing largely depends on to how and which types of nets are used to capture the fish. Correct gear may be chosen taking into consideration of the following points:

1. Body size and shape determine the mesh size required to hold the fish in gill nets and to retain the target size groups of the species without gilling in the trawls, seines and traps. Body size is also related to the tensile strength requirements for the netting twine in gill nets and hook size and lines in hook and line. Body size is again directly proportional to the swimming speed which is a significant attribute to be considered in the fishing success of dragged gear. For catching the big and strong fish, the gear should also be strong and sturdy with proper mash size.

2. To catch fish at various level of the water body, different nets should be used, viz. surface gill nets,'column gill nets and bottom gill nets.

3. Fishes which swim in shoals, may be caught by using encircling nets like drag nets, purse nets, etc. Similarly using hooks and lines can catch the individual fish.

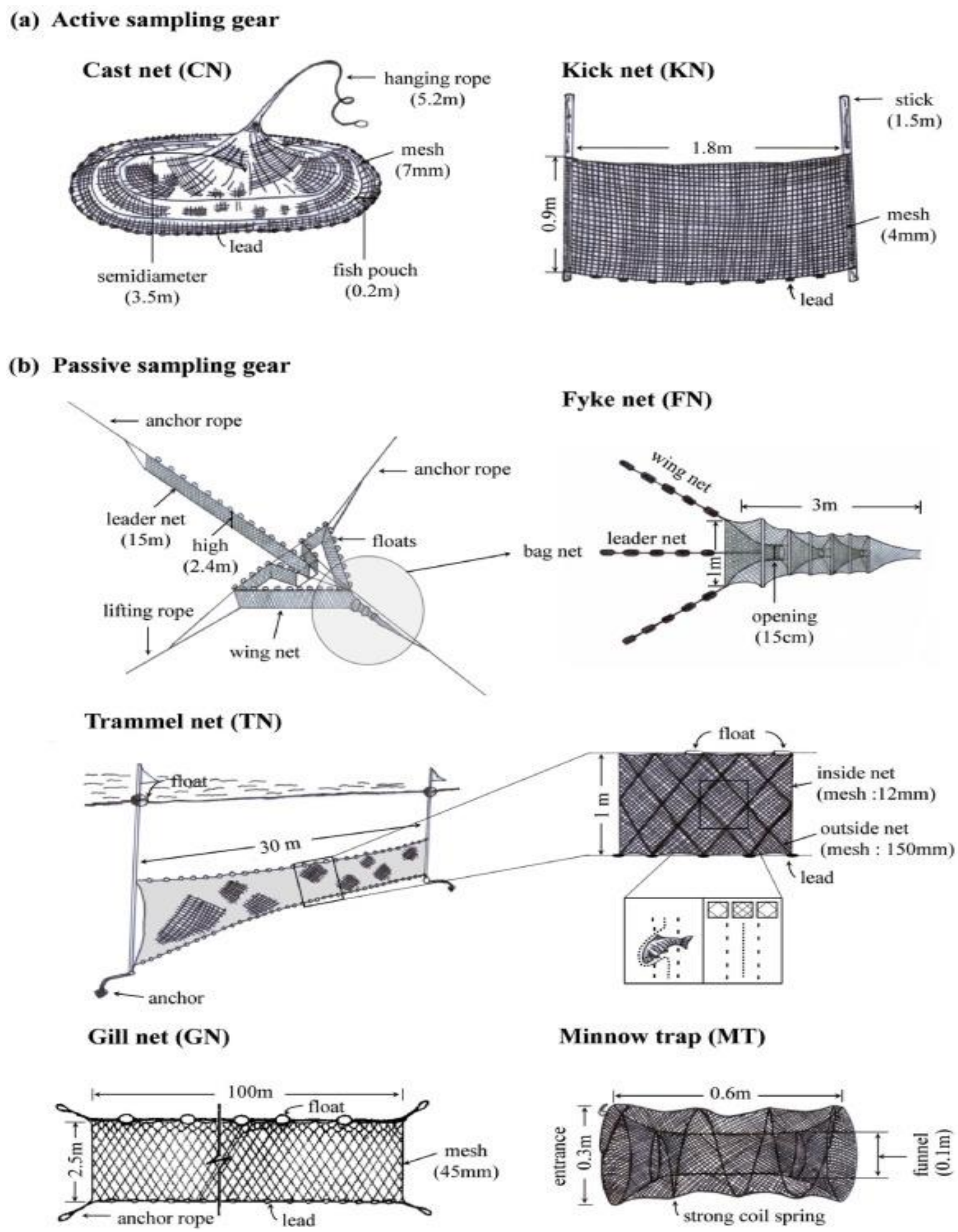


Fig.5.1 *Types of fishing gears*

4. Feeding habit of the target species is more important in passive fishing methods like hook and line and traps where the fish is attracted by the bait and in the active fishing methods like troll line used for catching predatory fishes.

India has a wide variety of diversified water bodies, hence the nets used are also diversified.

Nets used in hill streams:

Cast nets are used in small pockets of hilly regions. Different types of traps and cast nets are fixed in narrowgaps of streams. It catches fish during breeding seasons.

Nets used in Ponds and Lakes:

These are most commonly used for commercial fishing. Seines are large nets operated from boats. In biglakes and the Ganges, the most commonly used seine is Jagat Ber Mahajal. Simple drag nets are alsoemployed in ponds for commercial fishing.

Rangoon Nets and Uduvalai:

They are used in those lakes where use of seines and dragnets are not easy. Rangoon net is made by finecotton rectangular pieces of net. These pieces are tied in such a way so as to form a big wall. It is thenspread in water with the help of floats.The fish gets entangled in the net. Rangoon net is generally used for fishing in less deep water. However, indeep water bodies the use of uduvalai is preferred. It has small sinkers with footrope.

Gears used in rivers:

The following gears/ nets of different dimensions are used for fishing in rivers.

Seine and Drag Nets:They are most commonly used nets for fishing in rivers. Seines can be operated from one or more boats.

Purse Net: Special types of purse nets used for fishing in rivers are kharkijal and shanglojal or sharkijal. In shanglojal the mouth of purse can be opened or closed with a vertical cord. However, in kharkijal a vertical bamboo rod is fixed to the lower part of mouth of the purse to open or close it.

Common Inland Fishing Gears

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. 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. The two ends of the mouth are tied with floats.

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. 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.

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. They are also called drift nets as they drift vertically with the help of floats and sinkers. Among drift nets, Chhandijal is more popular. Three types of gill nets are in common use. They are :

Surface gill net-This gill net is generally meant for entrapping surface feeders among carps The fishes caught are generally surface feeders such as some major carps.

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. The catches are generally major carps.

Bottom 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.

Trammel Net

This net is a modified form of gill net, comprising three layers of gill nets. Because of this peculiar set up of three nets, fishes of various sizes are generally caught by this modified form of gill net

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. A strong cord or warp is attached to the apex of the cone or umbrella and a number of sinkers are fixed all along the circular periphery.

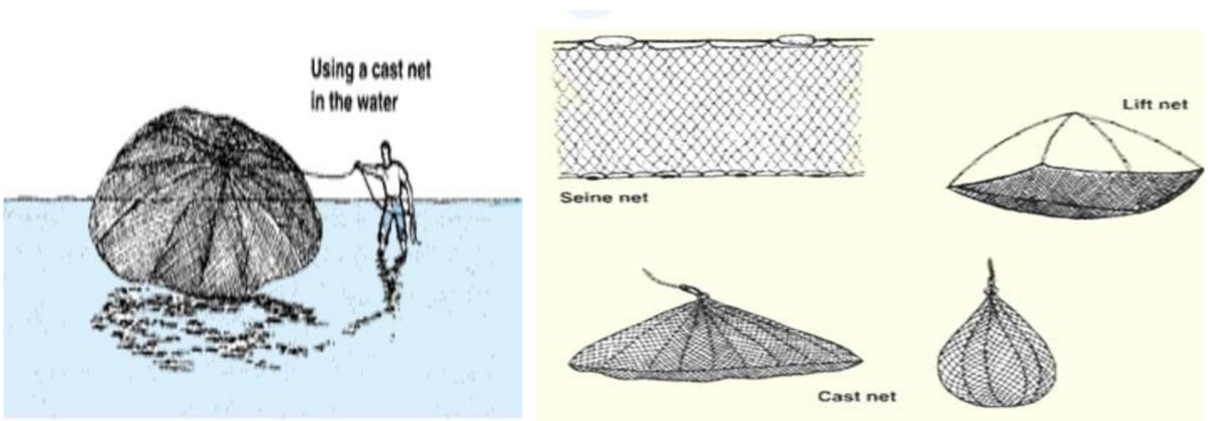


Fig 5.2 Cast Net

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 'Bhesaljal'), Kharrajal (another form of triangular dip net), Hela jal (anothertriangular net), Khorsulajal (rectangular dip net).

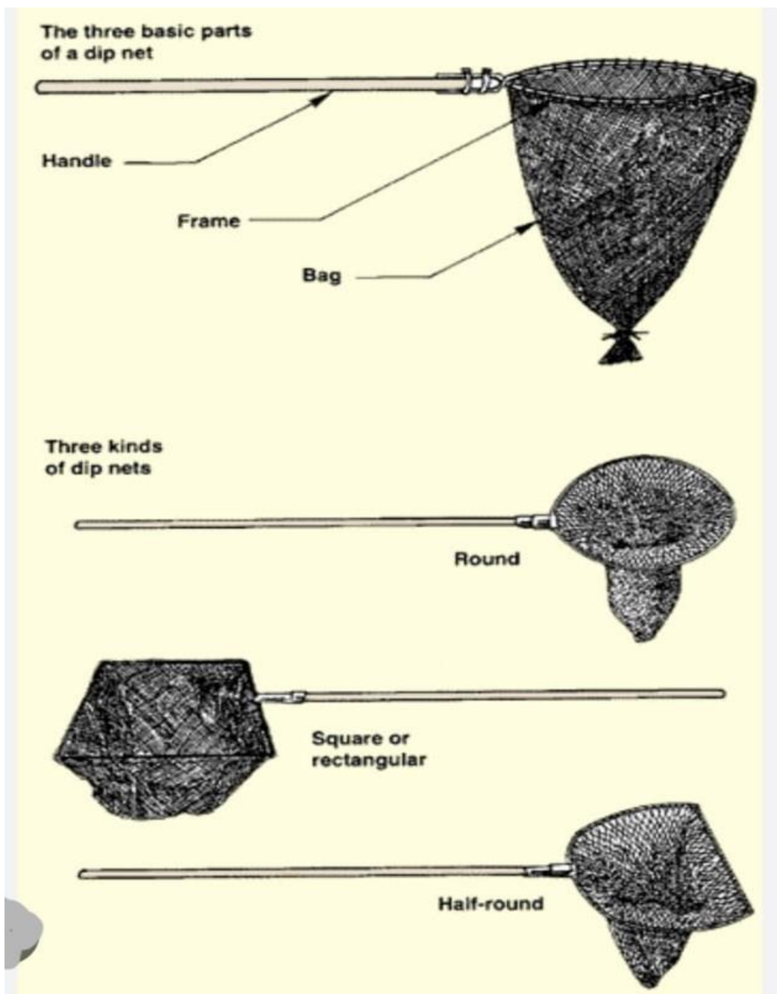


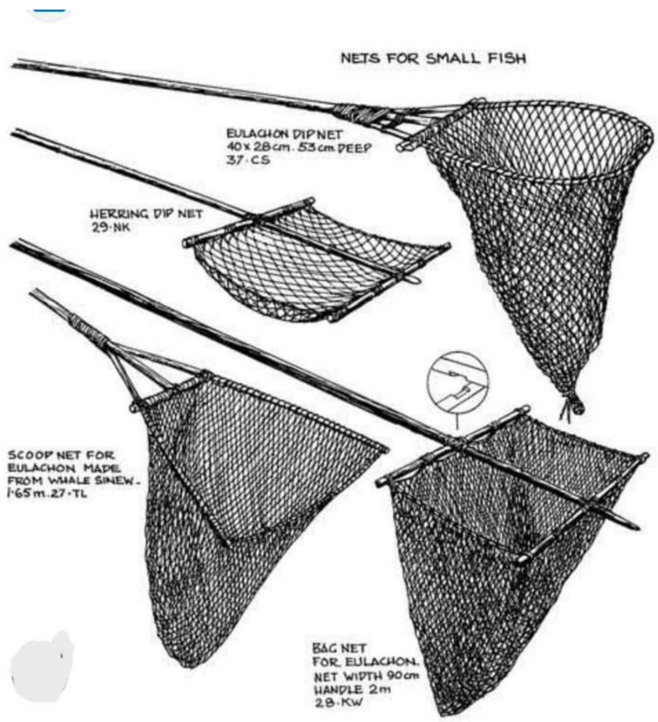
Fig .5.3 Type of Fishing Net

Purse Net

This is purse shaped net, operational from a boat. Two types of purse nets are in use: (a) Kharkijal and (b) Shangla jal.

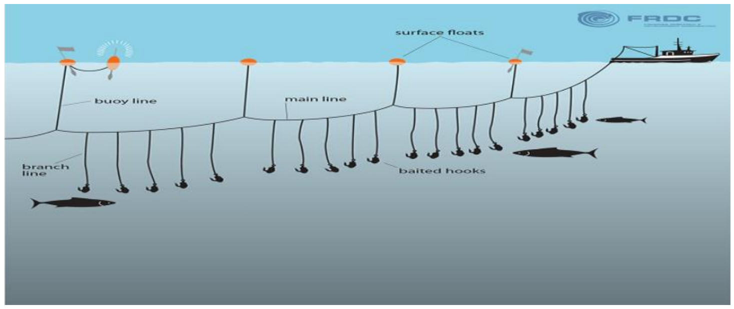
Bag set net

The bag set net has appearance of a conical type.The size of the mesh varies as perexpectation of kind of fish species to be caught. 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. The operation is generally done at night and the fishing places are long rivers, with the existence of some current in water, or streams joiningreservoirs or large tanks.



Hooks and lines

Among some other devices of minor grade for catching fishes, more popular are (i) poleand 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 is fixed to the hook, and the line with hook is dropped at a distance in front, after selecting a prospectivefishing 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.

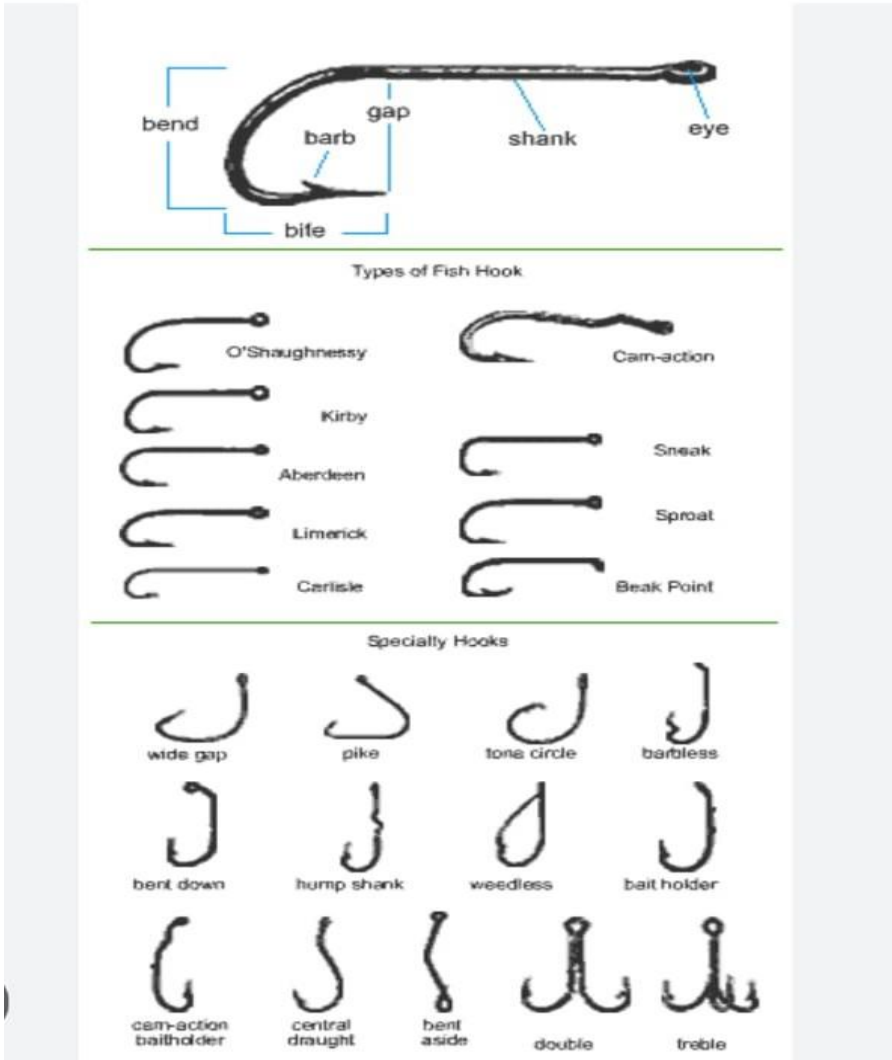


Fig 5.4 Type of Fishing Hoocks

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 useddepending upon the type of fish to be caught.

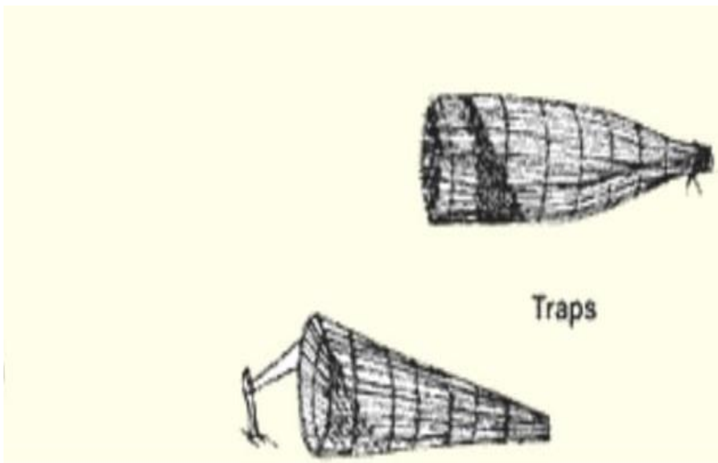
Hand line

The polyamide monofilament lines have a terminal lead sinker and a hook. Different types of baits are used according to the fish.Bait is a kind of 'lure', fixed on the hook, used for attracting the fish and then hooking it with the hook.

Dredges

Dredges are dragged gear, with an oblong iron frame with an attached bag net .

Traps



They are stationary nets and fishes are directed towards an enclosure through guarded entrance. The following types are used in inland waters.

Pots: They are small traps designed to catch fish. They are fabricated as small cages or baskets from locally available materials such as wood and wicker and alsoby using wire netting, metal rods,synthetic netting and reinforced plastic. Target organisms are enticed into the enclosure by bait or shelter spaces.

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.

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 .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 .

Fish Aggregation Device (FAD)

Fish Aggregation Device (FAD) is a man-made object that is used to attract fishes. Itconsists of buoys or floats tethered to the floor of the water body with concrete blocks.

5.5 NATURAL AND SYNTHETIC FIBERS

Netting yarns/twines forms the main part of majority of fishing gears. Apart from giving structure and shape to the gear, materials play a substantial role in resource and energy conservation. Netting materials for fabrication of fishing gear are either of textile or non-textile origin. Textile materials comprise of netting, twine and rope while floats, sinkers, hooks etc constitute non-textile origin materials. The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres.

Natural Fibres:

Different kinds of fibres originating from plant and animal body parts have been used for production of textiles and other products are termed as natural fibres.Fibres of plant origin such as that of cotton, manila, sisal, hemp, linen, ramie, coir etc. and of animal origin such as silk, hair etc are termed as natural fibres. Based on the source of origin, vegetable fibres come as seed fibre, fruit fibre, leaf fibre and bast fibre. Seed fibre is available from cotton (Gossipium sp.) while coir (Cocos nucifera) is a source of fruit fibre. Sisal (Agave sisalana), Abaca/Manila (Musa textiles) and pineapple leaf (Ananas comosus) are sources of leaf fibre. Examples of bastfibres are True hemp (Cannabis sativa), Indian hemp (Crotalaria juncea) and jute (Corchorus capsularis). While eco-friendliness and reasonable weather resistance are positive attributes for natural fibres, the high biodegradability (being cellulose in origin) and very short useful life time, when exposed to water, are negative attributes of natural fibres. To increase the service life, frequent preservation and protection measures are required which limit the effective and continued use of natural fibres in different fishing seasons. Moreover, on wetting, natural fibres absorb water and swell resulting in increased thickness, bulkiness and weight which limit the size of gear that can be handled from a boat. While eco-friendliness and reasonable weather resistance are positive attributes for natural fibres, the high biodegradability (being cellulose in origin) and very short useful life time, when exposed to water, are negative attributes of natural fibres. To increase the service life, frequent preservation and protection measures are required which limit the effective and continued use of natural fibres in different fishing seasons.

Synthetic fibres

Like elsewhere in the world, in India too, with the introduction of man-made synthetic fibres in the late 1950s, natural fibres used for the fishing gears have been substituted by these synthetic materials. This transition was mainly due to the highly positive properties of these fibres such as highly non-biodegradable nature, high breaking strength, better uniformity in characteristics, high abrasion resistance, low maintenance cost and long service life. Earlier, nettings used to be fabricated manually, which is laborious and time consuming while the introduction of synthetic fibres paved way for machine made nettings which revolutionized the fishing industry

Synthetic fibres have greatly extended the endurance of fishing gears, and together with mechanized vessels, have increased the size and complexity of nets. It is stated that synthetic fibres brought to one of man's oldest occupations, the miracle of science and in doing so provide easier living for the fishers.. This structure gives the fibre the properties required for a textile fibre. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene etc.

Polyamide fibres (PA): Polyamide, a synthetic polymer, popularly known as nylon.

Polyvinyl chloride: They are used in outdoor fabrics, such as tarps, awnings, rain gear and fishing nets.

Polyvinyl alcohol:They are durable and resistant to abrasion and wrinkling. Some polyvinyl-alcohol fibers are more hygroscopic than any other synthetic fiber. The fibers are resistant to light, microorganisms, sweat, and various chemical reagents . Industrial fibers are used in the production of cables and fishing equipment.

Polyethylene (PE): It has high crystallinity, melting temperature, hardness and tensile strength. In India, PE is used for manufacture of netting and ropes.

Polypropylene (PP): PP netting and ropes are available, in India. They do not absorb moisture and have a high resistance to UV degradation.

Polyester (PES): It was named the fibre "Terylene”.

Later introductions

Introduction of synthetic materials with high tensile strength properties has made it possible to bring out changes in the design and size of fishing nets. As the fishing industry became highly competitive, the search and research for new generation materials which give better strength for less thickness resulted in invention of new materials. Aramid fibres, Kevlar, UHMWPE, biodegradable plastic etc are recent introductions to the fishing gear material sector.These materials have advantages, especially less drag which results in fuel efficiency. Synthetic netting yarns/twines forms the main part of majority of fishing gears. Apart from giving structure and shape to the gear, materials play a substantial role in resource and energy conservation. Plastic materials due to very good strength, durability and other vital properties, are extensively used in fisheries. The introduction of synthetic fibres has revolutionized the fishing industry and it can be considered as the major single factor which led to the development of today’s efficient fishing gears. However, the responsible use and disposal of materials are very essential for resource conservation, energy saving and ecological well-being

5.6 PREPARATION AND MAINTENANCE OF FISHING NETS

Netting is defined by International Organization for Standardization (ISO) as a meshed structure of indefinite shape & size, composed of one yarn or one or more systems of yarns inter laced or joined or obtained by other means for example by stamping or cutting from sheet material or by extrusion . Netting materials for fabrication of fishing gear are either of textile or non-textile origin. Textile materials comprise of netting, twine and rope while floats, sinkers, hooks etc constitute non-textile origin materials. The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. Traditional fishing gears used earlier, till 1950s were made mainly with natural fibres such as cotton, manila, sisal, jute and coir. With the introduction of man-made synthetic fibres in the late 1950s, natural fibres used for the fishing gears have been substituted by these synthetic materials. This transition was mainly due to the highly positive properties of these fibres such as highly non-biodegradable nature, high breaking strength, better uniformity in characteristics, high abrasion resistance, low maintenance cost and long service life. Fishing Nets made from synthetic materials which makes them stronger, lighter and cheaper.With the development and wider availability of synthetic gear materials, recent advances in vessel technology, navigational electronics, gear handling machinery, fish detection methods and fish behaviour studies, large-scale changes have taken place in the design, fabrication, operation and catching capacity of modern fishing gears such as trawls, purse seines and long lines. Widely used traditional fishing gears such as entangling nets, hook and lines and traps have also benefited by way of design upgradation and efficiency improvement in the recent years

Properties of fiber used for making fishing nets

Choice of material for different gears Even though different types of synthetic fibres are available, an ideal material satisfying all the requirements of different fishing gears does not exist. The various types of synthetics having different qualities provide a range of choice for selecting the best suited material for each type of gear. The choice of material depends not only on the technical properties but also on the local availability and price. For each type of gear, a particular property of the material may be important; for example, sinking speed for purse seine, transparency and softness for gillnets, high breaking strength and abrasion resistance for bottom trawls etc.Synthetic netting materials generally are resistant to biodeterioration i.e., they are resistant against destruction by mildew in air and bacteria in water. This is the major advantage of synthetics over natural fibres and it is the prime requisite for a fibre for consideration as a fishing gear material. Besides, synthetic fibres have high breaking strength, better uniformity in characteristics, long service life and low maintenance cost. However, unlike natural fibres, they are prone to degradation under sunlight at a much faster rate. As far as the fishing gear purpose is concerned, properties which are of importance are linear density, diameter, specific gravity, knot stability, breaking load, elongation, weathering resistance and abrasion resistance.

Diameter: The diameter of netting material is an important factor influencing the fishing gear performance. Thickness and rigidity of the material influences the resistance of fishing gear to water flow and hence the power required or the speed obtained in towing gears are depended on it. Thinner twines offer less resistance.

Linear density: It is the mass per unit length of the material. The mass in g of 1000 m length of a material is expressed as R tex and mass of 9000 m of the material as R denier. While comparing different types of yarns, the Rtex values serve as a relative measure for the mass of netting. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis.

Specific Gravity: Specific gravity of most of the synthetic fibres is less than the natural fibres. Specific gravity influences the fishing gear as fibres with lesser specific gravity allows a greater length of netting for a given weight of yarn and helps in savings in handling and power.

Twist: The number of turns or twists imparted to a twine per unit length is important as it influences many properties especially the breaking strength, diameter, linear density, resistance to abrasion and general wear and tear of the twine.

Breaking load and elongation: The breaking strength/load of a material denotes the ability of a material to withstand the strain. It depends on the type of polymer, type of yarn, degree of twist and thickness of the material. The strength of fibre changes in the wet condition; in natural fibres the wet strength is higher while the reverse is true of synthetic fibres. Knotting also causes reduction in the breaking strength. This is dependent on the type of polymer, type of yarn and knot, twine construction and also on the degree of stretching.

Weathering Resistance: Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The main factor responsible for weathering is the sunlight, i.e. the ultra violet part of the sun's radiation. Different synthetic fibres show variation in their susceptibility to and rate of deterioration by sunlight depending on the type of polymer and fibre. PVC has very high resistance against weathering, while PES has high and PA and PE, have medium resistance against weathering.

Environment friendly fibre- In the fishing industry, environment friendly fishing line made of biodegradable polymer made from poly butylene succinate (PBS) is a recent development.`Bioline'is a commercial fibre made from PBS which retains its strength and durability for few months of use and then completely degrades in water (salt or fresh water) through the enzymatic reactions of naturally occurring microorganisms in the water. It does not deteriorate when kept clean and dry, but when exposed to bacterial activity underwater or underground, it deteriorates viz., it retains its strength and durability for the first 10-12 months of use and then completely degrade in water or on land within five years. FIELDMATE™ is another example for biodegradable polymer. If exposed for three months in salt or fresh water, it decomposes through the enzymatic reactions of naturally occurring microorganisms, before eventually being reduced to water and carbon dioxide.

Basic terms used in netting

Fibre: The basic material of netting, has length at least 100 times its diameter.

Netting yarn: It is the standardized universal term for all textile material which is suitable for manufacture of netting for fishing gears and which can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process.

Netting twine: or folded yarn is a netting yarn which is made of two or more single yarns or monofilaments.

Cabled netting twine: Combines two or more netting twines by one or two further twisting operations. Fibres are combined to form single yarns. Several single yarns are twisted together to form a netting twine. Several of these folded yarns or netting twines are twisted together by a secondary twisting operation to form a cabled netting twine.

Braided netting yarns: These are produced by interlacing a number of strands in such a way that they cross each other in diagonal direction.

Fishing gear construction

Fishing gear design

Design process for fishing gear has been greatly influenced in the recent years by the resource management and conservation, environmental safety and energy efficiency imperatives. Design process involves a divergent phase when analysis of the situation, statement of needs, specifications, standards of operation and constraints are spelt out; a transformational phase which includes generation of design ideas; and a convergence phase during which an evaluation in terms of objectives of design, utility and economic viability, prototype development, testing and evaluation takes place

Model testing

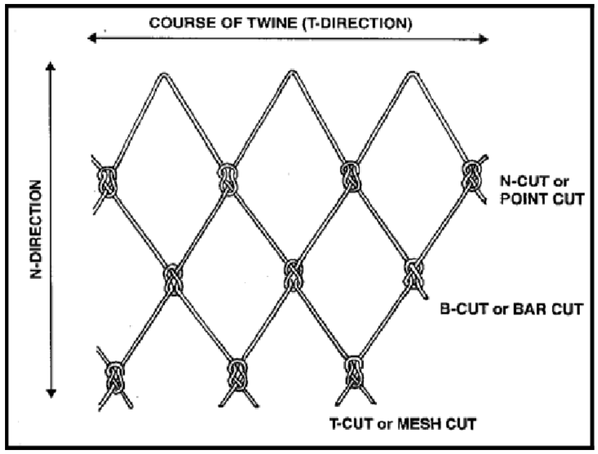
Model testing is increasingly used for design evaluation of the existing commercial fishing gear designs with a view to optimise their design parameters and for development of newer designs. Factors affecting fishing gear design Important factors which influence the design of fishing gears are (i) biology, behaviour and distribution of target species; (ii) fishing depth, current and visibility; (iii) sea bottom conditions; and (iv)other factors such as the scale of operations, size and engine power of fishing vessel, energy conservation objectives, selectivity and resource conservation objectives.

Shaping of netting

Each netting panel used in the construction of fishing gear can be derived from one ormore sections of particular geometric shapes such as rectangle, trapezium or triangle each with auniform mesh size and twine specifications .The shape of these component piecesconstituting the netting panels is achieved by increasing, decreasing or maintaining the numberof meshes in the N-direction or T-direction This is done by shape cutting the pieces frommachine made webbing. Three types of cuts viz., N-cut, T-cut and B-cut are used to shape the netting.

Taper ratio

Netting sections required to make up the gear panel are cut according to pre-calculated taper ratio from the machine made netting.



Types of cuts used to shape netting

Cutting rate

Cutting rate is regular repeated cycle of N-cuts; T-cuts; B-cuts; N-cuts and B-cuts; or Tcuts and B-cuts made in the correct proportion to obtain the required taper ratio. Netting usage can be economised by careful planning of thecuts of the complementary pieces used in gear construction.

Assembly of netting

The various constituent pieces of netting panels prepared by shape cutting, are assembledby either joining or seaming. Joining requires braiding an extra row connecting the two panels.In seaming, one or several meshes on the edge of each panel are re-joined together bylacing.

Design drawings and specifications of fishing gears

Design drawing of the fishing gear should provide all information relating to the size,shape, material and construction using recognised nomenclature and symbols.

Steps in Fishing gear construction

Extruding process - Nylon chip will be extruded to be a nylon monofilament fishing line.

Twisting process- In this stage, the extruded Nylon Monofilament Fishing Line will be twisted into Nylon Monofilament Net. While PE Monofilament is twisted from Polyethylene Net (PE)

Weaving process- The finest twine will be fed into the weaving machine with a computerized system and controlled by highly-experienced staff to ensure that tight knot, precise mesh size, At Running.

Dyeing process- we can design the character of the products, such as coloring, brightness, shine, and softness to meet our customer requirements.

Stretching processLengthway/Vertical Stretching (TATE): The nets will be heat-set by stretching according to the length of the net.

Packaging process- Finished goods will be packed perfectly with a standard plastic bag as per our premium quality standard in order to make sure that the goods will be in a good condition when delivered to our customers.

Maintenance of Fishing Gears:

Proper care and handling of fishing gears after their use is as important as their use. Proper maintenance increases the durability of the gears.Following care is necessary:

1. The gear should be washed thoroughly with the clean water and weeds and mud, etc. should be removed carefully.

2. Then dip the net in dilute $KMnO_4$ or $CuSO_4$ or common salt solution to get rid of harmful bacteria.

3. Wash again with clean water and then spread in shade for drying.

4. To increase durability and strength of the fibre of gear, it may be kept immersed for 10-15 min in hot tar

diluted with kerosene

5.7 DIFFERENT FISHING METHOD

The fishes are one of the main exploitable resources of the aquatic ecosystems that provide a major source of protein. Fishing technology is the discipline dealing with the natural sciences and technology for optimizing fish capture and fishing operations. Fishing techniques are methods for catching fish. Fishing techniques include hand-gathering, spearfishing, netting, angling and trapping. Recreational, commercial and artisanal fishers use different techniques, and also, sometimes, the same techniques.

Fishing without gear

Blast fishing

Dynamite or blast fishing is done easily and cheaply with dynamite or homemade bombs made from locally available materials. Fish are killed by the shock from the blast and are then skimmed from the surface or collected from the bottom.

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.

Pesticides

The most commonly used pesticides are Nuvan, Thiodon, and Malathion.These pesticides are applied in high concentrations to the areas with high probability of catching fishes. The application of pesticides not only damages the ecosystem but also affects the health of human beings.

Bleaching powder and lime

Bleaching powder and lime are two chemicals easily available in the Kumaon region, used to kill fishes. Soon after its application the fishes come to the water surface.

Electro fishing

This is another modern technique confined to the urban areas. The main objective of this method is tocapture fish by applying electric current to the stream water. Portable generator sets are used to apply electric current through the stream water.

Hammering

The upland stream fishes use the boulders as one of its hiding covers. When a strong blow is given on the boulders using a hammer, the fishes hiding beneath it are injured (Fig. 2). The injured fishes, including the small sized are collected.

Water diversion

This method is practiced where one or more secondary streams is found within a channel (Fig. 3). The water in one of the secondary streams is diverted to the other by blocking one stream with mud, boulders, and plants. Thereafter, the fishes are collected from the stream. This method is practiced in fast moving water habitats of the stream.

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.

Trap for jumping fish hand picking- In this method, the fishermen move intothe stream and chase the small fishes hidingbeneath the rocks

Fishing with gear

Type of Gears according to their mobility

Active nets: These are moved by man-powers (group of persons) or machine power to encircle theshoal of fish and bring them to shore (bank). In active netting, the floats and sinkers areso 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).

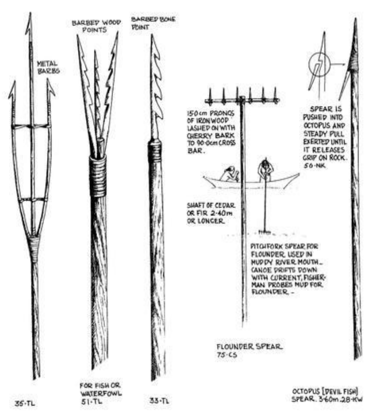
Passive net: These remain stationary at a place and the fish moving around are caught or gilled. Thenet is either set at the bottom with the help of anchors and stakes (stake net), or suspended at intermediate depths with the help of drop-lines from larger buoys at the surface or suspended near the surface 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.

Sticks

In shallow streams, the stick is often the best instrument to catch the mighty T. putitora. During monsoon, the T. putitora migrates to small streams. And takes shelter in the small shallow streamlets where it can be easily recognized. The local people beat it with sticks and kill the trapped fish.

Fishing by hunting

Spear- It is the earliest weapon employed by man and still in use to-day in many parts of theworld. A 'Spear' tip is fitted on a bamboo shaft and operated by throwing on the target from a boat or standing on the bank.



Spears and Harpoons

The harpoon – It has a shaft of about 3 m long to one end of which is attached a barbed iron point (single or double). The rake is a highly specialized weapon consisting of a long and thin blade at each end (look like a double-bladed oar)

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

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.

Hand-gathering

It is possible to harvest many sea foods with minimal equipment by using the hands

Noodling: noodler places his hand inside a catfish hole. If all goes as planned, the catfish swims forward and latches onto the noodler's hand, and can then be dragged out of the hole

Trout binning - Another method of taking trout. Rocks in a rocky stream are struck with a sledgehammer. The force of the blow stuns the fish.

Trout tickling - the practice of catching trout by hand is known as trout tickling

Spearfishing

Spearfishing is an ancient method of fishing conducted with an ordinary spear or a specialised variant such as a harpoon, trident, arrow or eel spear. Some fishing spears use slings (or rubber loops) to propel the spear.

Netting

Fishing nets are meshes usually formed by knotting a relatively thin thread. Netting is the principal method of commercial fishing, though longlining, trolling, dredging and traps are also used.

Cast nets - are round nets with small weights distributed around the edge. They are also called throw nets. The net is cast or thrown by hand in such a manner that it spreads out on the water and sinks.

Drift nets - are nets which are not anchored. They are usually gillnets, and are commonly used in the coastal waters of many countries.

Gillnets - catch fish which try to pass through by snagging on the gill covers. Trapped, the fish can neither advance through the net nor retreat.

Hand nets - are small nets held open by a hoop. They have been used since antiquity. They are also called scoop nets, and are used for scooping up fish near the surface of the water. They may or may not have a handle–if they have a long handle they are called dip nets.

Lift nets - are a method of fishing using nets that are submerged to a certain depth and then lifted out of the water vertically. The nets can be flat or shaped like a bag, a rectangle, a pyramid, or a cone. Lift nets can be hand-operated, boat-operated, or shore-operated. They typically use bait or a light-source as a fish-attractor.

Seine nets - are large fishing nets that can be arranged in different ways. In purse seining fishing the net hangs vertically in the water by attaching weights along the bottom edge and floats along the top.

Surrounding nets -

Tangle nets - also known as tooth nets, are similar to gillnets except they have a smaller mesh size designed to catch fish by the teeth or upper jaw bone instead of by the gills.

Trawl nets - are large nets, conical in shape. The trawl is pulled through the water by one or more boats, called trawlers. The activity of pulling the trawl through the water is called trawling.

Angling

Angling is a method of fishing by means of an "angle" (fish hook). The hook is attached to a line, and is sometimes weighed down by a sinker so it sinks deeper in the water. This is the classic "hook, line and sinker" arrangement, used in angling since prehistoric times. The hook is usually dressed with lures or baits such as earthworm, doughball and bait fish.

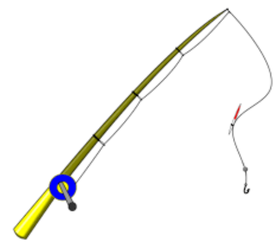
Line fishing

Line fishing is fishing with a fishing line, but not using rods. A fishing line is any cord made for fishing. Important parameters of a fishing line are its length, material, and weight (thicker, sturdier lines are more visible to fish

Rod fishing

Angling with a rod-

Angling with fishing rods give more control of the fishing line, and allows the bait/lure to be launched much farther than hand-throwing can reach. The rod is usually fitted with a fishing reel which functions as a mechanism for storing, retrieving and paying out the line. The hook can be dressed with lures or baits.



Fishing Rod

Trapping

Fish trap- Traps are culturally almost universal and seem to have been independently invented many times. There are essentially two types of trap, a permanent or semi-permanent structure placed in a river or tidal area and pot-traps that are baited to attract prey and periodically lifted.

Artisanal techniques

Dam fishing - An artisanal technique called dam fishing. This involves the construction of a temporary dam resulting in a drop in the water levels downstream—allowing fish to be easily collected.

Basket weir fish traps -Thesewere widely used in ancient times. Basket weirs comprise two wicker cones, one inside the other and easy to get into and hard to get out.

5.8 SUMMARY

Inland fisheries are any activity conducted to extract fish and other aquatic organisms from "inland waters". Fisheries in inland waters have long provided an important source of food for mankind. Inland fisheries are critical for a group of developing countries in the world, providing an important source of nutrition and income. Individuals can relatively easily begin fishing in inland waters because basic equipment needs (e.g., nets, hooks, traps) are generally inexpensive and do not require substantial skill to operate or maintain. Despite being 'low-tech, and inexpensive, these fishing techniques are highly effective at catching large amounts of fish and are used extensively in inland fisheries around the globe (Welcome et al, 2010).

Fishing nets and gears are refers to those devices having different shape and sizes and used in the water body to capture different sizes of fishs. Various fishing nets, fish poison and use of explosives were main part of this state fishing methods. Gill net, Cast net, Dragged net, Dip net, Hand net, Hanging rope, Trap, Hook, Line and Explosives were mainly used other than that six chemical poisons and thirteen Icthyo-toxic plants were observe which was used by the local fishermen. Explosives and Icthyo-poisons were polluting and damaging aquatic ecosystem by various ways and was one of the main causes of aquatic biodiversity loss.The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. Different kinds of fibres originating from plant and animal body parts have been used for production of textiles and other products are termed as natural fibres. Traditional fishing gears used earlier, till 1950s were mainly with natural fibres such as cotton, manila, sisal, jute and coir. Like elsewhere in the world, in India too, with the introduction of man-made synthetic fibres in the late 1950s, A variety of synthetic fibres are used as fishing gear material. Netting yarns/twines forms the main part of majority of fishing gears. Apart from giving structure and shape to the gear, materials play a substantial role in resource and energy conservation.

5.9 TERMINAL QUESTIONS AND ANSWERS

Q. 1 - Describe different type of Inland fishing gears with diagram

Q. 2 - What are the Biological factors in fishing?

Q. 3- Explain in detail about Types of fishing gears used in Inland fishing

Q. 4 - Describe Natural and synthetic fibers used for fishing gears

Q. 5 - Explain the process of Preparation of fishing nets

Q. 6 - Write about maintenance of fishing nets

Q. 7 - Explain Inland fishing method with diagram

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UNIT 6: COLD WATER AQUACULTURE AND ITS SCOPE IN UTTARAKHAND

6.1 OBJECTIVES

After studying this module, you shall be able to learn and understand :

- Coldwater Fisheries
- Scope of aquaculture for sustainable livelihood in Uttarakhand
- Aquaculture of cold water fishes
- Polyculture of carps
- Sewage feed fisheries

6.2 INTRODUCTION

Fisheries is an economic activity that involves harvesting fish directly from the natural resources (Capture Fisheries) or culture them in confinement (Aquaculture). It may be Traditional/ Small Scale Fisheries for sustenance, or Large-Scale/ Commercial Fisheries for profit.From very ancient time, the fishes are thecomponent of food and also as a great source of commerce and recreation. They also provide us a number of by products which are very useful for humans and their economic value is very high. Due to this, people started Aquaculture to fulfill their food and economic needs. Fish culture is a very ancient industry and nowadays it has become a large industry and is known as Pisciculture

The development of the hilly state of Uttarakhand requires a strong and comprehensive economic base. The economic development of the state can be given a new dimension through proper scientific and commercial use of the available natural resources. The state, is a very rich in terms of water resources. There is immense wealth of water resources which exist in the form of rivers, lakes, reservoirs and ponds. Due to the mountainous landscape and cold climate, the water resources here are cold water as well as pollution-free . The province is also fortunate in terms of biodiversity. Along with the diversity of many organisms and plants , about 100 species of cold water fish are found in the natural water sources here. 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 0o C to 20o C with an optimum range from 10o – 12oC. In India, lakes and streams located 914 m above mean sea level where the Indian major carps do not live, qualify for coldwaters. The characteristics of coldwater lakes include high oxygen, low carbon dioxide, inorganic soil, sparse vegetation and food, low fertility and high transparency. The rearing of almost all native and Chinese fishes is prevalent here. Given the breadth of water resources, the diversity of fish species and the importance of fisheries industry at present , cold aquatic fisheries in the State of Uttarakhand.The state's strong fisheries industry is very important for the development of the state , it can make the broad economic base for the development of rural people by giving employment to the rural people and common man .Polyculture or composite fish culture is based on the concept of total utilization of different trophic and spatial niches of a pond which results in maximum fish production. The combination of different fish species gives better utilization of available natural food in a pond. The compatible fish species having different feeding habits are reared so that all the niches of pond ecosystem are properly utilised.In order to obtain high production per ha of water body, fast growingcompatible species of fish of different feeding habits, or different weight classesof the same species, are stocked together in the same pond so that all itsecological niches are occupied by the fishes. This system of pond managementis called mixed farming or composite fish culture or polyculture

The farmers observed that there were differences in the feeding habits and different preferences for natural food organisms. This led to the thought of adjusting the stocking densities according to the occurrence of natural food and the niche occupied by each species in the ponds. Thus, it could be beneficial in traditional production systems by culturing appropriate species combinations.Such a practice could effectively lead to the utilisation of a much larger quantity of food resources and developing a symbiotic relationship between the cultured species in the system. This would lead to higher production at a lower cost and the farm environment can be maintained at required levels.

Sewage is universally considered as a valuable organic fertilizer as it contains abundant quantities of nutrient elements. In general way, the term sewage is used for a combined liquid waste discharged from all domestic, municipal and industrial sources within a given area. sewage fed fisheries is a new idea for India. Fish culture in sewage system involves little investment with high yield. A sewage itself provides fertilizers and supplemented food to pond. This reduces the cost of culture and at the same time the growth rate of fish in such ponds is also faster. In India the practice of sewage fed fisheries is not very popular.

6.3 SCOPE OF AQUACULTURE FOR SUSTAINABLE LIVELIHOOD

In terms of the scenario of economy of India, fisheries plays an important role by providing food security, generating big employments and also small livelihoods, and earning foreign exchange for the country.

Uttarakhand, one of the Hilly states of India has enormous freshwater fisheries resources that comprised of 2,700 km of rivers, 24,200 hectares of reservoirs, 297 hectares of lakes and about 2000 hectares of ponds. The state comprises two major regions namely Kumaon and Garhwal and both the regions are blessed with an abundance of aquatic resources. Since, water temperature in the hills falls below 20°C, the exotic carps (common, grass and silver carps), mahseers and other such coldwater fishes that can grow and survive at lesser temperature are more suitable for use in hill aquaculture. Among all the cultured species; Silver carp, Grass carp and Common carp are reported to perform better in composite culture system in the mid altitude conditions. Common carp plays an important role in augmenting fish production especially in the hill states of the region. Since the size of fish ponds in the hill areas are small and principally rain fed and seasonal, the small-scale integrated aquaculture utilizing available on-farm resources has great potential.

Food and nutritional security are global challenges. It is more of a problem in the hilly region; there are both challenges and opportunities in hill fisheries and aquaculture. mountain states are the major hilly regions, which have a huge scope for coldwater fisheries and aquaculture. Fish is a healthy food and is a rich source of all nutrients (except carbohydrates) and in combination with rice/wheat (carbohydrate rich) make a complete diet. Most of the coldwater fishes are quiet nutritious with high proteins (16-18%) and are moderately rich in oils (*Labeo dyocheilus* 5.7%, *Tor putitora*, 4.3%) and the polyunsaturated fatty acids (PUFAs), EPA in *Schizothoraxrichardsonii* and DHA in *T. putitora*. The PUFA content of some of the coldwater fishes are comparable or close to the marine fishes. Some coldwater fishes are very rich in essential amino acids arginine (*T.putotora*) and tyrosine (*T. putitora*). Similarly, some of them are rich in micronutrients calcium (*N. hexagonolepis*), iron (*N. hexagonolepis*) and zinc (*Cyprinus carpio*). If the coldwater fisheries and aquaculture production reach its potential, it could not only provide nutritional security to the hilly region but would ensure livelihood security also, owing to their nutritional richness. Thus, the coldwater fisheries and aquaculture sector needs special focus for increasing farmer's income as well as providing nutritional and livelihood security to the hill people. Understanding it, the aquatic resources in hills are quite valuable for the development of fishery both for food, sport, recreation and employment but scientific management of these resources is necessary to achieve the objectives. In order to manage these ecosystems, it is necessary to take up appropriate strategic plans and action so that hill aquatic resources and aquaculture activities may contribute to fishery and aquaculture substantially in remote hilly regions on a sustainable basis.

There is a vast scope and potential in improving fish production in hills by bringing natural Himalayan lakes located at different altitudes, under scientific management for fishery enhancement.This would actually reduce the gap between actual fish yield and production potentials. Through application of modern techniques, significant scope exists for promoting trout farming, which in long run, will have both domestic and export demand. There is also a great potential for sport fishery development and ecotourism in hill regions. Use of modern techniques such as molecular and biotechnological intervention, selective breeding programme for improvement of strains both of exotic and indigenous species, coldwater fish health management for the containment of diseases have now become imperative. Ornamental fish culture for small scale enterprises in the hills can provide an alternative source of employment.

6.4 AQUACULTURE OF COLD WATER FISHES

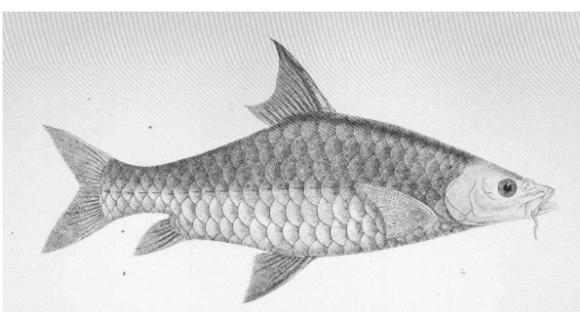
India has significant coldwater fishery resources in terms of gene pool, and some of them being suitable for food, sport and ornamentalpurpose.The Coldwater natural resources includes around 8243 km long streams and rivers, 20500 ha natural lakes, 50000 ha of reservoirs both natural and manmade and 2500 ha brackish water lakes at high altitude. Coldwater fishes occupy an important place amongst the freshwater fishes of India. The coldwater fisheries deal with fisheries activity in water where temperature of water ranges from 5 to 20 degrees centigrade. The gills of cold water fish are greatly reduced and the gill opening are smaller in size for adaptation to cold temperatures. Important coldwater fishes of India are Mahseers such as *Tor putitora, T. tor, T. khudree, T. mosal,* Snow Trout such as *Schizothoraxrichardsonii* and *Schizothoraichthysesocinus*, Mountain Trout such as *Barilius vagra, B. bendelisis*, other fish such as *Glyptothorax sp., Garra sp.*, etc.**Exotic trouts**: *Onchorhynchusmykiss ,Salmo trutta* *fario*.**Exotic carps**: *Cyprinus carpio var. specularis C. carpio var. communis C. Carpio Var. nudus CtenopharyngodonIdella,Hyphthalmichthys molitrix,Carrasiuscarrasius.***Minor carps**: *Labeo dyocheilus, Labeo dero,Chaguniuschagunio, CrossocheiluslatiuslatiusGaragotyla, G. hughi,* **Barils/Minnows/Catfishes/ Loaches**: *Barilius bendelisis B. bakeri B. vagra B. barilaRaimas bola Danio divarioBotiabirdiGlyptothoraxpectinopterus G. conirostreconirostre*.

The state Uttarakhand is blessed with plenty of natural beauty, including ice covered Himalayan Peaks and centre of beauty is many freshwater streams and snow fed rivers all along the landscape. The head water of the holy river Ganges such as Alaknada and Bhagirathi rivers take origin from Garwal Himalaya and the other major tributaries like Ramganga and Kali river drain along the Kumayan region of Uttarakhand region. The important game fishes reported from this regions are: golden mahseer (*Tor putitora*), silver mahseer (*Tor tor*), goonch (*Bagariusbagarius*), Mully (*Wallago attu*), murrels (*Channa spp*.) and snow trout (*Schizothorax spp*.).

Species of Cold Water Fisheries:

(1) Mahaseer:

There are 4 species of mahaseer. It has a big head hence it is known as Mahaseer. Two of them are edible fishes and are of commercial use, they are *Tor putitora* and *Tor tor.*



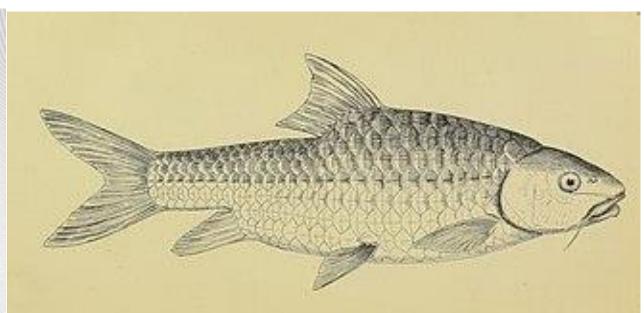


Fig 6.1 :(a) Tor tor(b) Tor putitora

(2) Snow Trout:

Two genera are present; *Schizothorax Spp.* and *Schizothoraichthys*are endemic to Kashmir and Ladakh while *Schizothoraxprograstus* occurs in Eastern Himalayas up to certain stretch. *Schizothoraxrichardsonii* is distributed almost all along the Himalayas.

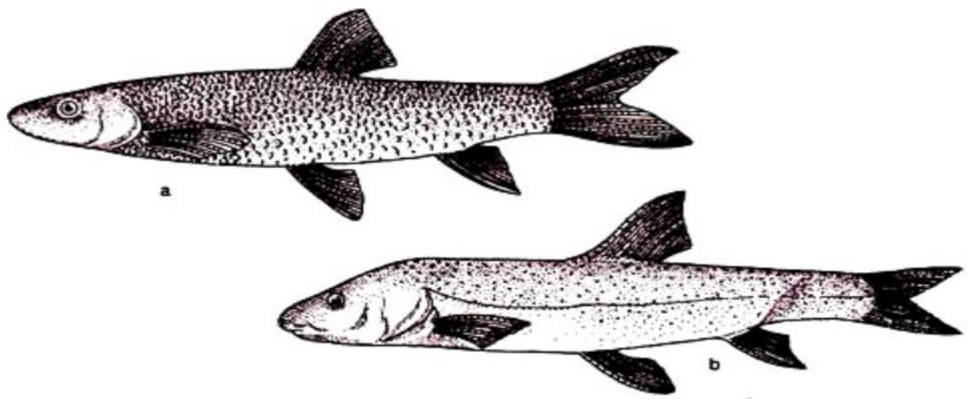


Fig: 6.2 (a)Schizothorax Spp.(b)Schizothoraichthysesocinus

(3) Barilius:*Barilius vagra, B. bendelisis and, B. bola* fishes are also called as Mountain trouts .

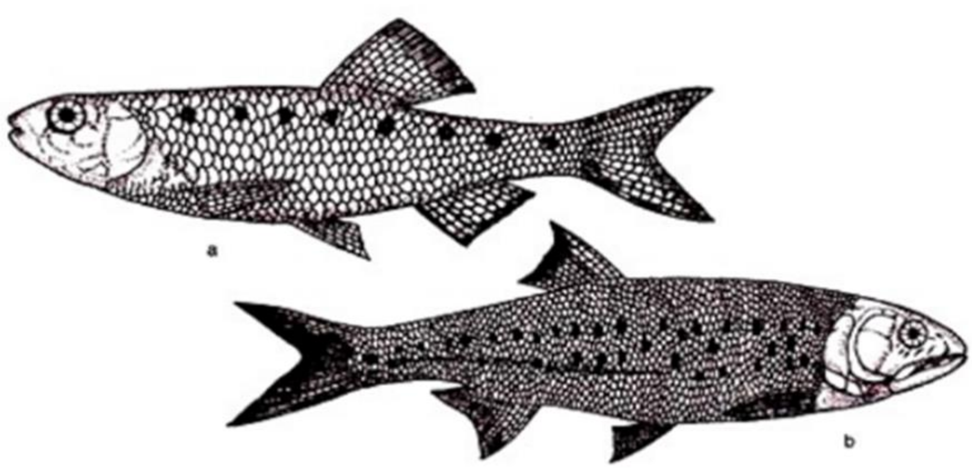


Fig: (a)Barelius bendelisis (b)Bariluis bola

(4) ***Labeo*****:**The fishes which are present in mountain rivers are minor carp and have no significance as commercial fisheries. The fishes are *L. dero, L. dyocheilus and Crossocheiluslatius.*

(5) ***Garra*****:**There are two species found in lakes of the Himalayas as they are not edible fishes but are relished as food of fishes. They are *Garra lamta* and *Garra gotyla*.

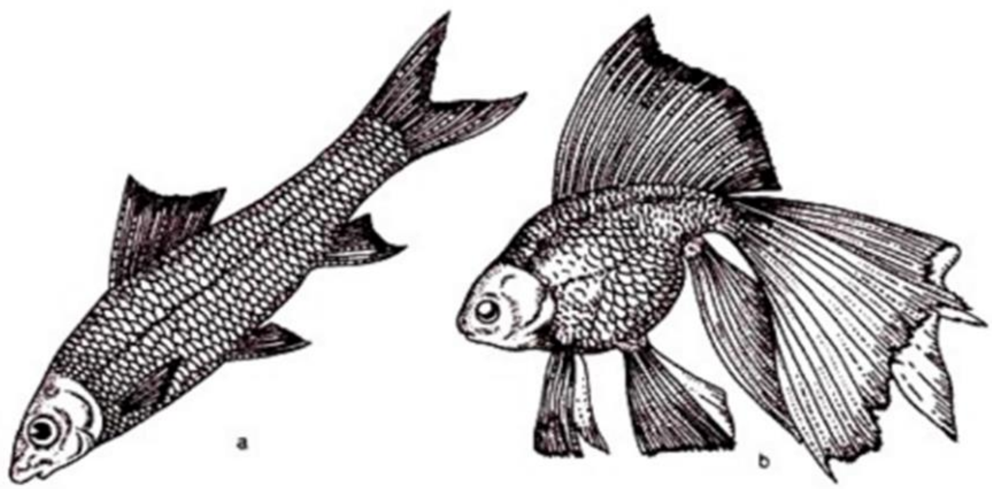


Fig:(a)Labeo dero(b)Carassious auratus

Exotic Fishes:

1. Trouts: Thefew trouts are now acclimatized in the streams, lakes and reservoirs in Indian waters. These are brown trout*Salmo trutta fabrio, Salmo eredius, Salmo gairdinarii*and *Oncorhynchus mykiss* (rainbow trout), *Oncohrynchusnakrii*

2. ***Cyprinus Carpio*****:** The culture is being successfully done by induced breeding methods.

Flow through Hatchery:

This is device for rearing fish seed up to the fry stage. It has been designed and fabricated by **National Research Centre on Coldwater Fisheries** at Bhimtal in Kumaun hills. It has the capacity of incubating 0.225b million eggs.The capacity of flow through hatchery further increased with installation of more troughs/ trays and nursery facilities with substantial increase in the quantity of water through overhead tanks. This method gives 30% more survival rate from traditional pattern.

6.5 POLYCULTURE OF CARPS

When different species of fast growing compatible fishes, occupying different ecological niches of a pond or any water body, are cultured together, they most efficiently utilises all the food sources available in the pond for fish production without harming each other.

Objectives of Polyculture:

(1) To obtain maximum yield or fish production.

(2) To utilise all the available niches.

(3) The fishes cultured should not cause any ecological disbalance.

(4) The fish species cultured should not have any serious competition between them but each species may have a beneficial influence on growth and production of the other. For example, grass carp by consuming aquatic vegetation, converts plant tissue into fish flesh but its excreta fertilises the pond which benefits all other species.

(5) Some species of fishes are cultured which have specific roles to play in maintaining water quality in ponds by feeding on wastes accumulated in it. For example common carp and mrigal consume the faeces of grass carp and silver carp, which contain large amounts of undigested plant matter.

(6) Recent combination of fish species cultured are based on one or two species as the main ones and the others as subsidiary compatible species which would be utilising those parts of the food resources that would have been wasted.

Fish used in polyculture

Polyculture method traditionally combines the Indian major carps rohu (*Labeo rohita*); catla (*Catlacatla*); and mrigal (*Cirrhinuscirrhosus*).The research modified the fish composition to include the small carps mola (*Amblypharingodon mola*) and punti (*Puntius sophore*) and the replacement of the bottom feeder mrigal by common carp (*Cyprinus carpio*). Chinese silver carp (*Hypophthalmitrix molitrix*), an inexpensive species that farmer families can afford to eat instead of selling, is currently being tested.Combinations of three Chinese carps (bighead, silver and grass carp) and the common carp are most common in Polyculture. Other species may also be used. While fish may be grouped into broad categories based on their feeding habits, some overlap does occur. In our state Polyculture systems has tremendous potential and our endemic *Schizothoracid species* can be utilized effectively in composite fish culture .

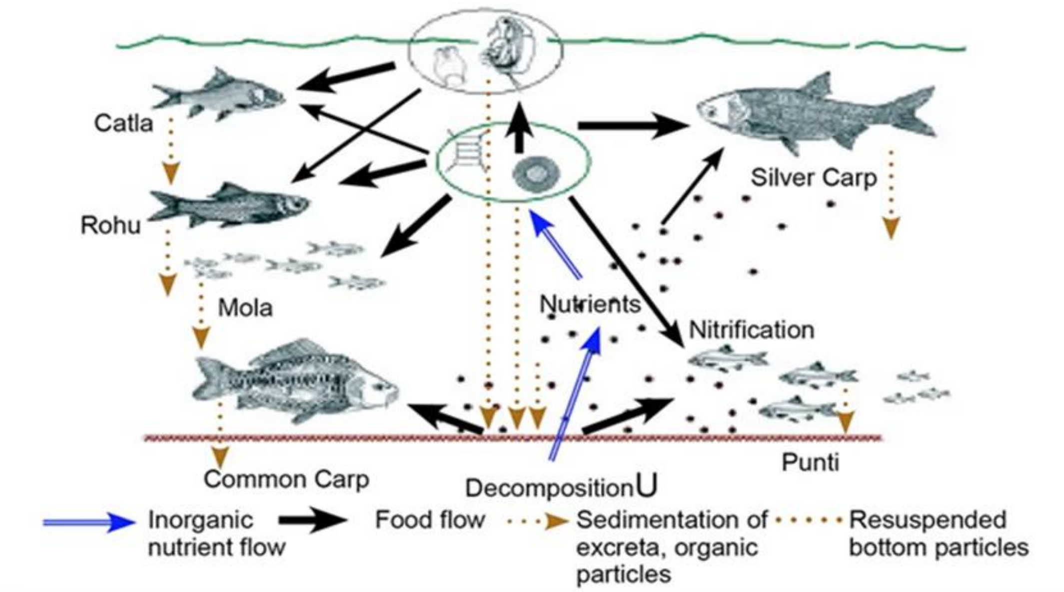


Fig:6.5. Polyculture of carps

Polyculture is an effective way to maximize benefit from available natural food in a pond. Polyculture or mixed fish farming or composite fish culture is the culture of fast growing compatible species of fishes of different feeding habits (or different weight classes of the same species) in the same pond so as to utilise the various available ecological niches in order to obtain high production per hactare of water body.

A pond according to its depth can be divided into three distinct zonesupper surface zone, middle column zone and bottom zone. A particular species exploits food of a particular zone. For example *Catlacatla* is a surface feeder, Labeo rohita a column feeder and *Cirrhinusmrigala* is a bottom feeder.

In case of single species or monospecies or monoculture only one zone will be utilised or exploited while the other zones would remain unutilised. As a result the entire ecological area would not be exploited and the yield or fish production would be less.

(A) Renovation of the Pond:

Generally due to rain and flood the edges or dykes of the ponds may get damaged and a lot of silt or mud may accumulate at the pond bottom, thereby decreasing the depth of water. In such cases the entire water of the pond is to be removed through the help of a pump.The pond bottom should be allowed to dry. The humus at the pond bottom should be removed through the help of manual labours. The dykes has to be repaired and plants to be planted on it so that its roots would prevent soil erosion. The pond is then filled with water.

(B) Clearance of Weeds:

One of the crucial problems encountered by Indian pisciculturists is the excessive growth of aquatic vegetation in water bodies and its control.

1. Manual and Mechanical Control:

If the weed infestation is scanty, then it can be easily removed manually with the help of a long bamboo. The entire weeds are swept with the bamboo to a side and then removed manually with the hand. As the weeds grow again, it is difficult to eradicate them completely. In case of denser infestation the weeds can be removed with the help of weed cutter.

2. Chemical Control:

In case of dense weed infestation suitable weedicides may be used. A large variety of chemical herbicides are used as weedicides.

3. Biological Control:

Weeds in a water body can be controlled by means of selected varieties of herbivorous fishes. The important herbivorous fishes used are: grass carp (Ctenopharyngodonidella), tawes (Puntius javanicus); common carp (Cyprinus carpio); Tilapia mosambica and gourami (Osphro-nemusgoramy).

(C) Eradication of Weed and Predatory Fishes:

It is not desirable to have weed and predatory fishes in the cultural impoundment. Weed fishes by consuming the nutrients from water competes for food, space and oxygen with the fingerlings of culturable carps

The predatory fishes, on the other hand, directly prey on the culturable carp spawn, fingerlings and young fishes.One way of eradicating these unwanted fishes is by dewatering and drying the pond. However, where dewatering is not possible then these fishes have to be killed by the application of fish poison, generally of plant origin.The most widely used fish poison of plant origin is mohua oil cake. The application of Brassica latifolia (mohua oil cake) is of much significance in fish ponds because of its role as piscicide in the initial phase of treatment and as manure in later phase after its loss of toxicity.

(D) Addition of Lime:

The first step in fertilisation is the application of lime. The common form used is limestone.

Liming is essential for successful pond manuring. .

(E) Addition of Fertilisers:

(a) Inorganic Fertilisers:

The major fertilising elements are nitrogen, phosphorous, potassium and calcium.

(b) Organic Fertilisers:

Organic fertilisers are either of plant or animal origin. It contains almost all the nutrient elements required in the metabolic cycle. The nutrients locked in them are either made available directly or after decomposition and transformation by the microbes.

Organic Manures

The manures falling under this category are:

- Liquid Manure from Stable and Byres has been found to impart fertility for good fish yield.
- Through the use of dried blood and guano an increase in fish yield has also been reported
- **Oil Cakes:**Oil cakes such as mustard oil cake, mohua oil cake, cotton seed meal, soybean meal, etc. have been used for manuring fish ponds. Mustard oil cake is used either singly or in combination with cowdung.
- **Green Manuring:**Green manuring is used to fertilise fish ponds. In this method green plant tissues are decomposed and turned into soil. This is done by sowing a nitrogenous or other crop on dry pond bottom at the time of pond preparation or by dumping it in a heap at one end of the pond.
- **Compost:**Another good organic manure is compost. It is formed by dumping organic wastes, vegetable debris, cut grass, cow dung, aquatic weeds, etc. into a large pit and then the pit is covered with soil. The aerobic bacteria in the presence of nitrogen convert the above mentioned wastes into humus.

Organic manures with carbohydrates and nitrogenous matter:

(i) Farm Yard Manure

(ii) Poultry Manure

2. Stocking Management

In aquaculture practices only the common carp is cultured in monoculture system. While in poly-culture system either the Indian major carps or in combination with the exotic carps are cultured in various combinations. However, prior to the introduction of fry or fingerlings the cultured water has to be tested whether it is suitable for culture or not.

For rearing of carp the main or basic objective is the production of an optimum quantity of the desired size of fish, at minimum cost.There are two systems of stocking that the fish farmers generally adopt:

(i) Multi-Size Stocking:

This involves stocking, in the same pond different sizes (fry, fingerlings and young adults) of fishes in order to utilise the food resources more efficiently. In this system additional stocking of fishes and periodic harvesting of marketable fishes are undertaken.

(ii) Multi-Stage Stocking:

In this system fishes are stocked in progressively larger ponds (nursery, rearing and stocking) as they grow in size. Here, the stocking rates are reduced and harvesting of marketable fishes are done after a period of approximately one year culture.

(B) Species Combination:

Three broad combinations are practised in India, i.e.

(1) Culture of Indian major carps alone,

(2) Culture of exotic carps alone and

(3) Culture of Indian and exotic carps together.

In cases where silver carp is cultured along with catla, the silver carps introduced should be smaller in size and lesser in number.

As silver carp feeds on phyto- plankton, the density of phytoplankton would fall if silver carp is introduced in large numbers. This would hamper the quantity of zooplankton and ultimately the growth rate of catla, that feeds predominantly on zooplankton.

Besides the above, a number of other species are also stocked in polyculture system. The more common ones being tilapia (*Tilapia mosambica*), gouramy (*Osphronemusgoramy*), grey mullet (*Mugil parsia*), tawes (*Puntius javanicus*) and a small number of carp hybrids (calbasu male x catla female).

Sometimes a carnivore, chital (*Notopteruschitala*), is added to control weed-fishes. However, this carnivore should be smaller in size (2 inches to 3 inches) so that they do not prey on carp fingerlings.

Although polyculture envisages compatible combinations of species or age groups that do not compete in feeding habits, but there is often considerable overlap of the feeding habits and preferred food items. When several species are added in ponds, the concept of exclusive ecological niches and special separation are not always applied.

Recent combinations are generally based on one or two species as the main ones (depending upon the market demand) and the others as subsidiary compatible species that will utilise the unutilised food resources or would help in reducing the deterioration of water quality by feeding on the wastes.

(C) Stocking Density and Ratio:

Several stocking rates in different combinations is practised in different areas depending upon the market demand and the size to which it is grown. Under normal management, a stocking rate per ha of 5000-6000 fingerlings of 2.5-5 cm length is grown to a size of 600-1000 g or more in one year or less. A lower stocking density 4000-5000 is recommended if the fishes are to be grown to marketable size in a short time.

Different species of fishes are stocked in varying ratios. The commonly stocked ratio of catla, rohu and mrigal in the ponds of Bengal are 3: 3: 4 (Alikunhi, 1957). Recently, the most commonly stocking ratio is catla 30 per cent, rohu 60 per cent, and mrigal 10 per cent.

3. Post-Stocking Management:

Culture of carps in pond is mainly based on fertilisation and supplementary feeding.

A. Pond Fertilisation:

Fertilisation with inorganic and organic manure helps to meet the requirement of carbon, nitrogen, phosphorous and other nutrients. It is a known fact that manure increases plankton and chironomid production in fish ponds, probably due to high production of bacteria and protozoa developing on the organic matter of the manure. Detritus or the decomposing organic matter has a high protein content.

The stocking density and the environmental conditions of the pond determine the rate of application of fertilisers. Moreover, the dosage and mode of application is also important, whether the entire quantity has to be applied in one lot or sporadically.Too much of nutrients, resulting from manuring may lead to the development of algal bloom, particularly under Indian conditions. It may cause clogging of the gills and also depletion of the oxygen concentration in the ponds. Manuring, thus, should not be done during persistent cloudy weather or when algal bloom appears.

(i) Application of Organic Manure:

Raw cow dung is generally used as an organic manure. Under most situations a dose of 100-120 kg (dry matter) per day can be safely used under most situations. Generally in India, the application of organic manure is 10,000- 20,000 kg (wet weight/ha/year).

(ii) Application of Inorganic Manure:

Using chemical fertilisers is advantageous. In intensive culture, where fishes are stocked in higher densities, fertilisation at a dose of 60 kg/ha of single superphosphate and 60 kg/ha ammonium sulphate, every two weeks is considered to be beneficial.In polyculture carp ponds where supplementary feeding is adopted, nitrogen, phosphorous and potassium fertilisers are applied at a ratio of 18: 8:4 at the rate of 500 kg/ ha/year.

(iii) Liming:

Liming should be done monthly, 1 -2 days after the application of organic manure

B. Supplementary Feed:

The spawns after being stocked, start feeding voraciously on zooplankton. Within 2-3 days of stocking, the natural food available in the pond gets depleted. At this time artificial feed along with natural food enhances the growth and survival of spawns. For Indian carps the commonly given feed are rice/ wheat bran and oil cakes of ground-nut, coconut, mustard, etc.

D. Control of Diseases:

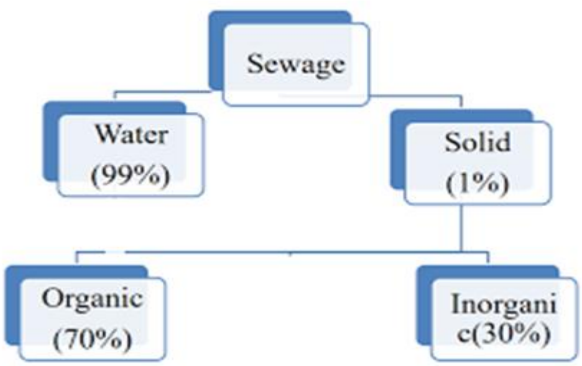
Prophylactic treatments with dip or bath in 0.38% potassium permanganate are given to fishes as a precautionary measure. Therapeutic treatments are given to cure parasitic infections and bacterial diseases.

E. Final Netting for Harvesting and Marketing:

Polyculture is generally practised for a period of 10 to 12 months, after which the entire stock is harvested in case of multi-stage stocking. Some farms have marketing ponds where the live fishes are temporarily kept till they are marketed. After harve¬sting, the catches are sorted out species-wise and size-wise before marketing.

6.6 SEWAGE FEED FISHERIES

Sewage is defined as a cloudy fluid arising out of domestic, municipal and industrial waste, containing mineral and organic matter in solution or having particles of solid matter floating, in suspension, or in colloidal and pseudo-colloidal form in a dispersed state. Sludge differs from sewage in that it is the solid portion of waste and does not include fecal matter urine.



pH	6.8-7.8
CO_2	10-140 ppm
Dissolve O_2	almost nil to traces
Total alkalinity	170-490ppm
BOD	100-500ppm

Fig:6.6 Physicochemical characteristics of Sewage

Domestic sewage has been reported to contain about 250 – 400 ppm of organic carbon and 80 – 120 ppm of total nitrogen. Thus giving the C:N ratio of around 3:1. Industrial sewage may contain more organic carbon and hence may have a higher C: N ratio. Nitrogen in sewage is present partly as organically bound element and partly as ammonical nitrogen. The fish farmer of Kolkata developed a unique technique of utilization of domestic sewage for fish culture long back in 1930s. The early inspiration of utilizing the sewage for fish culture emerged from the waste. Stabilization pond used as water source of vegetable fields. This technique is considered to be the largest operational system in the world to convert the waste in consumable product. The growing fish demand of the metro city Kolkata is widely met by this technique. Present

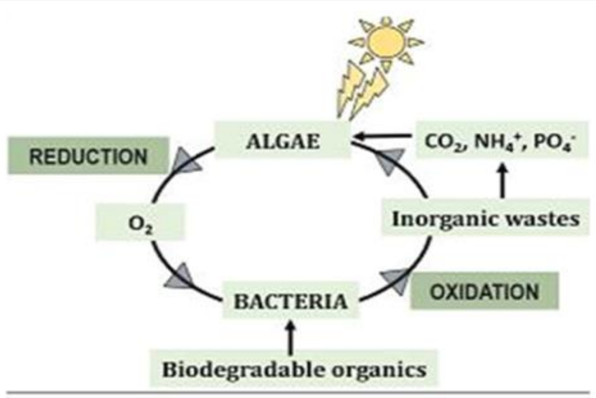
Status of Sewage Fed Fish Culture . In the course of time the area under sewage-fed fish culture reached up to 12,000 ha. But recently due to rapid and indiscriminate urbanization it has come down to 4,000 ha. Resulting in crisis of livelihood of rural people. There are appeals to Government to declare the existing sewage-fed aquaculture area as sanctuaries.

Treatments of Sewage

1.Primary treatment This is mostly the physical removal of solids by mechanical means. The solid material is removed by screening (for larger coarse particles), skimming (for floating solids) and sedimentation (for suspended particles whose density is greater than that of liquid) techniques.

2. Secondary treatment Soluble organic and inorganic matter, namely the carbohydrates, proteins, fats, hydrocarbons and other nitrogenous materials which are degraded mostly biologically, using microorganisms into the smaller constituents i.e. CO2 , H2O, NO3 , NO2 , SO4 , PO4 etc. which can be easily disposed. Some times chemical and physical removals of substances are combined with this to increase the effectiveness. There are three basic methods for secondary treatments: – Activated sludge (flocculation) – Biological filtration – Waste stabilization

3. Tertiary treatment This is biological and chemical removal of soluble products of partial or complete oxidation. For example, removal of NO3 , NO2 , SO4 , PO4 etc. Physical or chemical removal of refractory organic or other substances which may be unpleasant and even toxic. Chemical treatment comprises of : (a) Coagulation or chemical precipitation (e.g. by alum), (b) Deodorization (by Cl2 , FeCl3), (c) Disinfections or sterilization (by Cl2 , CuSO4 , liming etc.).



MECHANISM OF OXIDATION POND

Oxidation Pond : Organic mattercontained in the waste is stabilized and converted in the pond into more stable matter which find their way into effluents.A conventional oxidation pond contain the algal bacterial culture, which oxidizes the organic matter into CO_2, H_2O, H_2S, NH, and other decomposition products that are used as nutrients like nitrite, phosphate

FiltrationThere are two types of filtration process, viz., mechanical filtration and biological filtration such as trickling filter which uses filter medium grains covered with biofilm.

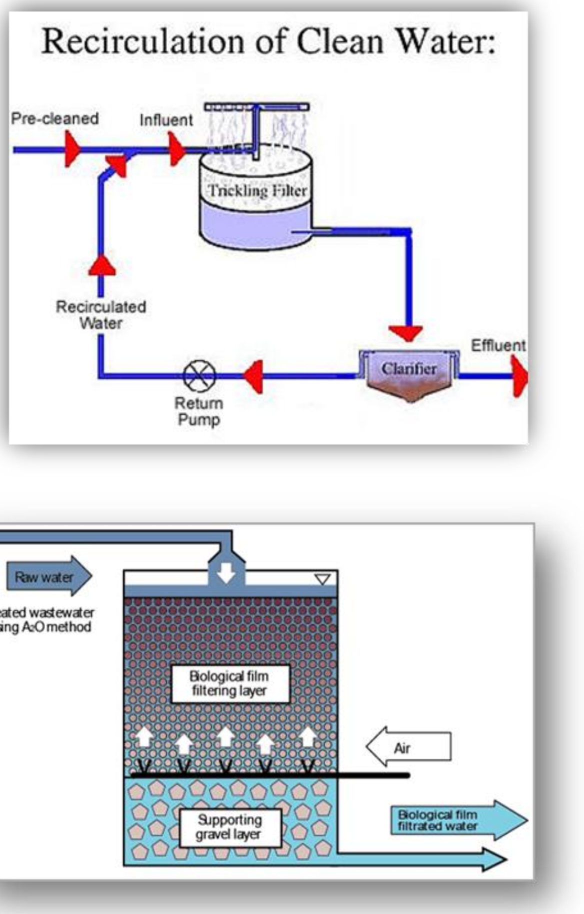


Fig:6.7 Filtration

The process generally adopted for the use of sewage treatment before release in fish ponds

- Sedimentation
- Dilution

- Storage

The process generally adopted for the use of sewage treatment before release in fish ponds Sedimentation Dilution Storage Technologies adopted by farmers. The sewage fed ponds are locally known as BHERIES. These are the ponds of different sizes, which can be as big as 40 ha.The ponds are shallow with a depth ranging from 0.5 to 1.5 m. Generally the culture practice includes five phases:

Pond Preparation

1. Sewage fed ponds are pumped out to dry
2. Drying of pond during winter months
3. Bamboo sluice & dikes are repaired

Primary Fertilization

After pond preparation, sewage is passed in to the pond from the feeder canal through bamboo sluice. It is left to stabilize for 15 – 20 days. The self-purification of sewage takes place in presence of atmospheric oxygen and sunlight. When the water turns green due to photosynthetic activity, the pond is considered ready for stocking. Allow sewage flow in pond through open channel

Fig:6.7 Sewage flow in pond through open channel

Fish Stocking

All the species of Indian major carps e.g. *Labeo rohita* (Rohu), *Catlacatla, Cirrhinusmrigala* (Mrigal) and Exotic carps e.g. *Hypophthalmichtys molitrix* (Silver carp), *Ctenopharyngodon Idella* (Grass carp), *Cyprinus carpio* (Common carps) are preferred to be stocked but the percentage of Mrigal is kept greater and that of exotic carps is lesser.The popularity of *Talapia* and fresh water prawn, *Macrobrachiumrosenbergii* is increasing these days. *Pangasius*hypophthalmus is also stocked by some farmers to get rid of mollusks. As the sewage contains high content of nutrient, the farmers keep very high stocking density, i.e. 40,000 to 50,000 fingerlings/ha.

Secondary Fertilization

After stocking, sewage is taken in ponds throughout the culture period at regular intervals @ 1–10% of the total water volume of the pond. In bigger ponds, water level is maintained by continuous inflow and out flow. The requirement of sewage is determined by observing the water colour, transparency, temperature and depth.

Feeding of stocked fishes

Due to high contents of nutrients in sewage, the cultured fishes don't require at all any supplementary feeding. However, occasionally, especially in rainy season when the potential sewage is lacking, they are fed with supplementary feed.

Health care of fishes

The fishes are most vulnerable to bacterial diseases, but surprisingly the occurrence of bacterial or any other disease is not common in sewage-fed fish farms. Even when EUS was prevailing in past years in other areas, the sewage-fed ponds were uninfected. However, parasitic infections by Lernea (Anchor worm) and Argulus (Fish lice) are common but they are not given any proper treatment.There is a need to develop a technique to keep these problems aloof.

Harvesting

The BHERI farmers have evolved rotational cropping system to maintain the supply to the market. Fishes are stocked and harvested throughout the culture period leading to periodical stocking and regular harvesting. After completion of one phase, fishes are restocked @ 1 Kg fingerlings per 5 kg harvested fish. Another harvest phase starts after 15days of restocking. Generally, drag nets are used for harvesting by encircling technique. Some fishes like Tilapia and Common carp require hand picking technique for their harvesting. Specialized fishermen are employed in fishing.7.5 cm long fingerlings of rohu, catla and mrigal stocked in the ratio 1: 1:1 @ 550 kg/ha gave an annual fish production of c. 3,237 kg/ha. The results of further experiments on the ratio of stocking and the yield/ha of water area. Best results were obtained when the ratio of stocking of rohu, catla and mrigal was 1:2:1.For fish culture sewage water of stablizing tank as well as the water after dilution can be utilized. Air breathing fishes are more suitable to be cultured in sewage treatment ponds as they can survive in water with lesser dissolved oxygen content. The fish like *Clarias batrachus, Heteropneustesfossalis, Channa spp., Tilapia mossambicus and Ctenopharyngodonidella*(grass carp) are the species of choice to be considered for culture in sewage treated ponds.

6.7 SUMMARY

Cold water Fisheries occupy anvery important place amongst the freshwater fisheries of India. The cold water fisheries deals with fisheries activity in water where temperature of water resource ranges from 5 to 25 degrees centigrade. The temperature of water under cold water fisheries should not be more than 25°C even in summer season.

Such conditions occur in Himalayan and peninsular regions of India . There are 16 big and small rivers in Himalayan and peninsular regions having an area of.Government of India established National Research Centre on Cold Water Fisheries in Uttarakhand at Bhimtal. It has played a significant role in the aquaculture improvement and conservation of indigenous as well as in the successful survival of exotic species of fishes in this region.Thesurvival at high altitude depend upon several factors resulting in different adaptations in fishes. The torrential streams of water in mountain regionis rich in oxygen and low incarbon di-oxide quantity, the parameters of which are very important for the growth of fishes.

In the cold-climate State of Uttarakhand, the general public needs a protein-rich digestible, easy-to-eat food. Fish can provide good nutrition. Cold aquatic fish species like Mahashir and Trout have always been the choice of hunting lovers. By organizing the fishing areas in the beautiful places of Uttarakhand and more, tourism of the state can be made attractive and economically beneficial.

Fish as a source of Protein will provide abundant nutrition as well as become an assured synonym for future food security.In addition to animal protein, fish contain unique long-chain poly-unsaturatedfatty acids (LC-PUFAs) and highly bioavailable essential micronutrients—vitamins D and B, minerals (calcium, phosphorus, iodine, zinc, iron, and selenium). These compounds,often not readily available elsewhere in diets, have beneficial effects for adult health and child cognitive development (HLPE, 2014). So, fisheries can effectively play a role in economic development, food provision, and ultimately poverty alleviation and reducing malnutrition.This requires the implementation of a comprehensive project with a scientific and professional basis . The species being more tasty and nutritious sells at higher prices in the market and at the same time has good demand in the international market. The export of these fish is likely to generate good foreign exchange in the State.

The possibilities of increasing fish production per unit area, through polyculture, is considerable, when compared with monoculture system of fish.Polyculture is the practice of culturing more than one species of aquatic organism in the same pond. The motivating principle is that fish production in ponds may be maximized by raising a combination of species having different food habits. Different species combination in polyculture system effectively contribute also to improve the pond environment. Algal blooming is common in most tropical manure fed ponds. By stocking phytoplanktophagusSilver carp in appropriate density certain algal blooming can be controlled. Grass carp on the other hand keeps the macrophyte abundance under control due to its macrovegetation feeding habit and it adds increased amount of partially digested excreta which becomes the feed for the bottom dweller coprofagous common carp. The bottom dwelling mrigal, common/mirror carp help re-suspension of bottom nutrients to water while stirring the bottom mud in search of food. Such an exercise of bottom dwellers also aerates the bottom sediment. All these facts suggest that polyculture is the most suitable proposition for fish culture in undrainable tropical ponds.

With the purpose of getting maximum production of fishes from a water body (lake/reservoir/pond) culture of fast growing compatible species of different feeding habits and ecological niches is being practiced in different parts of the globe. This is popularly known as composite fish culture or mixed farming. Termpolyculture is also loosely applicable for such a culture. In composite fish culture, all available food supply of the pond (phytoplankton, zooplankton, periphyton, macrophytes, benthos and detritus matter etc.) is mostefficiently utilized by the cultured fishes. Such fishes do not harm each other; rather, they promote growth of other fishes. By proper care and management fish production can be raised by 5-6 times more than usual production through polyculture.Polyculture is the practice of culturing more than one species of aquatic organism in the same pond. The motivating principle is that fish production in ponds may be maximized by raising a combination of species having different food habits. The concept of polyculture of fish is based on the concept of total utilization of different trophic and spatial niches of a pond in order to obtain maximum fish production per unit area. The mixture of fish gives better utilization of available natural food produced in a pond. The compatible fish species having complimentary feeding habits are stocked so that all the ecological niches of pond ecosystem are effectively utilised

Ponds that have been enriched through chemical fertilization, manuring or feeding practices contain abundant natural fish food organisms living at different depths and locations in the water column. Most fish feed predominantly on selected groups of these organisms. Polyculture should combine fish having different feeding habits in proportions that effectively utilize these natural foods. As a result, higher yields are obtained

Sewage fed fisheries is a new venture for India. Fish culture in sewage system involves little investment with higher yield. A sewage fed pond does not require fertilizers and supplemented food. This reduces the cost of culture and at the same time the growth rate of fish in such ponds is also faster. Unfortunately, in India the practice of sewage culture of fish is not very popular

6.8 TERMINAL QUESTIONS AND ANSWERS

Q. 1 - What is Cold water aquaculture? Explain.

Q. 2 - Write the scope of Cold water aquaculture in Uttarakhand.

Q. 3 - Explain Scope of aquaculture for sustainable livelihood.

Q. 4 - Explain Aquaculture of cold water fishes.

Q. 5 - Describe in detail about Polyculture of carps.

Q. 6 - Explain Sewage feed fisheries in detail.

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UNIT 7: EXOTIC FISHES AND THEIR ROLE IN FISH FARMING

CONTENT

7.1 OBJECTIVES

The study of this unit will let the students understand the following:

- Exotic fishes for aquaculture
- Trout farming in uplands and culture of common carp

7*.2 INTRODUCTION*

The exotic fishes are those species that are non-indigenous having their origin in another country and has been introduced into the Indian waters. They commonly have recognized culture technologies and the economics of manufacture and marketability. Species of fishes imported and introduced into a country for the purpose of culture are called exotic species. Several exotic species have been introduced successfully into different parts of India and belong to three categories food fishes, game fishes and larvicidal species.

For such well-known exotic species, there is a strong dispute for their introduction and transplantation. But, the difficulty often faced is whether it is essential to initiate such exotic species and what are the procedures and protection to be taken to prevent likely unwanted consequences.

7.3 EXOTIC FISHES FOR AQUACULTURE

Regional transplantation of new species has also been attempted in India. This includes Catla transplanted from the Godavari and the Krishna Rivers to the Cauvery, Rohu (Labeo) has been successfully transplanted from Bengal to Madras. A few salt-water food fishes have been acclimatized to fresh water in Madras, e.g., fingerlings of coastal species of mullets, *Mugil cephalus,* milk fish *Chanos chanos.*The milk fish and the Bekti have been found to grow in fresh water.

However, great care must be exercised in introducing exotic species for culture, since they might disturb the biological balance of the existing species. For example, introduction of Tilapia into carp culture areas in India adversely affected the survival of mrigal (Cirrhina), when the two species were stocked together. Hence, a detailed study must be made regarding the overall suitability of the exotic species, before they are introduced into an area. Some important exotic species is given below:

1. Trout: There are three main species of *Salmo* which are important game fishes introduced into India. These are *S. gairdnerii* (Rainbow trout) and *S. trutta fario* (Brown trout) and *Oncorhynchus nerka* a hybrid species. Earlier attempts to introduce *S. trutta* made by Sir Francis Day in 1863 were not successful. Trouts were first successfully transplanted in Nilgiris in 1960. At present there are six trout reservoirs in the Nilgiris. Trout have been introduced into the Kodaikanal lake of Tamil Nadu in 1965 by the Madras Fisheries Department.

Brown trout was introduced into Kashmir in 1901 by the Maharaja and is flourishing in several snows fed streams. In 1909, 10,000 eggs of salmon were introduced into Kashmir. Besides the brown and rainbow trouts, another species, the brook trout (salvelinus fontinalis) has also been introduced into Kashmir. In 1919, about 5000 ova of the rainbow were transplanted from Kashmir to kulu water of Himanchal Pradesh. Ova and fingerlings of trout were introduced in Bhowali, Nainital, Naukuchia Tal and Sat-Tal of Kumaun but did not prove to be a success.

2. Mirror carp: This is also called the common carp and is the native of temperate region of Asia. But is now worldwide in distribution and is extensively cultivated in different parts of world. There are three varieties of this fish:

(i) *Cyprinus carpio var*, *communis* (scale carp)

(ii) *Cyprinus carpio var,specularis (mirror carp)*

(iii) *Cyprinus carpio var,nudus (leather carp)*

The mirror carp was first introduced into the Nilgiris in 1939 from Ceylon and stocked in Ootacamund lake. Later on, it was carried to Bangalore, and in 1947, transplanted into the Nainital lake and and other lakes of Kumaon Himalayas. The mirror carp is now well established in Himachal Pradesh, Panjab, Jammu and Kashmir, Madhya Pradesh, Rajasthan, Delhi, Bihar, Manipur and Sikkim. It is an ideal fish for introduction into the hilly regions, being an omnivorous, non-predator and fast growing species. It breeds in confined waters and has two peak breeding periods, one from mid January to March and the other from July to August. In India, breeding of common carp is done in hapas or cement cisterns. The brooders comprising one female and two-three males are introduced into the hapas in the evening and eggs are collected in the morning with the help of aquatic weeds. Pituitary injection is also used in some countries for breeding the common carp. In India the common carp is generally cultured in combination with other carps.

3. Carassius carassius: This is commonly called the crucian carp or golden carp and is a native of Central Europe. It was introduced into the Ooty lake in Madras in 1874 from Central Europe. It is well estabilished in Nilgiri waters, and breed in ponds throughout the year. Attempts have been made to introduce the species in the plains, and it is reported to have bred at Sunkesula fish farm in Andhra Pradesh.

4. Silver carp:*Hypothalmichthys molitrix* is a native of China but has now been introduced in several countries like India, Japan, Malaysia, Nepal, Burma, Pakistan, Philippines, Ceylon, Hongkong, Israel etc. In India, silver carp was brought from Japan in 1959, and introduced in Orissa, Cuttack. Later on, the fish has been transplanted in various states all over the country. It feeds on phytoplankton and thrives on rice bran and flour. The species naturally breeds in rivers in China and Japan. But in India, silver carp was bred in ponds by hypophysation in 1962 (alikunhi et al., 1963). Later on Chaudhuri was also successful in breeding grass and silver carp by pituitary injection in 1966. The technique adopted is almost the same as for other Indian major carps. Silver carp grows very fast and attained the weight of 2-5 kg in reserve Kulgarhi reservoir in Madhya Pradesh. It is cultured in combination with *Catla catla* in ponds, and has shown faster growth rate than the Indian carp (Sukumaran et.al 1968). The maximum yield was obtained when silver carp and Catla were stocked in the ratio of 2:1.

5. Tunca tinca: The tench was first introduced in 1874 in the Ootacamund, Madras from England. It is not able to acclimatize itself to the warmer water of the plains. But is reported to be breeding and living in the Sunkesula Fish Farm, Andhra Pradesh along with *Carassius carassius.*

6. Grass carp:*Ctenopharyngodon idella*, the grass carp, also known as the 'white Amur' in Russia, is the natural inhabitant of China and introduced into the ponds of Central Inland Fisheries Research Station (CIFR), Cuttak Orissa. The first shipment of grass carp comprising 382 fingerlings (5.5 cm in length), which came to India from Hong Kong, was introduced into the Pond Culture Division of CIFRI, Cuttack in December, 1959.

In due course they were effectively bred by hypophysation at Cuttack in 1962 and the fry were then circulated to the other states of India. Gift consignments of grass carp fry were sent for culture to other countries like Philippines in 1964, Nepal in 1966 and Burma (Myanmar) in 1968.

Although a freshwater fish, grass carp can tolerate slightly brackish water. Grass carp has a toothless mouth but has strong and specialised pharyngeal teeth (which occur in two rows) for rasping aquatic vegetation. It is, therefore, herbivorous and feeds on macro vegetation, including grass and aquatic plants. It starts feeding on macro vegetation when about 2.5-3.0 cm in length and can ingest plants up to 50% of its weight.

Although grass carp is not of high profitable value, still it has been a popular species for aquaculture due to its capability to control macrovegetation. It is a fast grower, compatible and its excreta fertilises the pond water. Grass carp, however, when cultured with prawn, makes serious inroads in the habitat of prawn and the two thus cannot be said to be compatible (Sinha, 1978).

This species has acclimatised itself in Indian conditions and can breed even in weed-infested water bodies and can control the growth of economically important fishes. To avoid the breeding of this species efforts have been made to produce all-male grass carp by management of methyltestosterone, however, with little success.

7. Tilapia: The natural habitat of *Tilapia mossambica* is along the East coast of Africa, but it has been transplanted to several countries and reared in ponds. In India, Tilapia was brought by the Central Marine Fisheries Research Institute, Mandpam, from Bangkok in 1952, and by the fisheries Department, Madras from Ceylon. The fry of Tilapia feeds on zoo-and phytoplankton, but the adult is chiefly herbivorous. It becomes mature when about two months old growing to a size of 80-90mm. It breeds throughout the year, with an interval of about 16-25 days between successive spawning. The male prepares a shallow circular nest in the sand, and the eggs are laid by the female after brief courtship. The eggs are fertilized by male and soon the female picks up the eggs in her mouth thus exhibiting buccal incubation. Hatching takes place in 3-4 days and 8.0mm fry are liberated from the mouth. it can tolerate wide range of salinity and is therefore, recommended for culture in coastal lagoons.

Tilapia is a fast growing hardy fish but does not survive at a temperature lower than 10°C. As it feeds on carp fry, Tilapia is not suitable for culture along with carp. When cultured in sewage water mixed with fresh water, it is reported to yield 7000 kg/year, in Indonesia, It can also be successfully cultured in rice fields. Tilapia also serves well as a forage fish and when cultured with *Channa striatus* in ponds, the yield is considerably increased as it is utilized as food by the murrels.

8. Gourami:*Osphronemus goramy* was first brought to Tamil Nadu from Mauritius and Java in 1865, but was successfully established in 1916. The fish naturally breeds in ponds and streams, but does not survive below 15°C. The fry feed insect larvae, crustaceans, but the adult is a herbivore. Gourami builds nests from grasses and weeds. Both the sexes take part in building nest taking about 10 days. Nest is oval in shape with a circular mouth of about 10cms. The female lays eggs in batches which are fertilized by the male, after which both the parents stand guard over the nest. In India, Gourami is cultured in ponds which are provided with marginal plants to help in nest building. It is considered as an excellent food fish and has a flesh of good flavor. It is therefore, a popular fish for fish culture in Madras, but has a slow growth rate. It has now been introduced into Bombay, Bengal, Orissa and a few other states.

7.4 TROUT FARMING IN UPLANDS AND CULTURE OF COMMON CARP

Trout farming in India

The freshwater fish trout is of family Salmonidae. Of the 15 trout species which are found universal, brown (Salmo Trutta fario) and rainbow trout (Oncorhynchus mykiss (Old name Salmo gairdneri)) are found in India. The main trout producing states are Uttarakhand,Himachal Pradesh, Jammu and Kashmir, Tamil Nadu and Kerala.These states have recognized a well developed infrastructure for trout production depending on the accessibility of water in necessary quantity and quality, i.e. from springs and snow-melt/glacier-fed streams.British were the first to introduce trout in the country from Europe to get together their need for entertaining fishing in absence of any fast-growing indigenous fish in Indian waters. Thus, trouts were introduced to support sport fisheries. Now not together from sport fisheries, culture of trouts is increasingly being recognized as a profitable project for table fish production.The first attempts to transport brown trout eyed-eggs from England into India were from Howeiton in Scotland and the eggs fruitfully hatched in a small trout hatchery at Harwan in Kashmir. In 1905, in Kashmir,the first batches of eggs were obtained from the store which had been produced from the Scottish eggs.

This was the establishment of the spread of brown trout in the Himalayas and in another place.From Kashmir the species was taken to Jammu, Himachal Pradesh, Uttar Pradesh, North Bengal, Arunachal Pradesh, Meghalaya and Nagaland In 1918 steelhead strain of rainbow trout was introduced from England. Of the two species of trout, brown has become cultivated in culture systems, streams and lakes, and has emerged as a self-financing population in the Himalayas. The rainbow trout, however, has remained restricted to pond culture and is not very common in streams and rivers of India.

The transplantation of these fishes has provided outstanding game fishing to the anglers and ongoing attracting large number of tourists to the country. However, large scale road construction in the valleys followed by destruction of breeding and feeding grounds of the fishes, progress of river-valley projects, rapid urbanization, fishing pressure and of course illegal and unhelpful means of fishing etc. have been posing threat to this species as sports.

CULTURE OF COMMON CARP

Culture in Paddy fields: Various techniques are employed for fish culture in paddy fields depending upon the climate, local condition, species of fish available and the verity of paddy cultivated. The cultivation of paddy is the primary purpose of the farmer, hence fish culture is to be adopted to the schedule of paddy cultivation. Species that are suitable for culture in paddy fields must be able to thrive in shallow water. They should be able to tolerate relative higher temperature and tubidity. Certain carps, murrels and Tilapia are suitable for culture in paddy fields.

In India experiments conducted on fish culture in paddy fields in W. Bengal have shown that the survival rate of *Labeo, Catla and Mrigal* ranges from 34-40% and the species showed more rapid growth in paddy fields than in ponds.

During the recent years, however, high yielding varieties of paddy are being cultivated. These requires of insecticides, pesticides, weedicides etc, which are harmful to the fish. Under such conditions, fish culture along with paddy is not possible. However, where common varieties of paddy are cultivated, fish culture is practiced. Fields that are left flooded for a long or short period after harvesting can be easily utilized for fish culture.

It is, therefore, essential to make a well planned survey of prevailing condition before attempting fish culture in paddy fields on a large scale.

Fig.7.1 Some Indian carp species

(Source:https://www.google.com/search?q=indian%20major%20carps&tbm=isch&hl=en&sa=X &ved)

Culture in manmade lakes: A large number of dams and reservoirs have been constructed during the recent years to provide water for irrigation and power generation. It is estimated that these manmade lakes provide about two million hectares of water and this would continue to increase. These bodies of water offer immense scope for fish culture.

For successful fish culture in dams and reservoirs, it is essential to make a detailed hydrological study of the water body. Suitable species that are stocked in dams are major carps such as *Catla catla*, *Chirrhina mrigala* and *Labeo calbasu.* These are capable of adjusting successfully to ecological condition of reservoir. The reservoirs, in their initial stages are very rich in microscopic organisms which start dwindling after 5 or 6 years. It is therefore necessary that new reservoirs are stocked on a large scale with fry of Gangetic carps so that they are able to establish themselves and provide sustained fisheries during later years. In the absence of large scale stocking of major carps weed fishes and carp minnows establish themselves in the reservoirs. Some of these like *Ambassis nama*, *A.ranga*, *Osteobrama cotio* and Gudusia chapra, compete with *Catla* for food and reduce the latter productivity. Carp minnows compete with *Chirrhina mrigala, Labeo rohita* and *L. calbasu.*

Of the major carps, *Labeo rohita* has not been has not been able to adjust to the environmental conditions of the reservoirs. But catla, mirgal and calbasu form a best assortment of species. In Rihand dam, Catla forms 98% of the total fish catch. Rohu has not been able to adjust to the ecological condition of the reservoirs and dams. A catla- rohu hybrid, however, grows successfully in the reservoirs and is a good fish for stocking. It has feeding habits of rohu and can be used as a substitute for rohu. The exotic silver carp also thrives in manmade lakes and is a suitable species for thrives in manmade lakes and is a suitable species for culture. Besides the Gangetic major carps, some of the medium sized carp like Labeo *fimbriatus, C. cirrhosa, Puntius dubius* and *P. carnaticus* are alsoconsidered to be useful for culture in dams and reservoirs. The omnivorous Cyprinus carpio is also a good species for stocking in reservoirs.

Studies have shown that fry and fingerlings of the major carps should be stocked in the intermediate zone of the reservoir, after removing predatory fishes. This zone is rich in plankton. For successful fish farming in reservoirs, it is necessary to impose restriction on size limit. Fish below a minimum size should not be caught.

Carp Culture in Cages: Rearing of carp spawn to produce fry or fingerlings has recently been attempted in cages because nursery space available in the country is far short of requirement. Velon screen cage were used in Poongar swamp (Bhawanisagar, Tamil Nadu) for this purpose. Four cages, each measuring 5×5m with 1/32ʺ mesh, were tied to poles in the marginal area of the swamp at 1.5 to 2 m depth. The bottom of the cage was kept just above the bottom and the margin of the cage is 0.5 m above the water level to prevent entry of predatory fishes and escape of fry. Manuring of the cage was done with cow dung, superphosphate and ground-nut oil cake. Carp spawn was released into the cages 2 days after the manuring, and after two days of stocking cages were cleaned of algal growth with the help of nylon brush to allow free exchange of water. The cages had to be cleaned every day. Spawn (5-6 mm long) of *Labeo rohita* was stocked at 60,000 spawn/cage. After 16 days rearing,fry 10-15 m were harvested with 55-66% survival. In another cage, spawn (5-7mm) of *Cirrhina mrigala* were stocked at 15,000/ cage. After 18 days of rearing, 10-20 mm long fry were harvested and survival was 66-80%. Rice bran and ground nut oil cake in the ratio of 1:2 was used as supplementary feed.

Thus, the marginal area of a tank can be successfully used for growing carp spawn and fry in cages. Natural food available to the spawn and fry can be increased if the cage is allowed to touch the bottom of the pond. In cage culture, harvesting is complete and management easier, Carp fry upto 20-25 mm size can be reared in velon screen cages with 1/8″ mesh size.

7.5 SUMMARY

The exotic fishes are those species that are non-indigenous having their origin in another country and has been introduced into the Indian waters. Species of fishes imported and introduced into a country for the purpose of culture are called exotic species. Several exotic species have been introduced successfully into different parts of India and belong to three categories food fishes, game fishes and larvicidal species.

For such well-known exotic species, there is a strong dispute for their introduction and transplantation. But, the difficulty often faced is whether it is essential to initiate such exotic species and what are the procedures and protection to be taken to prevent likely unwanted consequences.

Some important exotic species are Trout, Mirror carp, Carassius carassius, silver carp, tunica tinca, Grass carp, Tilapia, Gourami etc.

The freshwater fish trout is of family Salmonidae. Of the 15 trout species which are found universal, brown (Salmo Trutta fario) and rainbow trout (Oncorhynchus mykiss (Old name Salmo gairdneri)) are found in India. British were the first to introduce trout in the country from Europe to get together their need for entertaining fishing in absence of any fast-growing indigenous fish in Indian waters. The rainbow trout, however, has remained restricted to pond culture and is not very common in streams and rivers of India.

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Various techniques are employed for fish culture in paddy fields depending upon the climate, local condition, species of fish available and the verity of paddy cultivated. In India experiments conducted on fish culture in paddy fields in W. Bengal have shown that the survival rate of *Labeo, Catla and Mrigal* ranges from 34-40% and the species showed more rapid growth in paddy fields than in ponds.

A large number of dams and reservoirs have been constructed during the recent years to provide water for irrigation and power generation. It is estimated that these manmade lakes provide about two million hectares of water and this would continue to increase. These bodies of water offer immense scope for fish culture.

Rearing of carp spawn to produce fry or fingerlings has recently been attempted in cages because nursery space available in the country is far short of requirement.

7.6 TERMINAL QUESTIONS AND ANSWERS

7.6.1 Multiple Choice Questions:

1. Induced breeding technique is used in

a) Culture fishery (b) Marine fishery (c) Capture fishery (d) Inland fish

2. Smooking is used as a technique of

a) Fish preservation (b) Crop harvesting (c) Crystalisation of sugar (d) Mushroom cultivation

3.Inand fisheries are

a) Raising and capturing fishes in fresh water 9(b) Oil extraction from fish (c) Deep sea fishing

d) Capturing fishes from sea coast

4. If more than single species of fish is cultured at a time, then it is called

a) Mori culture (b) Monoculture (c) Aquaculture (d) Polyculture

5. Identyfy the edible freshwatwr teleost

a) Hilsa ilisha (b) Sharks (c) Rays and skates (d) Catla catla

6. Cartilaginous fishes are

a) Osteichthyes (b) Chindrichythyes (c) Acanthodians (d) Placoderms

ANSWERS: 1. a), 2a), 3d, 5d), 6b)

7.6.2. Short Answer Question:

1.What do you mean by exotic fishes? Name three important exotic fishes that are being cultured in India.

2. What is exotic species in aquaculture?

3.What are the exotic major carps?

4.What are the scientific names of two exotic fish?

7.3.3. Long Answer Question:

1. Detailed account of exotic species in aquaculture.

2. Describe the methods ofculture of common carp.

3. Describe Trout farming in India.

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UNIT 8: LARVIVOROUS FISHES AND THEIR CULTURE

CONTENT

8.1 OBJECTIVES

In this topic we will learn about the Larvivorous fishes, different species of Indigenous and Exotic Species of Larvivorous fishes, About the Culture of larvivorous fishes, Use of larvivorous fishes for biological control.

8.2 INTRODUCTION

The **western mosquitofish** (***Gambusia affinis***) is a North American freshwater fish, also known commonly, if ambiguously, as simply **mosquitofish** or by its generic name, *Gambusia*, or by the common name **gambezi**. Its sister species, the eastern mosquitofish (*Gambusia holbrooki*) is also referred to by these names.

Mosquitofish are small in comparison to many other freshwater fish, with females reaching a maximum length of 7 cm (2.8 in) and males a maximum length of 4 cm (1.6 in). The female can be distinguished from the male by her larger size and a gravid spot at the posterior of her abdomen. The name "mosquitofish" was given because the fish eats mosquito larvae, and has been used more than any other fishes for the biological control of mosquitoes. Gambusia typically eat zooplankton, beetles, mayflies, caddisflies, mites, and other invertebrates; mosquito larvae make up only a small portion of their diet.

Mosquitofish were introduced directly into ecosystems in many parts of the world as a biocontrol to lower mosquito populations which in turn negatively affected many other species in each distinct bioregion. Mosquitofish in Australia are classified as a noxious pest and may have exacerbated the mosquito problem in many areas by outcompeting native invertebrate predators of mosquito larvae. Several counties in California distribute mosquitofish at no charge to residents with human-made fish ponds and pools as part of their mosquito abatement programs. The fish are made available to residents only and are intended to be used solely on their own property, not introduced into natural habitat. On 24 February 2014, Chennai Corporation in India introduced western mosquitofish in 660 ponds to control the mosquito population in freshwater bodies.

Fertilization is internal; the male secretes milt into the genital aperture of the female through his gonopodium Within 16 to 28 days after mating, the female gives birth to about 60 young. The males reach sexual maturity within 43 to 62 days. The females, if born early in the reproductive season, reach sexual maturity within 21 to 28 days; females born later in the season reach sexual maturity the next season, in six to seven months.

8.3 LARVIVOROUS FISHES

Fishes are the natural enemy of mosquito eggs and mosquito larvae and use as a biological control which has been identified since olden times, because mosquito are the vector of several disease & carry parasites of malaria, filarial & yellow fever etc. They breed in all sorts of stagnant water & shallow weeds, infested pond, swamps, pits, gutters & all other kind of water for breeding purpose ,during the past several years, DDT and other insecticides have been used in increasing quantity to control the mosquito hazards but these chemical have their ill effect on human health also.

Several species of the fresh water fishes are known to be larvicidal and of used in control of mosquito population, some important features of the larvicidal fishes like:

(a) It should be of small size so as to capable of moving freely among weeds.
(b) It should be hardy fish.
(c) It should be breed freely in confined waters.
(d) It should be surface feeder and carnivorous in habit
(e) It should have no food value.

The Eggs, larvae and adult mosquito form an excellent food for several species of fish, but those of small size prefer the mosquito larvae and feed on them throughout their life, these species are more useful as larvicidal fishes than the larger one. There are several exotic and indigenous species which at one stage or the other feed on larvae and are considered larvicidal; fishes.

8.3.1 INDIGENOUS

Freshwater fish are those that spend some or all of their lives in fresh water, such as rivers and lakes, with a salinity of less than 1.05%. These environments differ from marine conditions in many ways, especially the difference in levels of salinity. To survive fresh water, the fish need a range of physiological adaptations.

41.24% of all known species of fish are found in fresh water. This is primarily due to the rapid speciation that the scattered habitats make possible. When dealing with ponds and lakes, one might use the same basic models of speciation as when studying island biogeography

PHSIOLOGY

Freshwater fish differ physiologically from saltwater fish in several respects. Their gills must be able to diffuse dissolved gases while keeping the salts in the body fluids inside. Their scales reduce water diffusion through the skin: freshwater fish that have lost too many scales will die. They also have well developed kidneys to reclaim salts from body fluids before excretion.

MIGRATING FISHES

Many species of fish do reproduce in freshwater, but spend most of their adult lives in the sea. These are known as anadromous fish, and include, for instance, salmon, trout, sea lamprey[1] and three-spined stickleback. Some other kinds of fish are, on the contrary, born in salt water, but live most of or parts of their adult lives in fresh water; for instance the eels. These are known as catadromous fish.

Species migrating between marine and fresh waters need adaptations for both environments; when in salt water they need to keep the bodily salt concentration on a level lower than the surroundings, and vice versa. Many species solve this problem by associating different habitats with different stages of life. Both eels, anadromous salmoniform fish and the sea lamprey have different tolerances in salinity in different stages of their lives.

Among fishers in the United States, freshwater fish species are usually classified by the water temperature in which they survive. The water temperature affects the amount of oxygen available as cold water contains more oxygen than warm water.

Coldwater

Coldwater fish species survive in the coldest temperatures, preferring a water temperature of 50 to 60 °F (10–16 °C). In North America, air temperatures that result in sufficiently cold water temperatures are found in the northern United States, Canada, and in the southern United States at high elevation. Common coldwater fish include brook trout, rainbow trout, and brown trout.

Warmwater

Warmwater fish species can survive in a wide range of conditions, preferring a water temperature around 80 °F (27 °C). Warmwater fish can survive cold winter temperatures in northern climates, but thrive in warmer water. Common warmwater fish include catfish, largemouth bass, bluegill, crappies, and many other species from the family Centrarchidae.

Habitat destruction

Intentional anthropogenic reconstruction and rerouting of waterways impacts stream flow, water temperature, and more, impacting normal habitat functionality. Dams not only interrupt linear water flow and cause major geological channel shifts, but also limit the amount of water available to fishes in lakes, streams and riversand have the potential to change the trophic structure because of these alterations of the habitat and the limitations to movement and connectivity.

Unnatural water flow below dams causes immense habitat degradation, reducing viable options for aquatic organisms. Upstream migration is hindered by the dam structure and can cause population declines as fishes don't have access to normal feeding and/or spawning grounds. Dams tend to affect upstream species richness, that is, the number of fish species in the ecological community. Additionally, dams can cause the isolation of fish populations, and the lack of connectivity creates possible problems for inbreeding and low genetic diversity. The loss of connectivity impacts the structure of community assemblies and increases the fragmentation of habitats, which can compound existing problems for vulnerable species.

Temperature alterations are another unintended consequence of dam and land use projects. Temperature is a very important part of aquatic ecosystem stability, and thus changes to stream and river water temperature can have large impacts on biotic communities. Many aquatic larvae use thermal cues to regulate their life cycles, mostly notably here, insects. Insects are a large part of most fish diets, so this can pose a great dietary problem. Temperature can cause changes in fish behavior and distribution habits as well by increasing their metabolic rates and thus their drive to spawn and feed.

Linear systems are more easily fragmented and connectivity in aquatic ecosystems is vital. Freshwater fishes are particularly vulnerable to habitat destruction because they reside in small bodies of water which are often very close to human activity and thus easily polluted by trash, chemicals, waste, and other agents which are harmful to freshwater habitats.

Land use changes because major shifts in aquatic ecosystems. Deforestation can change the structure and sedimentary composition of streams, which changes the functionality of the habitat for many fish species and can reduce species richness, evenness, and diversity. Agriculture, mining, and basic infrastructural building can degrade freshwater habitats. Fertilizer runoffs can create excess nitrogen and phosphorus which feed massive algae blooms that block sunlight, limit water oxygenation, and make the habitat functionally unsustainable for aquatic species. Chemicals from mining and factories make their way into the soil and go into streams via runoff. More runoff makes its way into streams since paved roads, cement, and other basic infrastructure do not absorb materials, and all the harmful pollutants go directly into rivers and streams. Fish are very sensitive to changes in water pH, salinity, hardness, and temperature which can all be affected by runoff pollutants and indirect changes from land use.

Snow Trout:

Two genera are present; *Schizothorax Spp.* and *Schizothoraichthy s*are endemic to Kashmir and Ladakh while *Schizothorax prograstus* occurs in Eastern Himalayas up to certain stretch. *Schizothoraxrichardsonii* is distributed almost all along the Himalayas.

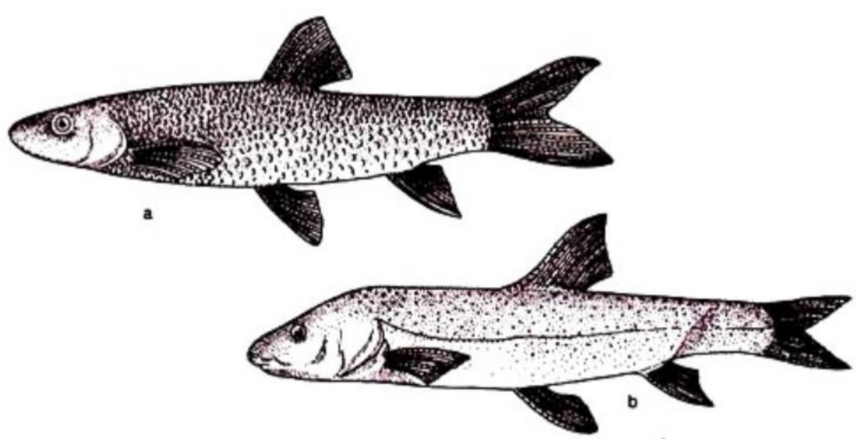


Fig:8.1 (a)Schizothorax Spp.(b)Schizothoraichthysesocinus

Barilius:*Barilius vagra, B. bendelisis and, B. bola* fishes are also called as Mountain trouts .

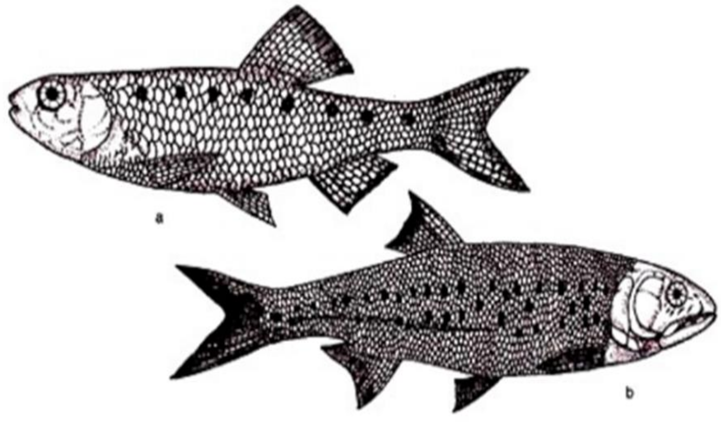


Fig: 8.2 (a)Barelius bendelisis (b)Bariluis bola

***Labeo*:**The fishes which are present in mountain rivers are minor carp and have no significance as commercial fisheries. The fishes are *L. dero, L. dyocheilus and Crossocheiluslatius.*

***Garra*:** There are two species found in lakes of the Himalayas as they are not edible fishes but are relished as food of fishes. They are *Garra lamta* and *Garra gotyla*.

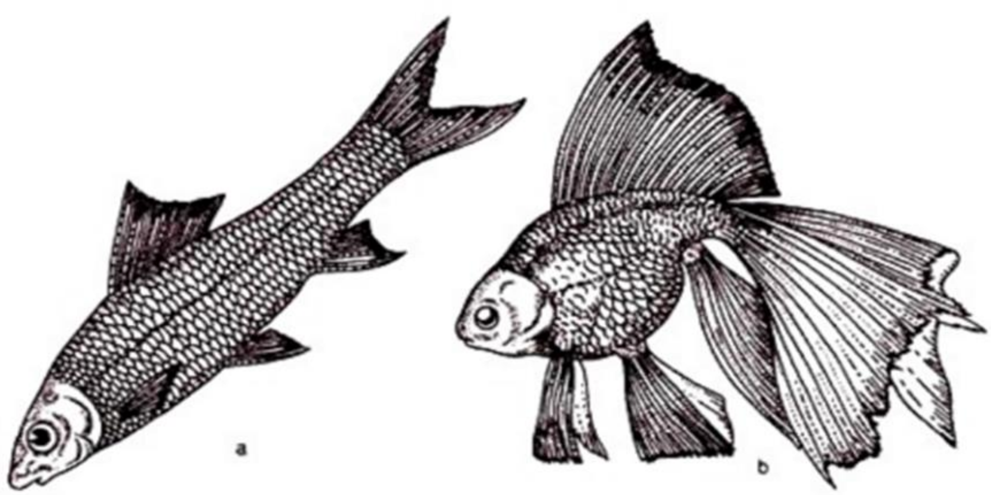


Fig:8.3(a)Labeo dero(b)Carassious auratus

LIST OF FISHES OF INDIA

Albuliformes

Albulidae (Bonefishes)

Albula vulpes (native) Roundjaw bonefish, bonefish

Anguilliformes

Anguillidae (Freshwater eels)

- *Anguilla bengalensis bengalensis* (native) Indian longfin eel, Indian mottled eel
- *Anguilla bicolor bicolor* (native) Shortfin eel, Indonesian shortfin eel

Colocongridae

- *Coloconger raniceps* (native), Froghead eel

Congridae (Conger and garden eels)

- *Ariosoma Bathyuroconger vicinus* (native) Large-toothed conger
- *Conger cinereus* (native) Longfin African conger
- *Gorgasia maculata* (native) Whitespotted garden eel
- *Heteroconger hassi* (native) Spotted garden eel
- *Heteroconger obscurus* (native)
- *Promyllantor purpureus* (native)
- *Uroconger lepturus* (native) Slender conger
- *Xenomystax trucidans* (native)

Moringuidae (Worm or spaghetti eels)

- *Moringua abbreviata* (native)
- *Moringua arundinacea* (native) Bengal spaghetti-eel
- *Moringua bicolor* (native)
- *Moringua javanica* (native) Java spaghetti eel
- *Moringua microchir* (native) Lesser thrush eel
- *Moringua raitaborua* (native) Purple spaghetti-eel

Muraenesocidae (Pike congers)

- *Congresox talabon* (native) Yellow pike conger

- *Congresox talabonoides* (native) Indian pike conger
- *Muraenesox bagio* (native) Common pike conger, pike eel
- *Muraenesox cinereus* (native) Dagger-tooth pike conger

Muraenidae (Moray eels)

- *Anarchias allardicei* (native) Allardice's moray
- *Anarchias cantonensis* (native) Canton Island moray
- *Echidna delicatula* (native) Mottled moray
- *Echidna leucotaenia* (native) Whiteface moray
- *Echidna nebulosa* (native) Snowflake moray
- *Echidna polyzona* (native) Barred moray
- *Enchelynassa canina* (native) Viper moray
- *Gymnomuraena zebra* (native) Zebra moray
- *Gymnothorax afer* (questionable) Dark moray
- *Gymnothorax buroensis* (native) Vagrant moray
- *Gymnothorax enigmaticus* (native) Enigmatic moray
- *Gymnothorax favagineus* (native) Laced moray
- *Gymnothorax fimbriatus* (native) Fimbriated moray
- *Gymnothorax flavimarginatus* (native) Yellow-edged moray
- *Gymnothorax hepaticus* (native) Liver-colored moray eel
- *Gymnothorax javanicus* (native) Giant moray
- *Gymnothorax meleagris* (native) Turkey moray
- *Gymnothorax monochrous* (native) Drab moray
- *Gymnothorax monostigma* (native) One-spot moray
- *Gymnothorax pictus* (native) Peppered moray

Nemichthyidae (Snipe eels)

- *Nemichthys scolopaceus* (native) Slender snipe-eel

Nettastomatidae (Duckbill eels)

- *Nettenchelys taylori* (native)

Ophichthidae (Snake eels)

- *Bascanichthys deraniyagalai* (native) Indian longtailed sand-eel, Indian longtailed sand-eel
- *Bascanichthys longipinnis* (native)
- *Caecula pterygera* (native) Finny snake-eel, Finny snake eel
- *Callechelys catostoma* (native) Black-striped snake eel
- *Lamnostoma orientalis* (native) Oriental worm-eel, Oriental sand-eel
- *Lamnostoma polyophthalma* (native) Ocellated sand-eel
- *Leiuranus semicinctus* (native) Saddled snake eel
- *Muraenichthys gymnopterus* (questionable)

Atheriniformes

Atherinidae (Silversides)

- *Atherinomorus duodecimalis* (native) Tropical silverside
- *Atherinomorus lacunosus* (native) Hardyhead silverside
- *Atherion africanus* (native) Pricklenose silverside
- *Hypoatherina barnesi* (native) Barnes' silverside
- *Hypoatherina temminckii* (native) Samoan silverside
- *Hypoatherina valenciennei* (native) Sumatran silverside

Notocheiridae (Surf sardines)

- *Iso natalensis* (native) Surf sprite

8.3.2 EXOTIC

An exotic (or non-native) species is defined as a species that does not naturally occur in a certain area or ecosystem. This includes eggs and other biological material associated with the species. Non-native species are considered invasive if they cause ecological or economic injury

The introduction of exotic fish species into ecosystems is a threat to many endemic populations. The native species struggle to survive alongside exotic species which decimate prey populations or outcompete indigenous fishes. High densities of exotic fish are negatively correlated with native species richness.Because the exotic species was suddenly thrown into a community instead of evolving alongside the other organisms, it doesn't have established predators, prey, parasites, etc. which other species do, and the exotic species thus has a fitness advantage over endemic organisms.

Some of the exotic fishes found in India are:

1. Carassius carassius
2. Ctenopharyngodon idella
3. Cyprinus carpio
4. Hypothalmichthys molitrix
5. Tilapia mossambica
6. Puntius javanicus
7. Osphronemus gouramy.

India has abundant water resources in which several species of indigenous variety of fishes survives successfully. Until now the fish culture in India was mainly dependent upon the culture of some of the most common Indian species like Labeo, Catla and Mrigal.

But it has been found in recent years that the introduction of the foreign breeds of fishes to Indian fresh water ponds and reservoirs and their culture in isolated condition or in suitable combination with the Indian counter-parts yields a higher production. In this view a number of fish species have been imported from foreign countries and introduced into Indian fresh water. Since, these fish are not the natives of this country, are called as exotic fishes.

The exotic fishes have been brought to India for different purposes. On the basis of their utility, the exotic fishes have been classified into three different categories. These are –

(1) Food fishes

(2) Game or Sports fishes

(3) Larvicidal fishes.

A list of important exotic fishes along with their source and year of introduction in India is given below-

	Species	Common Name	Source	Year of introduction
1	**Food fishes**			
	Carassius carassius	Crucian carp or golden fish	England	1870
	Ctenopharyngodon idella	Grass carp or White amur in Russia	Japan	1959
	Cyprinus carpio	Common carp	Bangkok, Ceylon	1957, 1939
	Hypophthalmichthys molitrix	Silver carp	Hongkong	1959
	Tilapia mossambica	Tilapia	Bangkok	1952
	Tinca tinca	Tench	England	1870
	Puntius javanicus	Tawes	Indonesia	1972
	Osphronemus goramy	Gouramy	Java and Mauritius	1916
2.	**Game fishes**			
	Salmo trutta	Brown trout	England	1901
	Salmo gairdneri	Rainbow trout	Ceylon and Germany	1907
	Salmo salar	Atlantic salmon	North America	1968
	Oncorhynchus nerka	Kokanee	Japan	1968
3.	**Larvicidal fishes**			
	Gambusia affinis	Cichlid	Italy	1928
	Lebistes reticulatus	Cichlid	South Africa	1908

Table 8.1

Brief account of important exotic fishes:

1. Carassius carassius:

It is commonly called as crucian carp or golden carp. It was brought to India from central Europe in 1874 and was first introduced by Maclvor in the Ooty Lake. Later on, it was transplanted to other places in Nilgiris and to Sunkesula fish farm of Andhra Pradesh. The purpose of its import is to use as food fish. These are fresh water river fish but survive and reproduce in confined water, too. In tropics, its breeding season extends throughout the year. Its growth rate is quite slow and attains a maximum length of 45 cm and a weight of 1.4 kg as recorded in Ooty Lake.

Gold carp feeds on insects, Cladocerans and Crustaceans. They attain sexual maturity in the first year of their life. The eggs remain attach to aquatic weeds till hatching. The culture of this fish is of little significance as its growth rate is low and the flesh is also not well relished. However, when it is cultured along with other species the yield increases. They help to control predators and weeds in the pond.

2. Ctenopharyngodon idella:

"Grass carp or white amur" is a native of flat land rivers of China and the middle and lower sections of the river Amur in Russia. In India it was introduced in 1959 at Cuttack (Orissa) for the sole purpose as food fish. After the successful hypophysation at the Cuttack, in 1962 the grass carp culture started at different parts of India and a gift consignment of grass carp fry was send to Philipines, Nepal and Burma in subsequent years.

Grass carp is a fresh water fish which can tolerate slightly brackish water. The body of an adult fish is elongated and slightly compressed with broad head. The upper jaw is slightly longer than the lower jaw. The barbels are absent. The dorsal fin is short. Body is dark grey dorsally with silvery belly. The scales are of moderate size.

The fries of grass carp feeds upon both zoo and phytoplankton's (rotifers, crustaceans, unicellular algae etc.). After attaining a length of 27 mm they take macrovegetations and when reaches to about 30 mm they becomes strictly herbivorous. By the end of first year, the fish attains a length of about 120 mm and weight about 225-500 gm. After two years, these attain a length of 600 mm and weight between 1.8 to 2.3 kg. In about 4 years, a fish attains a weight of 4.5 kg to 7 kg or more.

The grass carp do not breed in stagnant water. In India the maturity of male and female fish was attained in 2 and 3 years, respectively. Mature females having weight group 4, 766 to 7,036g and length ranging from 73.8 to 79.2 cm contains 3,08,800 to 6,18,100 eggs in her ovary (Alikunhi et. al, 1963). In natural conditions, the eggs are usually deposited in the middle of the river. The egg hatches in 30-40 hours and larvae acquires adult shape in 15-20 days after hatching.

Silver carps are being cultured in India. Breeding of the grass carp from the original stock by hypophysation was carried in June-July, 1962 (Alikunhi, et. al. 1963; Chaudhari et. al; 1966). The technique employed for breeding the fish in India is same as those of the other major carps. One set of breeders consists of one female and two males.

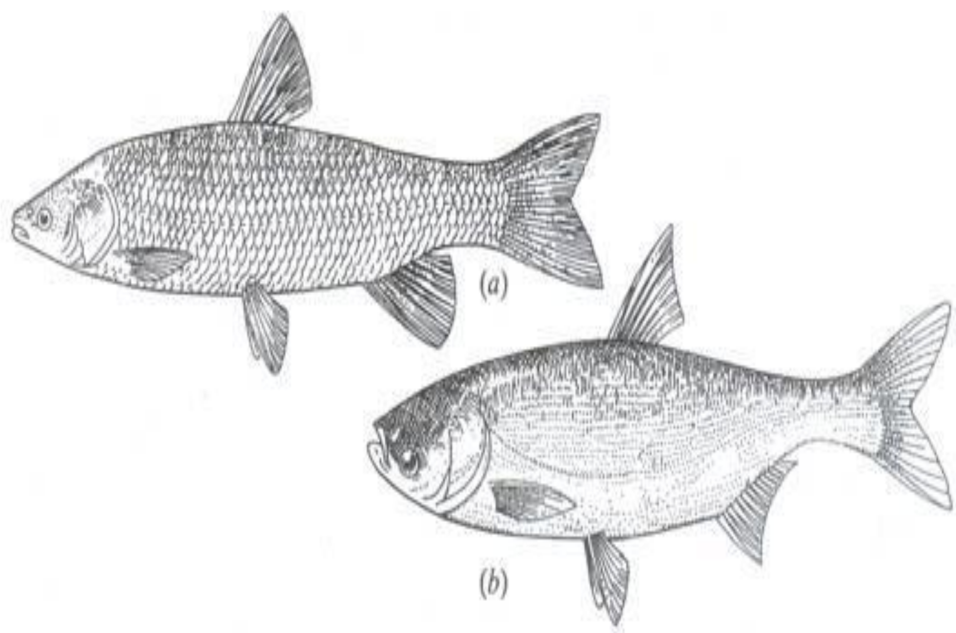
The recommended dose of injecting pituitary extract (Barrackpore, 1971) is 10-14 mg/kg body weight in females and 2—4 mg/kg in males. The donars are Indian major carps and Chinese carps.

The preparation of different tanks is made in the same manner to that of the culture of indigenous breeds. In nursery ponds the spawn stocked at the rate of 125,000/ha attained 38 to 52 mm in length and average weight of 1.5 g during 15 days (Alikunhi et. al., 1963).

The growth of grass carp fry and fingerlings, when reared in combination with silver carp and common carp in the ratio of silver carp 4; grass carp 3: common carp 3, gave 96.8% survival of grass carp.

Grass carp being a voraciferous herbivorous fish thrives well on aquatic weeds like Hydrilla, vallisneria and Najas. Sinha and Gupta (1975) observed that 75 grass carps, having an initial weight of 31 g consumed 17.7 tones of Hydrilla in six months.

Alikunhi and Sukumaran in 1964 at Cuttack observed that grass carp is stocking ponds within three years attains a length of 73.8 to 86.0 cm and a weight ranging from 4.54 to 7.03 kg.



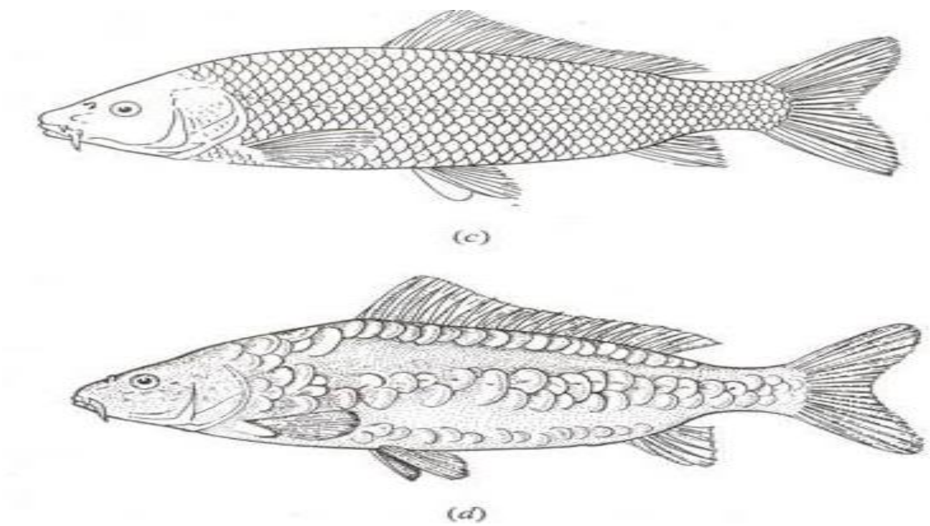


Fig 8.1 Exotic Carp

(a) Ctenopharyngodon idella (The Grass carp)
(b) (b) Hypophthalmichthys molitrix (The Silver carp)

(c) (c) Cyprinus carpio communis (The Scale carp)

(d) (d) Cyprinus carpio specularis (The Mirror carp)

3. Cyprinus carpio:

Cyprinus carpio, which is commonly called as “common carp” is a native of temperate Asia but now it has a world-wide distribution. It was initially, imported in 1939 from then Ceylone and was transplanted in Nilgiri. However, another variety (scale carp) was brought from Bangkok to Cuttack (Orissa) in 1957. In India, it is being cultivated for quit long, either, singly or along with other Indian major carps. The fish has considerable food value. The fish is ideal for culture in both cold and warm water of India however the optimal water temperature ranges between 20 – 25°C.The fish has a moderately compressed oblong body. The protractile mouth bears smooth simple lips. Two pairs of barbels are present, of which one pair is rudimentary. The dorsal fin is long which originates opposite to the ventral fin. The body colour, scales and size of the body varies in different varieties of common carp.

The three varieties of this fish are Cyprinus carpio var. Communis (scale carp), Cyprinus carpio var. Specularis (mirror carp) and Cyprinus carpio var. Nudus (leather carp). Mirror carp possess large, shiny, yellowish scales, scale carp bears small scales covering whole body while, leather carp is devoid of scales giving leathery appearance.

Cyprinus carpio is voraciously omnivorous, grows very fast, have the capability of efficiently converting food into flesh. In culture, they thrive well on artificial food. In the plains of India the fish attains maturity within six month of hatching but it takes about an year in upland lakes. In natural conditions the carps breed in confined water, in shallow, marginal, weed infested areas. They breeds twice a year. In India the season is July to August and January to March. The eggs are released on plant roots hanging below water surface. Hatching occurs in 2 to 3 days. Fry feeds on the zooplanktons and later shift on all kinds of food available in the pond.
In India, prior to breeding the males and females are segregated few months earlier and stocked in separate ponds, prefrebly free from other fishes. The breeders are regularly fed on artificial food which is mixture of oil cake and rice bran in the ratio of 1:1. Breeding is done in hapas or in cement hatcheries or in ponds.

One female and two or three males comprises one set of brood. Hydrilla and Najas, which act as egg collector are released in the hapas or cement hatcheries at the rate of 2 kg per kilogram weight of the female. About 40,000 to 100,000 eggs get adhered to about 1 kg of aquatic weeds. Larvae hatches in 4-5 days. Such larvae are transferred to nurseries. The nursery and rearing ponds for spawn are prepared as those prepared for Indian major carps.

Common carps are generally cultured in combination with Indian carps. The growth rate depends upon enviornment and temperature. In India, at a stocking density of 2,500/ha the growth of common carp in manured pond withoutt artificial food and with artificial food in one year, the weight becomes 600 – 800 g and 1 kg, respectively. In second year, the weight of individual fish, becomes 1500 g to 2000 g at a stocking density of 1500/ha. Alikunhi (1966) recorded fish with ten kilogram weight after 30 months at Barang Fish farm in Orissa. Common carps are probably the easiest fish to culture. A matured fish breeds upto five years of age.

4. Hypothalmichthys molitrix:

It is commonly called as “silver carp”. This exotic species is a natural inhabitant of Amur basins of Russia and river systems of China. Its culture is extensively practiced in China, Thailand, Taiwan, Malaysia, Japan, Sri Lanka, and Russia and now in India, Pakistan, Nepal and Philippines. Owing to its rapid growth and valued flesh, the fish is becoming popular in many parts of the world. In India, for the first time 360 fingerlings of silver carp was brought from Hongkong in 1959 to the pond culture division of CIFRI, Cuttack, and Orissa. These fingerlings were cultured and successfully bred by induced breeding techniques to raise the population.

The adult fish bears an oblong and slightly compressed body with pointed head. Lower jaw is little protruding and the eyes are small. Body is covered by small scales. Abdominal keel is present. Silver carp is a pelagic and planktophagus species. According to Nikolskii (1961) post larvae feed, on zooplankton and on reaching 1.5 cm of length, “the fry begins to feed on phytoplankton. The adult subsist on protozoa, rotifers, decayed macro-vegetation and detritus. Hora and Pillay (1962) noticed that during culture, they survive well on artificial food like rice bran, bone meal etc. Kuronuma (1968) reported that in wild the fish attains sexual maturity in 2 to 6 years, however Alikunhi (1965) found that the induced bred specimens in India becomes sexually mature in only eleven months.

Silver carp is a freshwater river fish but can survive in slightly brackish water. It does not naturally, breed in confined water but through induced breeding techniques breeding is possible even in confined water areas. The breeding technique is the same as that of other Indian major carps. For breeding, each set of breeders consists of one femal and two males. Both males and female are injected with pituitary extracts. The donars are usually Indian major carps or Chinese carps.

For rearing spawn of silver carps, nursery pond is prepared on the same pattern as those used for Indian major carps. At a stocking rate of 5 lakhs per hectare, silver carp spawn, with an average length of 7.4 mm, recorded a growth of 24 mm in length and 103.8 mg in weight with a survival of 42.5% during nine days of rearing. Survival rate upto 83% have also, been achieved in other nursery ponds. Rearing of silver carp fry and fingerlings along with other exotic species have been experimentally studied at Inland Fisheries Research Institute, Barrakpore. Six silver carps, five grass carps and five common carps at a stocking density of 93,750 fry per hactere gave 99.5% survival of silver carp fingerlings. Silver carp cultured along with Catla was experimentally observed by Sukumaran et. al., (1968) and it was found that silver carp develops faster than Catla. A stocking ratio of 2 silver carp: 1 Catla gave the highest production after six months.

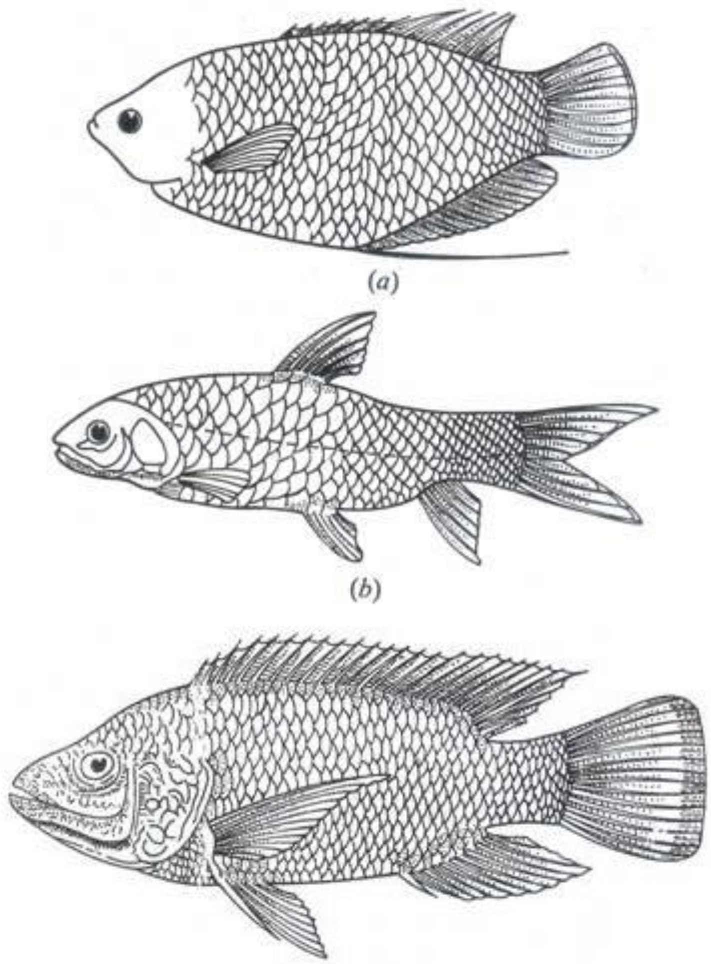
5. Tilapia mossambica:

It is commonly called as “tilapia”. Tilapia is a native of rivers on the East coast of Africa. The fish is being cultured in both fresh-water as well as in brakish water ponds. The first consignment of Tilapia was brought to India in August 1952 from Bangkok and was introduced in Mandapam. The fish is very hardy with rapid growth rate.

Adult fish has oblong and compressed body, with grey, brownish or blackish body colour. Body is covered by small scales. Head is round with upper concave profile. Pectoral and anal fins are large. Dorsal fin is very much extended. The maximum body length is 40 cm. Sexual dimorphism exist in the form of body colour. The female is grayish with black spots while the males are strickingly black with whitish lower part of head.

The fry of Tilapia, initially feeds upon zoo-planktons, but later on they take phytoplanktons, as well as zoo-planktons. The adult’s predominantely become herbivorous feeding upon phytoplankton’s, filamentous algae and the leaves of aquatic plants. In scarcity of the vegetable food, the adults may feed upon crustaceans, worms, insects, fish larvae and detritus. During culture they are fed with rice bran, oil cakes, chopped leaves and kitchen refuse.

Breeding in Tilapia takes place throughout the year at an interval of two months. During breeding phase the edges of pectoral, dorsal and caudal fins become red. Tilapia becomes sexually mature when it is only two months old and attains a length of 9 to 10 cm. Mironova (1969) recorded the fecundity of Tilapia between 80 – 1000 eggs. In natural habitat male fish, by scooping out sand from mouth, makes a shallow circular pit of about 25 cm diameter and 6 cm deep. After a brief courtship female extrudes a single batch of eggs. Males quickly pour its sperm over the spawp and then leave the site. Female picks up the eggs in her mouth for buccal incubation. The embryo hatches out within 3-5 days. The younge fries, in hour of danger enters into the mouth of female, exhibiting a highest order of parental care.



(c)

Fig 8.2 Exotic Fishes

Since Tilapia breeds readily and frequently in all types of water, no special breeding techniques have been developed. The polyculture with carps however is not recommended because it feeds upon the fries of carp and produces adverse effect on the growth of carps. According to Hora and Pillay (1962) under favourable ecological conditions Tilapia attains a weight of 850 g at the end of first year Monosex culture experiments have been attemped in Indonesia Belgium, Congo and todia During monosex culture Tilapia attains larger size, which is good for marketing.

Tilapia can be cultured in sewage water ponds and in perrenial water lodged paddy fields. India the Tilapia is not preferred by consumers, hence its culture is not practiced on large scale.

6. Puntius javanicus:

It is commonly known as “Tawes”. It was brought o India from Indonesia in the year 1972 and was first introduced in the ponds of West Bengal.

Puntius breeds naturally all over the year; however it requires well oxygenated water. Owing to its not very familiar taste, it is not recommended for culture. Its Cultivation is done along with other carps in poly-culture system mainly to keep the aquatic weeds under control.

7. Osphronemus gouramy:

It is commonly known as “Gouramy”. Osphronemus gouramy is a native of fresh water ponds and streams of Indonesia, Thailand, Malaysia, Cambodia and Veitnam. Gouramy was brought to India from Java to Calcutta and then from Mauritius to Madras in 1916 Gourami is a fresh water fish of the tropical countries which do not survive and reproduce below 15° C. They may, however, survive in water with low oxygen content as they possess air breathing organs.

Gourami breeds in ponds and streams all the year round, with a peak period in April and May. Ovoid nest is build of grasses and aquatic weeds at the bank of ponds by both males and females. Female lays 3000 – 4000 eggs in batches inside the bottom of the nest and male instantly fertilizes them. Incubation period is 36 hours. Newly hatched out larvae are transparent measuring 5.3 mm to 6 mm in length. Initially, they are without gills, mouth and fins. After 4th - 5th day of hatching they start feeding. The fry feed on insect larvae, crustaceans, rotifers, infusorians and other coarse zoo-planktons. The adults are herbivorous feeding upon aquatic vegetation but in scarcity may become omnivorous.

No special technique is employed for breeding gouramy in India as the fish is prolific breeder. Same pond is used for breeding and culture of fish. A pond where plants like Typha grows near the bank is suitable for gouramy culture. Nest building materials like “indjuk fibres”, grasses etc. are thrown in the pond. Larvae are fed with white ants and after they attain a length of 1 cm are transferred to rearing ponds which is four times larger than spawning tank. In Sri Lanka the breeding and culture of gouramy is more organised.

The pond is provided with coconut fibres and frames made of bamboo or sticks tied together. In this frame brood make nests. In Indonesia, the fish breeds in spawning tank of about 100 m^2 in size and 60 cm in depth with muddy bottom and steep bank.

Growth of gourami is very slow and therefore it is not preferred for culture in India. Sukumaran (1969) at CIFRI, Cuttack noticed that fry stocked at 2,500/ha attained an average size of only 92 mm and 15 g in weight during nine months of culture. Despite, its slow growth the fish is cultivated in Chennai, Mumbai, Orissa and West Bengal because people appreciate its taste

8.3.3 CULTURE OF LARVIVOROUS FISHES

Mosquito control operations require the introduction of a large number of larvivorous fish in aquatic habitats. With the exceptions of guppies, Gambusia and Oreochromis species, most other fish species do not breed in large numbers in their natural habitats since they require special spawning grounds, egg laying sites and optimum temperature. Because of the low food value of these other fish species; fish farmers do not culture them in captivity as part of inland fisheries. Thus, mass production of these other fish species, often under controlled conditions, is required. Mass production of guppies and Gambusia can be achieved by rearing these fish in specially constructed hatcheries or in naturally available ponds as both fish are viviparous and require no special breeding sites. These fish breed throughout the year and, therefore, large stocks can be produced within a short time. The mass culture techniques for guppies and Gambusia fish are described below and can be adapted for other fish species. Developing natural ponds/habitats into nurseries Site selection Perennial ponds of different sizes are commonly found in rural areas, many of which could be used for mass production of larvivorous fish.

In urban and industrial areas, man-made tanks of suitable sizes can be similarly used. The important steps for preparation of natural ponds into hatcheries are outlined below. Removal of predatory fish It is important to remove large predatory fish for better survival of the mother stock of larvivorous fish to be raised in the ponds. Predatory fish such as catfish (Mystus spp.), snake-headed fish (Channa spp.) and freshwater shark (Wallago attu) may devour the mother stocks and offspring of larvivorous fish. The various methods for removal of predatory fish are described as follows. Repeated netting. A fine mesh (3 mm) seine net is generally used for removal of predatory fish by repeated netting. A seine net is the most commonly used fish net and is available in different mesh and sizes. It has Use of fish for mosquito control 33 floats (hollow plastic balls) fastened on the upper margin and some weights (often iron balls) on the lower side. When fishing in ponds, when the two ends of the net are pulled forward, it presents a horseshoe shape. Total cleaning and drying up of the water body is the most favourable method where small ponds are developed for mass multiplication of larvivorous fish. After pumping out the water, the bottom should be exposed to sunlight for up to a fortnight. The bed of the pond is then treated with powdered quicklime at 250–300 kg/hectare to ensure hygienic conditions and adjustment of soil pH. Lime neutralizes the acidic condition and kills bacteria and fish parasites (optimal pH is 7.0–8.5). After 15 days of lime application, the pond may be refilled with water for fish culture. Using fish toxicants. Mahua (Madhuka indica) oil cakes (MOC) may be used at 2500 kg/ha for removal of the predatory fish. Bleaching powder may also be applied at 500-1000 kg/hectare to kill predatory fish. Two weeks after the application of fish toxicants and the removal of the dead fish, the pond may be used for fish culture.

8.4 USE OF LARVIVOROUS FISHES FOR BIOLOGICAL CONTROL

Some fish species eat mosquito larvae and pupae. In disease control policy documents, the World Health Organization (WHO) includes biological control of malaria vectors by stocking ponds, rivers, and water collections near where people live with larvivorous fish to reduce Plasmodium parasite transmission.

Use of fish in mosquito control has been well-known for more than 100 years. In India, as far back in 1904 larvivorous fishes were used in Mumbai City for the control of malaria vector An. stephensi. Larvivorous fishes Poecilia reticulata (Guppy), a native of South America and Gambusia affinis (Gambusia), a native of Texas were imported in India in 1908 and 1928, respectively for the control of malaria vectors. Soon after that use of larvivorous fish became a common practice in India, e.g. in Bengaluru and Kolkata cities and during the construction of Sharda Canal in Uttarakhand. During mid-1980s National Institute of Malaria Research demonstrated the use of larvivorous fish as part of an integrated vector control strategy. Though use of larvivorous fish is an important component of vector control in the urban malaria schemes in India.

Mass Production of Larvivorous Fish

Mass Production of Larvivorous Fish Mass production of P. reticulata and G. affinis was undertaken for mosquito control programme as part of the bioenvironmental control of malaria at many places in India. Some innovative methods have been developed to reduce the cost of mass production and distribution of fish. A number of hatcheries for mass production were established and fish were transported to the villages where they were stocked and introduced in the mosquito breeding places from time-to-time.

Species of fish that can be used for mosquito control Fish species known to have larvivorous and herbivorous potential in different regions of the world and the most promising larvivorous fish belong to the families Poeciliidae, Cyprinidae, Cyprinodontidae and Chichlidae. Use of fish for mosquito control 15 Fish species with proven larvivorous potential in the Eastern Mediterranean Region are:

Indigenous species

Aphanius dispar

Aplocheilus panchax

Aplocheilus blockii

Aplocheilus lineatus

Nothobranchius patrizii

Nothobranchius cyaneus

Nothobranchius guentheri

Nothobranchius microlepis

Oreochromis spilurus spilurus

Oreochromis niloticus

Oreochromis zillii

Puntius ticto

Puntius sophore

Rasbora daniconius

Exotic/Introduced species

Gambusia affinis

Gambusia holbrooki

Poecilia reticulata

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UNIT 9: INTEGRATED AQUACULTURE

Contents:

9.1 OBJECTIVES

1. Understand key concepts in integrated fish farming.
2. Understand various ways of Integrated Fish Farming
3. Understand some of the economic & biological benefits of Integrated Fish Farming

9.2 INTRODUCTION

Aquaculture is the fastest growing food production sector in the World with annual growth ofmore than 10 percent over the last two decades. Asia has seen a large portion of this evolution and also has the greatest diversity of cultivated species and cultural systems. Since aquaculture has a long history in many parts of the region and traditional systems are the most well-known, Asia is also regarded as the "home" of aquaculture. Additionally, Asia has the best-developed system for combining cattle and fish production.

Aquaculture is the practice of raising aquatic organisms under regulated conditions, including fish, algae, crustaceans, mollusks, and other valuable species including aquatic plants like lotus.The breeding, cultivation, and harvesting of fish and other aquatic plants is referred to as aquaculture, or "farming in water." It is an environmental source of food and commercial product which helps to improve healthier habitats and used to reconstruct population of endangered aquatic species.

Aquaculture can be conducted in completely artificial facilities built on land (onshore aquaculture), as in the case of fish tank, ponds, aquaponics or raceways, where the living conditions rely on human control such as water quality (oxygen), feed, temperature. As an alternative, they can be carried out inshore (nearshore) in well-sheltered shallow waters where the farmed species are exposed to a somewhat more natural habitat.

Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, mariculture, pisciculture, algaculture (such as seaweed farming), and the cultivation of ornamental fish. Aquaponics and integrated multi-trophic aquaculture are two specific techniques that combine fish farming and aquatic plant farming.

Integrated fish farming system is a type of farming practices in different forms mostly in the East and South-East Asian countries is one of the important ecological balanced sustainable technologies. Integrated fish farming has a long and illustrious history throughout Asia. Aquatic plant cultivation and fish farming were combined, according to written accounts from the first and second century B.C. Records date back to the ninth century and describe fish farming in a paddy field. There are records of fish and grass culture rotation from the fourteenth to sixteenth centuries, and by the 1620s, sophisticated systems of various companies integrated with fish farming, the mulberry-like fishpond, and the integration of fish and cattle farming had all been established.

Integrated fish farming is the method by which fish is cultured along with paddy, piggery, poultry or any livestock, or horticulture. Based on their knowledge and practises that have been used for a very long time, farmers in Asian nations, particularly China, have embraced the integrated aquaculture tenets. Small farmers have supported themselves for millennia by using integrated agricultural systems and various forms of crop diversification. Given that cultivating crops and raising animals, birds, and fish has shown to be a successful integrated technique, small-scale farmers in China are adopting it.

Fish species for integrated fish farming are Catla (*Catlacatla*) which are zooplankton feeder and exotic species.The greatest example of a surface feeder is the silver carp (*Hypophthalmichthys molitrix*), while Rohu (*Labeorohita*) is an omnivore and a column feeder. Detritivores include the Mrigal (*Cirrhinusmrigala*) and Kalabasu (*Labeocalbasu*), whereas bottom-feeders include common carp (*Cyprinus carpio*), which is both a detritivore and an omnivore. Herbivorous species like grass carp (*Ctenopharyngodonidella*) cover the surface, column, and periphery of the feeding zone. The common fish species raised under integrated fish animal husbandry to increase productivity is tilapia (*Oreochromis niloticus*)(Fagberno and Sydenham, 1988).

9.3 CONCEPT OF INTEGRATED FISH FARMING

The various forms of aquaculture play a crucial role in the development of agricultural and farming systems and can help reduce food insecurity, malnutrition, and poverty by producing food with a high nutritional value, creating income and jobs, lowering production risk, enhancing access to water, managing resources sustainably, and boosting farm sustainability. Aquaculture may benefit from the byproducts of the production and processing of livestock. Direct utilization of livestock wastes and recycling of nutrients derived from manure, which act as fertilisers to promote natural food webs, are the key connections between livestock and fish production.

Integrated fish farming is based on the concept that 'there is no waste', and waste is only a misplaced resource which can become a valuable material for another product. Utilizing the synergistic effects of linked agricultural activities and conservation, including complete utilisation of animal wastes, are the fundamental tenets of integrated farming(Dalsgaard *et.al.*, 1995).

Integrated fish farming systems refer to the production, integrated management and comprehensive use of agriculture, aquaculture, and livestock, with an emphasis on aquaculture. The technology combines fish polyculture with cattle and agricultural output. Recycling on-farm trash, a crucial element of integrated fish farming, benefits farmers greatly by enhancing production economics and reducing the negative environmental effects of farming. One of the best examples of mixed farming is integrated fish aquaculture.

Integrated fish farming serves as a model of sustainable food production by following certain principles:

1. The waste products of one biological system act as food for a different one.
2. A polyculture is created when fish and plants are combined, which boosts diversity and produces a variety of goods.
3. Through biological filtration and recirculation, water is reused.
4. Access to wholesome foods is made possible through local food production, which also boosts the local economy.

Integrated fish farming incorporates two or more than two production technologies running simultaneously on parallel footing to boost each other's farming. It decreases the adverse environmental impact of farming. It also increases farm output while minimizing the wastes.

Basically, the integrated fish farming is of two types -

a) Agri-based fish farming: Rice-fish integration, horticulture-fish systems, mushroom-fish systems, and seri-fish systems are a few examples of agri-based systems. In this system, the cultivation of fish is combined with the cultivation of crops including rice, bananas, and coconuts, resulting in the production of both fish and crops in a single interconnected system.

b) Live-stock fish farming: Practically, vast aquaculture is the most popular traditional method of fish production since it uses the least number of resources while producing a lot of fish per unit of land. The production of fish may be enhanced through integration with agriculture or other activities. This system provides comparatively high yields with relatively cheap input costs since it is more practical and better solution.

It is believed that this combination would be advantageous for all of the system's components. However, fish are typically the biggest winners since they either directly or indirectly use agricultural and animal waste as food.Due to the fact that integrated farming recycles trash, it has been seen as an economical and effective method of environmental management.

9.4 DIFFERENT PRACTICES OF INTEGRATED FISH FARMING

In countries like China, Thailand, Japan, Indonesia, Malaysia, etc., integrated fish farming is widely used, and it is now becoming more common in India. For the full and best use of available resources, fish culture is coupled with agriculture or livestock. It boosts productivity and generates more money from modest landholdings. With a few adjustments, the farming methods of fish-cum-pig, fish-cum-duck, and fish-cum-poultry can be easily applied in diverse regions to fully utilize farm waste and available resources. Some of the important integration models are discussed hereunder.

9.4.1 Fish-cum-poultry

Integrated fish poultry farming is practiced in many countries of the world, more particularly in Asia. The integration of aquaculture with poultry results in a more efficient use of resources. Such integrated farming is not only an efficient way of recycling the farm wastes but also yields high economic returns.In this kind of integrated fish farming, the Nitrogen and Phosphorous rich dropping of poultry is used as a fertilizer for fishponds.

In India it is practiced in Andhra Pradesh, Bihar, Haryana, Kerala, West Bengal, Uttar Pradesh, Maharashtra, Orissa, and Tamil Nadu etc.The costs associated with pisciculture operation are reduced by approximately 70% when integrated with chicken. It is because such an integrated fish farming recycles chicken wastes and spilled chicken feed as food and fertilizer for the fishes. Consequently, supplemented food and fertilizer is hardly required. A strict adherence should be followed in the schedule of vaccination against some of the contagious and infectious diseases, as it is important to prevent the loss of the birds.

Raising chicken over ponds has various advantages:

1. The chicken coops built on ponds make the best use of the land available for various uses.
2. Because the excrement fall directly into the pond's water, hygienic conditions are better in chicken houses built over ponds.
3. Chicken waste feeds the pond's plants and encourages planktonic bloom.

Methodology

Poultry house may be constructed above the water level using bamboo poles, and the dropping may fertilize the pond directly.About 500 birds produce enough litter to fertilize one ha of water and poly fish culture. Balanced feed needs to be given to the chicks. Eggs can be collected every morning and evening, and the birds to be sold after 18 months of egg laying. Under the integrated fish-cum-poultry farming, 4000-4,500 kg fish, more than 70,000 eggs and 1,250 kg chicken meat can be produced from one ha of pond in one year.

The poultry barn may be built over the pond, depending on conveniences, so that bird droppings may directly contact the pond water or land on the pond banks. Fully built-up deep litter is taken from the chicken pans and stored in appropriate locations for remote poultry homes. It is applied to the pond @ 50 kg/ha/day every morning(Singh and Khanna, 2006).

Nutritional status of poultry manure: Each bird produces about 40 g of manure/day. Poultry manure is considered a complete fertilizer having both organic and inorganic contents.The application of poultry manuring in the pond provides a nutrient base for dense bloom of phytoplankton, particularly nano plankton which helps in intense zooplankton development.Bacteria that eat the organic portion of the added poultry excrement provide the zooplankton with an extra food source.

This shows that Phytoplanktophagous and Zooplanktophagous fish need to be stocked in the pond. The pond bottom produces a lot of detritus in addition to phytoplankton and zooplankton, which serves as a substrate for the colonisation of microorganisms and other benthic species, particularly chironomid larvae. Another addition will be macro-vegetation feeder grass carp, which can feed on green cattle fodder grown on the pond embankments in the absence of macrophytes. Bottom feeders eat this fish's semi-digested excretions as food. Three primary Indian carps and three foreign carps are raised in polyculture in fish and poultry ponds in order to utilise the aforementioned food sources. Due to the harsh winters, which have an impact on fish growth, ponds in the northern and north-western states of India should be supplied in March and harvested in October or November.

Ponds should be stocked between June and September in the southern, coastal, and north-eastern states of India where the winters are moderate. Fish should then be taken after a full year of raising. Mixed culture of only Indian major carps can be taken up with a species ratio of 40 % surface, 30 % column and 30 % bottom feeders. For high fish yields, a species ratio of 40% surface feeders, 20% column feeders, 30% bottom feeders, and 10%–20% weedy feeders are desirable. The ponds may be stocked with fingerlings of the three Indian major carps or together with exotic carps as in case of carp polyculture at a stocking density of 5,000-6000 nos/ha. After the pond water has been thoroughly detoxified, it is stocked(ICAR, 2009).

9.4.2 Fish-cum-duckery:

Probst conducted the first scientific study on duck-cum-fish farming in 1934 in Germany, but the results were never put to use because of the Second World War. In order to find the best husbandry practises for rearing ducks in fishponds in the climatic conditions of central Europe, large-scale studies were launched in Hungary (1952), Czechoslovakia (1953), and East Germany (1955) during the period of severe protein shortage that followed World War II.

The best breeds and strains available have been developed for their excellent egg/meat production in Europe and America through systematic breeding, feed management and disease control.Fish-culture in combination with duck rearing is highly profitable, as it enhances the production of both the animals and decreases expenditure on fertilizers for the pond.Duck-fish integration is most common in China, Germany, Hungary, Poland, Russia and to some extent in India.In India, this farming is practiced in Tamil Nadu, Assam, Bihar, Andhra Pradesh, Tripura, Orissa, Karnataka, Kerala, and Uttar Pradesh.

The 'Indian Runner' and 'Khaki Campbell' varieties are found more suitable for this culture. Duck eggs are an important source of food in India. Consumption as well as production of duck eggs in India is mostly done by socially weaker sections of community.By integrated fish and duck culture, it is possible to obtain 3500-4000 kg fish, 18000 eggs and 500-600 kg duck meat from one hectare of pond, without using fertilizer for the pond and supplementary food for fish, thus ensuring high profit with less investment (Singh and Khanna, 2006).

Some of the advantages of integrating fish and duck farming are:

1. The fish polyculture approach works very well with duck farming.
2. Duck droppings serve as fertiliser and cut the cost of creating planktonic fish food by roughly 60%.
3. The majority of the feed that ducks need comes from the pond in the form of aquatic weeds, earthworms, leeches, insects, larvae, and other food sources.
4. Farmers typically provide rice bran, a byproduct of the kitchen, for their relatively limited dietary needs.
5. Ponds use 10–20% of the feed that ducks squander as fertiliser and fish food.
6. Ducks loosen the pond bottom with their dabbling and help in release of nutrients from the soil, which increase pond productivity.
7. Ducks are referred to as biological aerators because they aerate the water as they swim.
8. Since duck houses are built on pond dikes, no extra land is needed for duckery operations.

Housing and management:

The ducks normally do not need elaborate house, as most of the time they remain in pond. Split bamboo can be used to build a cheap duck house on the pond embankment, or a floating duck house can be placed on the water's surface. It should protect birds from their natural predators, such as foxes, jackals, dogs, cats, crows, and snakes etc. From sunrise till dusk, the ducks are given free reign over the pond, at which time they scatter poop all over it. Night droppings are collected from the duck house and applied to the pond every morning. There is no need of additional fertilizer. 10,000–15,000 kg of droppings are made available for the pond each year by stocking 200–300 ducks per ha.

Selection of ducks: Ducks of strong breeds should be chosen.Due to its hardness, the upgraded breed of "Indian Runners" has been discovered to be more appropriate. To create the amount of dung needed to fertilise one hectare of water area, around 300 ducklings are needed. The duck controls aquatic vegetation (Lemna, Azolla, etc.), aquatic insects, mollusks, tadpoles, and other organisms by splashing water with their webbed feet. The ducks are fed premium poultry feed and rice bran in a weight-based 1:2 ratio at a rate of 100 g feed per bird per day.

Pond Management: Successful Pond management is the basis of profitable fish culture. Build the pond (about 1000 m^2) close to your home so you can properly care for the ducks and fish and deter poaching. Examine the pond dikes and, if necessary, fix any damage. Increase the pond's depth so that it can hold more water throughout the dry seasonmore than 1 m. Applying 15 kg of bleaching powder and 15 kg of urea per 1,000 m^2 will drain or dry the pond and destroy or kill every last fish stock present in the pond. The dead fish can be removed with a net after being treated with urea and bleaching powder. A different option is to use 250 kg of Mahua oil cake (*Basia latifolia*), which not only kills fish but also serves as pond fertilizer.

Apply 20-25 kg of lime about a week before manuring the pond. In case a mixture of bleaching powder and urea is applied to eradicate the predatory and weed fishes, apply only 5-10 kg of lime (reducing the amount of bleaching powder applied). Manure the pond with a basal dose of cattle dung at 500 kg/1 000 m^2. Stock the pond with fingerlings 7 days after poisoning as the toxicity of bleaching powder lasts for about 1 week. Some alterations can be made on the stocking density and species ratio depending upon the pond conditions and availability of fish seed (Fig 1).

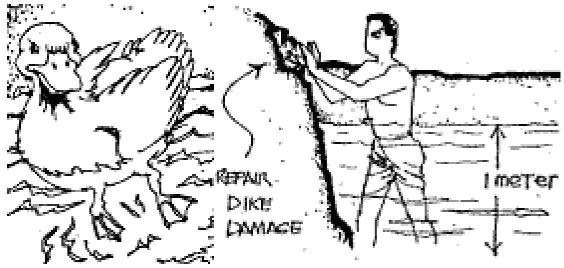

Fig. 1:Duck-cum-fish farming

Feeding: Feeding is very important component, as first three weeks are vital for future growth. There should be enough protein in the feed. Natural food might not be sufficient in the beginning, thus artificial feed must be given daily. Ducks eat a range of creatures, including snails, earthworms, aquatic insects, fingerlings and aquatic weeds, tadpoles, and frogs, as well as natural food from the pond. Better pelleted feed minimizes wastage. After feeding, about 50 to 60 percent of their waste enters the pond and fertilises it.Regular feedings of aquatic or terrestrial vegetation are necessary for grass carp. Before letting the ducks out of the duck house, it needs to be fed; otherwise, they'll spread the weeds across the pond's entire surface. Since the ducks might eat smaller ones, it is preferable to stock advanced fingerlings (those larger than 10 cm) when raising fish and ducks.

Egg-laying of ducks:When the ducks are 6 months old, they begin to lay eggs.Only 3 months old, the Khaki Campbell breed begins laying eggs, and the process lasts for 2 to 3 years, depending on the variety of duck, its health, diet, and environment.In the morning, eggs are collected after being laid overnight. Due to a decline in egg production after two years, ducks are sold once they reach that age (ICAR, 2006).

Composition of duck manure: Ducks are known as "living manuring machines" because they are excellent fertilisers for fishponds. Additionally, as ducks dangle their heads at the bottom in quest of food, nutrients are released from the soil, increasing pond productivity. They consume aquatic weeds, insects, larvae, tadpoles, mollusks, and other organisms that do not constitute food for stock fish, making the relationship between the two particularly compatible. Duck droppings cause enhanced production of both Phyto- and Zooplankton, hence Catla, Common Carp and mrigala are most suitable species for culture. Duck droppings act as a good fertilizer and are used as food by fish. The duck droppings contain 25% organic and 20% inorganic substances and are rich in carbon, nitrogen, phosphorus, potassium, calcium etc.

Management of ducks for fishponds:

Ducklings that are day old or 10 to 14 days old are best for stocking. Breeders must be between 1 and 2 years old, with a sex ratio of 1 male to 4 to 6. Egg laying can last up to 4 years;however, the yield is decreasing. Egg laying starts around the sixth to seventh month after reaching sexual maturity towards the end of the fifth month.

A suitable protein rich feed, drinking water and proper illumination are essential. A daily feed ration of 9 to 10 percent of body weight is recommended. About 120 to 140 eggs per female per year. An average egg weighs about 80–90 grammes, is 8 cm length by 5 cm wide. There is a 28-day incubation period. Seventy-five percent of day-old ducklings that are incubated survive. Up until the age of 10 to 14 days, when they can be stocked in the ponds, day-old ducklings need specific attention and a controlled environment with regard to temperature, feed, drinking water, light, and space, among other factors.

9.4.3 Fish-cum-piggery: Fish culture is linked with pig husbandry by providing pig-houses on the pond embankment or near the pond so that the waste and excreta is directly drained into pond or carried from the animal house to the pond. Pig waste works well as fertiliser. Pig excrement, which provides around 70% digestible food for fish, is another source of food for fish. As a result, there is a significant decrease in the cost of fertiliser and artificial feed for fish production.

FAO (1977) report reveals that Chinese consider pigs as free fertilizer factories on hooves.Pig manure is a full manure and contains a lot more phosphorus than cow dung. Along with trace elements including Ca, Cu, Zn, Fe, and Mg, pig dung also contains significant amounts of the inorganic nutrients N, P, and K. Pig urine contains a large amount of easily decomposable nitrogen in the form of urea.

Use of pig dung in the pond causes heavy growth of phytoplankton followed by zooplankton, and there is considerable increase in detritus at the bottom of the pond. Microvegetation is expanding, providing food for grass carp, whose semi-digested excreta are consumed by bottom feeders. In light of this, a polyculture of Catla, Rohu, Mrigala, Silver, Grass, and Common Carp produces a high output of 4,200–4,500 kg of pig meat and 6,000–7,000 kg/ha/year of common carp. We stock fingerlings at 8,000–8,500/ha (Singh and Khanna, 2006).

Feed of pigs: Balanced quality feeding plays an important role in successful pig production. Pigs are the livestock that grows the fastest, but they are also more prone to nutritional shortages than ruminants. To prevent mineral deficiencies, chopped grass is also provided to pigs once a week. Protein, carbs, fats, minerals, healthy water, and vitamins make up a pig's full diet.

Growth of pigs: Pigs take 8 to 9 months in the winter and 9 to 11 months in the summer to reach a body weight of 70 kg. The piglets weigh about 15–16 kg when they are ready to be weaned. Pigs managed properly may attain a body weight of 70–80 kg in six months (Pandey and Shukla, 2007).

Advantages of fish-cum-pig farming: Fish-cum-pig farming system has obvious advantages:

1. Pig excrement serves as a great pond fertiliser, increasing the pond's biological productivity and, as a result, the number of fish produced.
2. Some fish consume pig excrement directly, which contains 70% digestible fish food.
3. There is no need for supplemental feed, which in conventional fish production typically makes about 60% of the overall cost of input.
4. The pond dikes offer room for the construction of animal dwelling structures.
5. Pigs are bathed in pond water after being cleaned in the pigsties.

9.4.4 Fish-cum-horticulture:

Fish farming in the paddy field is documented in ninth-century records. There are records of fish and grass culture being rotated between the 14th and 16th centuries. By the 1620s, mulberry-dike fishponds, the blending of fish and animal farming, and complex systems of numerous companies integrated with fish farming had all been developed.

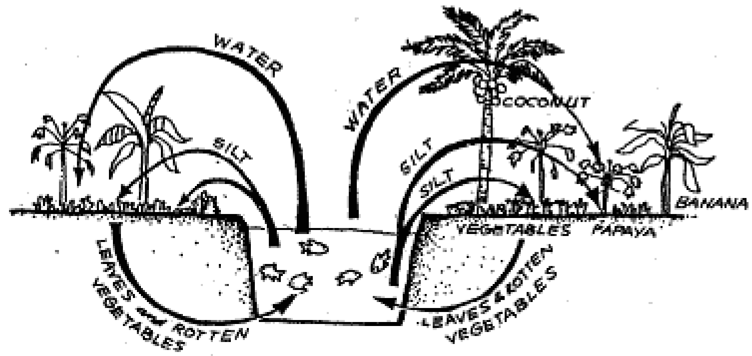

Fig. 2Fish-cum-horticulture

Pond preparation: Get rid of aquatic weeds.Compost them and utilise them later as pond manure. By repeatedly netting and draining the pond, get rid of all the fish that are already there. If draining the pond is not an option, kill the fish by putting 15 kg of bleaching powder and 15 kg of urea in the water (for 1000 m^2 pond). After using urea, bleaching powder may be used the next day. Fish can be eliminated by applying a 250 kg cake made of mahua oil. To catch all the fish, thoroughly combine it with the pond water.

Make compost and fertilise the pond. Apply 500 kg topically; the remaining 500 kg may be applied in two equal portions spaced four months apart, but more frequent doses, such as twice a week, are preferable. Since bleaching powder toxicity only lasts for about a week, replenish the pond with fingerlings 7 days after being poisoned. Depending on the pond conditions and the availability of fish seed, changes can be made to the species ratio and stocking density (Fig 2).

Harvesting: The rest of the fish should be left to continue growing while the fish that reach marketable size should be harvested. Ten to twelve months after stocking, the last harvest may be conducted. Pond silt is used to strengthen, terrace, prepare, and nourish the dikes. On the dikes, crops like bananas, papayas, pumpkins, gourds, spinach, brinjals, tomatoes, cucumbers, and leafy greens are produced. Inorganic fertilizer is also applied to the plants in addition to pond silt. Crops are watered with pond water.Banana and papaya are planted in October or November, and harvesting begins six and eight months after planting, respectively. A fraction of the gathered fruits are consumed by the farmer, while the remainder are sold in the market.

The vegetable crops are grown and harvested twice in a year-once during August/September and another in March/April. The vegetables are sold once they have satisfied the needs of the farming family (Tripathi and Sharma, 2001).

The horticulture-cum-fish farming system includes the culture of fruits, vegetables and flowers on the embankment of the pond. The pond's inner and outer dykes as well as the surrounding regions are used for the cultivation of horticulture crops. The main criterion for this system's success is the choice of plant. The plant ought to be little, seasonal, evergreen, lucrative, and less shade-producing. Mango, Banana, Papaya, Coconut, Lime, and other fruit crops can be employed, while vegetables like Brinjal, Tomato, Cucumber, Gourds, Chilies, Carrot, Radish, Turnip, Spinach, Peas, Cabbage, Cauliflower, and Ladies Finger can be produced throughout the year according to their season.

Another helpful feature is the flower garden on the embankment. We can utilise plants like roses, jasmine, gladioli, marigolds, and chrysanthemums, among others, which offer beauty and extra cash to the farm. Compared to aquaculture alone, this technique offers a 20–25 percent higher yield. Pulses and oil seed crops may also be grown in pond bundhs. Along with air-breathing or carnivorous fish, aquatic cash crops like Makhana (Euryale ferox) and Singhara (Trapa natans) can also be included.

Advantages:

1. The farmer earns extra money by planting fruits and vegetables on the embankment of the pond, which is usually left barren.
2. Organic manure is not needed because the nutrient-rich pond mud is used as fertiliser instead to cultivate crops.
3. Pond water that has been fertilised is utilised to water plants.
4. Remains from fruits and vegetables are fed to the fish.
5. Thevegetation on the embankment helps the dikes.

9.4.5 Paddy-cum-fish culture:

Rice-fish farming is practiced by the farmers mostly in rainfed and well irrigated areas.Rice-fish farming is a culture that involves growing rice and fish at the same time in irrigated rice fields to produce fish in addition to rice. Rice farming with- fish culture is a type of duo culture farming system in which rice is the sole enterprise and fish are taken to initiate additional for extra income.

Production of fish in rice fields is almost as primitive as the practice of rice culture itself. Rice-cum fish culture is practiced in many rice-growing belts of the world including China, Bangladesh, Malaysia, Korea, Indonesia, Philippines, Thailand and India. Rearing of fish along with paddy is an older farming practice adopted in India. It has largely been practiced in a traditional primitive way in the coastal areas of the country.

The paddy plots should be properly repaired for paddy cum brackish water aquaculture. An earthen dyke must be built around the paddy plot to retain water and keep the fish and shrimp during the aquaculture operation. Depending on the terrain of the plot and the tidal amplitude at the location, a dyke height of 50 to 100 cm must be maintained.

In April, rice is transplanted from rice seedbeds to large paddy fields. The paddy is then allowed for two weeks to strengthen the roots before the release of fish seed at a rate of 2500 nos./ha area. Fish are raised for 3-6 months while rice crops are raised for 5-7 months. A total of 1200+4300=5500 kg/ha/yr is produced by the kharif paddy, which yields 1200 kg/ha, and the rabi crop, which yielded 4,300 kg/ha. An output of 700 kg of fish/ha might likewise be attained in the ten months (Pandey and Shukla, 2007).

Advantages of paddy-cum-fish culture: The principal advantages of this integrating farming system are:

1. Farmers may employ this strategy for a second crop of paddy and a big harvest of fish in low-lying places without irrigation infrastructure or rabi crop possibilities.
2. The integrated agricultural system's operational economics demonstrate a higher return than paddy production alone.
3. Fish faces are used as fertiliser for paddy, increasing paddy yield by 10% to 15%.

All fishes are not suitable for such a type of culture as paddy-fields provide special ecological conditions such as shallow turbid water with high temperature. A tiny population of fish always has access to rice fields that are submerged in water for three to eight months out of the year.

This most likely led to the deliberate stocking of fish and fishing practises. A long-standing custom in India is the use of "gamcha or dhoti" to catch fish and prawns in barren paddy fields.

9.4.6. Economic and biological importance of integrated fish culture:

An integrated system of elements or components and activities that farmers carry out on their own farms with their own resources and under their own conditions in order to maximise productivity and net farm revenue on a sustainable basis is known as an integrated farming. Consequently, integrated farming is a combination of agricultural businesses to which farm families dedicate their resources in order to effectively use the current businesses to raise the productivity and profitability of the farm. Crop, livestock, aquaculture, agroforestry, and agri-horticulture are the many agricultural enterprises listed.

It is a multidisciplinary, all-farm approach that can be used to effectively address the issues faced by small and marginal farmers. IFS uses the notion of synergism to integrate multiple farm enterprises, recycle agricultural leftovers and by-products within the farm itself, and increase employment and income from small holdings.

Although the land has a very high potential, crop and livestock productivity remain at a very low level until properly managed and technology with input support is made available to the tribal communities. Pigs are the fundamental components and play a significant part in the security of rural livelihoods in tribal communities' animal husbandry practises, which are another significant support activity in addition to crop cultivation. Bullocks are kept as draught animals and cows are mostly kept for milk, both at subsistence levels. Like poultry, raising poultry is a domestic activity.

For local applications and situations, the cash flow analysis will differ, and it for local businesses, the cash flow analysis will differ. For local applications and situations, the cash flow analysis will differ, necessitating adaptive trials. Overall, the technology might only be practical under specific operating circumstances. Only if the ducks are fed only agricultural waste and kitchen scraps could the duck rearing component be financially sustainable. This limits the number of ducks that can be retained in the system; typically, five to ten are supported on household garbage.

An economically sustainable size of the duck farm must be maintained if the farmer must rely on purchased feed (to the extent that this is even available in rural locations), which will depend on regional preferences, market conditions, egg and meat prices, and the cost of duck feed. Rearing units with even 100 to 200 ducks could not be sustained for a long time, according to prior experience. In this situation, the farmer would choose to get and use organic manure from alternative sources instead of starting a duck farm where such a significant cost and risk are involved. Despite repeated efforts to popularise it over the previous 10 to 15 years, these factors are the reason why this integrated fish farming technology package has not yet gained popularity among resource-poor farmers in India, Bangladesh, Nepal, and other neighbouring countries.

The economic benefit of integrated fish farming cannot beover-emphasized since the integration is varied anddiversified in nature. It is among the most profitable, dependable, and viable farming ventures there are. It makes a significant contribution to the economic empowerment of many families, particularly in rural areas. It helps the farmer to maximise productivity and be productive throughout the entire year.

9.5 SUMMARY

Integrated fish farming and animal husbandry combines fish cultivation with the production of poultry, pigs, ducks, and other animals. Due to the efficient recycling of waste or byproducts from one system, this method of farming offers excellent resource use. It also makes it possible to use the available farming space efficiently to increase production.

Integrated fish farming has the ability to boost a society's socioeconomic standing and increase farm output. It makes a significant contribution to the economic empowerment of many families, particularly in rural areas.

It boosts output and economic efficiency while reducing input. Given that the integration is varied and diversified in character, the economic value of integrated fish farming cannot be overstated. It is among the most profitable, dependable, and viable farming ventures there are. It lowers the additional expense for fertilisation and supplemental feeding.

In integrated fish farming, the majority of the manure loading comes from poultry and other farm animals, which are rich sources of nutrients for fish growth. Additionally, it includes undigested feed. It can be used to substitute appropriate amounts of the feed materials used in traditional fish production to reduce costs.

The various forms of aquaculture play a crucial role in the development of agricultural and farming systems and can help reduce food insecurity, malnutrition, and poverty by producing food with a high nutritional value, creating income and jobs, lowering production risk, enhancing access to water, managing resources sustainably, and boosting farm sustainability.

Integrated fish poultry farming is practiced in many countries of the world, more particularly in Asia. The integration of aquaculture with poultry results in a more efficient use of resources.

Poultry house may be constructed above the water level using bamboo poles, and the dropping may fertilize the pond directly.

Duck eggs are an important source of food in India. Consumption as well as production of duck eggs in India is mostly done by socially weaker sections of community. The 'Indian Runner' and 'Khaki Campbell' varieties are found more suitable for this culture.

Use of pig dung in the pond causes heavy growth of phytoplankton followed by zooplankton, and there is considerable increase in detritus at the bottom of the pond.

The horticulture-cum-fish farming system includes the culture of fruits, vegetables and flowers on the embankment of the pond. The pond's inner and outer dykes as well as the surrounding regions are used for the cultivation of horticulture crops.

Rice-fish farming is practiced by the farmers mostly in rainfed and well irrigated areas. Rice-fish farming is a culture that involves growing rice and fish at the same time in irrigated rice fields to produce fish in addition to rice.

All fishes are not suitable for such a type of culture as paddy-fields provide special ecological conditions such as shallow turbid water with high temperature.

It is a multidisciplinary, all-farm approach that can be used to effectively address the issues faced by small and marginal farmers.

An economically sustainable size of the duck farm must be maintained if the farmer must rely on purchased feed (to the extent that this is even available in rural locations), which will depend on regional preferences, market conditions, egg and meat prices, and the cost of duck feed.

The economic benefit of integrated fish farming cannot be over-emphasized since the integration is varied and diversified in nature.

9.6 TERMINAL QUESTIONS AND ANSWERS

Q1. What is integrated fish farming? Explain in detail.

Q2. Write an essay on integrated fish farming.

Q3. Describe duck-cum-fish farming.

Q4. Write a note on paddy-cum-fish farming.

Q5. Give an account on horticulture-cum-fish farming.

Q6. Explain economic and biological importance of integrated fish culture.

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UNIT 10: FISH NUTRITION AND PATHOLOGY

Contents:

10.1 OBJECTIVES

1. Understand nutritional requirements of fish.
2. Understand different kinds of Fish feed.
3. Artificial feeding and Feeding devices.
4. Satisfy all known nutrient requirements for growth of the species.
5. Minimize feed cost.
6. Various viral diseases observed in fishes and the methods of prevention and treatment of these diseases.
7. The important fungal diseases observed in fishes, the methods of prevention and treatment.
8. The various bacterial diseases observed in fishes, the methods of prevention and treatment.
9. Understand parasitic disease observed in fishes, methods of prevention and treatment.
10. Select and use ingredients that will result in products that are readily utilized to minimize wastage.

10.2 INTRODUCTION

Aquaculture has seen a lot of developments in the last few decades and is currently the fastest growing agricultural sector in the world. Fish nutrition, feeds, and feeding management play important roles in increasing the productivity of aquaculture farms and to prevent nutritional diseases. Feed represents the largest variable cost in most fish production.

To effectively raise fish for food production, aquaculture needs to optimise nutrition. Although there is a definite demand for less expensive feeds, it is crucial that fish feeds be designed to be cost-effective rather than just less expensive. This can be done by selectively choosing and combining several conventional and alternative feedstuffs that are appropriate for use in fish feeds. The nutritional and physical quality of the feed, fish development, processed production, and product quality must not be compromised while employing less expensive substitute feedstuffs.

Diseases are an important constraint to aquaculture development and sustainability because of investment loss due to fish mortality, cost of disease treatment and loss of product quality and quantity. Some of the crucial ingredients for healthy fish growth are lipids, carbs, proteins, vitamins, and mineral salts. Due to their chronic nature, most nutritional illnesses are highly challenging to diagnose, but they can be prevented by using effective eating management techniques.

10.2.1 Nutritional requirement of fish

Nutrition plays a critical role in intensive aquaculture because it influences not only production costs but also fish growth, health and waste production. Knowing a species' nutritional needs is essential for creating nutrient-dense, affordable meals that satisfy those needs through balanced diet formulations and sensible feeding techniques. Our understanding of the nutritional needs of farmed fish has grown during the past 20 years of research. Different kinds of nutrients are necessary for the growth, health, and maintenance of fish.

The body metabolises the many nutrients needed by fish, including proteins, lipids, carbs, vitamins, and minerals, to provide the energy required for a variety of physiological functions and physical activities. The capacity of different fish species to utilise nutrients that provide energy varies greatly. Their natural feeding behaviours, which can be categorised as herbivorous, omnivorous, or carnivorous, are linked to this variety. Thus, there is a connection between dietary protein needs and natural feeding patterns.

Compared to some carnivorous animals, herbivorous and omnivorous species need less protein in their diets. Carnivorous creatures use their food's protein and lipids for energy quite effectively, while they use their carbs less effectively. Research, quality assurance, and biological assessment are required for the creation of nutrient-balanced fish feed. Poor nutrition undoubtedly reduces fish productivity and causes a decline in health before noticeable problems appear.

Protein and amino acids:

Proteins are large, complex molecules that play many critical roles in the body. They are made up of hundreds or thousands of smaller units called amino acids, which are attached to one another in long chains. They do most of the work in cells and are required for the structure, function, and regulation of the body's tissues and organs.Proteins are among the most important constituents of all living cells.

In fish, it is the major organic material in fish tissue constituting about 65-75% of the total (on the dry weight basis) and are needed for replacement of worn-out tissues as also several proteinaceous products required for proper body function. Proteins are also required for synthesis of new tissues and hence growth. For proper growth and health, a fish's diet must have enough protein or a balanced combination of amino acids. Carnivorous species may need a diet with 40 to 50 percent crude protein, while the majority of herbivorous and omnivorous fish studied to far need a diet with 25 to 35 percent crude protein. The gross protein demand decreases as fish get older and bigger.

Table1: Dietary protein requirements of some fish species for their optimum growth

No.	Species	Protein %	Protein source
1.	*Cyprinus carpio* (spawn, fry and fingerlings)	45	Casein
2.	*C. carpio* (Fingerlings)	54	Fish meal
3.	*Labeo rohita* (fry)	45	Casein
4.	*L. rohita* (fry)	40	Fish meal and ground nut oil cake
5.	*L. rohita* (Fingerlings)	30	Casein and groundnut oil cake
6.	*Cirrhinus mrigala* (Fry and fingerlings)	40	Fish meal and groundnut oil cake
7.	*Catla catla* (Fry)	47	Casein and gelatin
8.	*C. catla* (Fingerlings)	40	Casein and gelatin
9.	*Ctenopharyngodon Idella*	36	Leaf protein concentrate
10.	*C. Idella* (Fry)	42	Casein
11.	*Anabas testudineus*	40	Carecass waste and groundnut oilcake
12.	*Clarias batrachus*	40	Casein gelatin)

	(Fingerlings)		
13.	*Channa striatus* (Fry)	55	Fish meal, groundnut (oilcake)
14.	*Macrobrachium rosenbergii*	35	Fish meal, groundnut oilcake, soybean meal
15.	*Penaeus monodon*	40	

The quantity and quality of protein in the feed affects fish growth and health maintenance. Additionally, protein promotes fish growth and assures the production and function of vital hormones and enzymes. The quantity and biological availability of the necessary amino acids play a key role in determining the protein quality for fish nutrition.

The most common signs of protein and/or amino acid deficiency in fish are:

- Reduction of growth rate.
- Mortality
- Scoliosis and Lordosis.
- Anemia (Reduction of RBCs)

The fish needs a well-balanced blend of essential and non-essential amino acids instead of a genuine protein requirement. For a fish to maintain its metabolic processes, it needs enough non-specific nitrogen and the necessary amino acids. About 20 distinct amino acids are released during protein hydrolysis, of which 10 are essential for fish, including arginine, isoleucine, histidine, lysine, leucine, methionine+cystine, phenylalanine+tyrosine, threonine, tryptophan, and valine (Table 2).

Table 2: Essential amino acid requirement of some fishes and shrimp (% dietary protein)

Amino acid	Rohu	Catla	Mrigal	Common carp	Tilapia	Rainbow trout	Prawn	Milk fish
Arginine	5.75	4.80	5.25	4.3	4.2	5.0	3.7	5.2
Histidine	2.25	2.45	2.13	2.1	1.7	1.8	0.7	2.0
Isoleucine	3.00	2.35	2.75	2.5	3.1	2.0	0.6	4.0
Leucine	4.63	3.70	4.25	3.3	3.4	3.5	1.0	5.1

Lysine	5.58	6.23	5.88	5.7	5.1	4.5	3.2	4.0
Methionine	2.88	3.55	3.18	3.1	2.7	*3.5	1.2	2.5
Phenylalanine	4.00	3.70	4.00	6.5	5.5	**4.5	1.7	**4.2
Threonine	4.28	4.95	4.13	3.9	3.8	2.0	1.6	4.5
Tryptophan	1.13	0.95	1.08	0.8	1.0	0.5	0.5	0.6
Valine	3.75	3.55	3.50	3.6	2.8	3.2	2.06	3.6

*With cystine; **With tyrosine

In addition to size, other factors that affect a fish's need for protein include water temperature, dissolved oxygen levels, pH, and feeding frequency. To guarantee that requirements for protein and amino acids are met, commercial feeds are carefully prepared.

Lipids: The lipids are a heterogeneous group of substances found in plant and animal tissues, which share the property of being relatively insoluble in water, and soluble in organic solvents, such as ether, chloroform and benzene etc. Lipids are an important source of energy, essential fatty acids, and phospholipids. Lipids provide a vehicle for absorption of fat-soluble sterols and vitamins. Lipids are important sources of metabolic energy (ATP) and the energy value of lipid is higher (9.5 kcal/g) when compared to protein (5.6 kcal/g) and carbohydrate (4.1 kcal/g). Free fatty acids derived from triglycerides (fats and oils) are the major aerobic fuel sources for energy metabolism of fish muscle. Fatty Acids from lipids are essential for the maintenance and integrity of cellular membranes. They are also a source of essential steroids, which in turn perform a wide range of important biological functions.

Lipids may be classified into two basic groups - glycerol-based lipids and non-glycerol-based lipids, according to the presence or not of the alcohol glycerol. In terms of feed technology, lipids reduce the dustiness of feeds, increase feed palatability, and act as lubricants for the flow of feed through pellet dies. Although estimates of the gross lipid requirements for various species range from 4 to 15 percent, the ideal level of dietary lipids for carps and prawns is typically thought to be between 7 and 9 percent.

A fish's ability to digest and absorb food is decreased by an excessive amount of dietary lipid, which also suppresses the production of fatty acids and slows growth. Additionally, it is well recognised that feeding too many lipids can result in fatty fish and harm the flavour, consistency, and shelf life of final goods. Although the body can produce cholesterol, some crustaceans, like prawns, need cholesterol in their diet. Prawns responded favourably to diets containing sterol and cholesterol at levels of 0.25 and 0.5 percent.

Animals' main energy stores are fats, which are fatty acid esters of glycerol.These are used to meet long-term energy needs during periods of intense exercise or when food and energy intake are insufficient. Fish have the special capacity to easily metabolise these substances, which allows them to survive for extended periods of time without food. Salmon migrate for weeks to return upstream to spawn; throughout this arduous journey, accumulated lipid deposits are consumed as fuel to keep body functions running smoothly.

Esters of fatty acids and phosphatidic acid make up phospholipids.These are the primary lipids that make up cellular membranes, allowing the orientation of the lipid molecules into intracellular or extracellular regions to determine whether the membrane surfaces are hydrophobic or hydrophilic. The substances found in brain and nerve tissue are known as sphingomyelins, which are fatty acid esters of sphingosine. Long-chain alcohols are fatty acid esters, and these are waxes. Through the stored lipids of some plant and several animal molecules, these substances can be digested to provide energy and to impart physical and chemical properties. Sterols are polycyclic, long-chain alcohols that have a role in several hormone systems, particularly in the physiological processes of sexual maturation and sex.

Carbohydrates:

Sugars, starches, gums, and celluloses are all included in the large category of compounds known as carbohydrates. The only elements found in carbohydrates are carbon, hydrogen, and oxygen, and when they are burned, they produce carbon dioxide and one or more molecules of water.

The three-carbon sugars, which play a significant role in intermediate metabolism, are the simplest carbohydrates, while the naturally occurring polysaccharides, mostly of plant origin, are the most complicated. Although fish do not specifically need to consume carbs, having these substances in diets provides a cheap source of energy.

In the diet of animals and fish, two classes of polysaccharides are significant:

(A) The structural polysaccharides cellulose, lignin, dextrans, mannans, inulin, pentosans, pectic acids, algic acids, agar, and chitin are all edible by herbivorous organisms.

(B) Polysaccharides that are universally digested, mostly starch.

It has been demonstrated that in many aquaculture species, carbohydrates have a sparing impact on the consumption of dietary protein. Fiber would be able to transfer other nutrients through gastrointestinal tracts for efficient digestion if there was a sufficient balance of carbs in the diet. Tilapia, milkfish, prawns, and carps all effectively use carbohydrates as fuel.

Dextrin and gelatinized starch are effectively used by rainbow trout. A tiny amount of carbohydrate in the diet of salmon is usually healthy. Poly and di-saccharides are used more effectively by shrimp. Carps are capable of digesting carbohydrates at a rate of 55–60%, compared to rainbow trout at less than 25%, salmon species at 6–15%, and humans at 20% when lipids and protein are balanced properly. However, carp diets typically do not contain more than 30% of carbohydrates. Typically, 35 to 40% of prawns consumed commercially.

Energy: Energy is not a nutrient, but is a property of nutrients, which is released during metabolic oxidation of proteins, lipids and carbohydrates. Energy is the ability to do work, but in a biological sense, it also refers to muscle activity, energy for bodily chemical reactions, the ability to transport molecules against concentration gradients, and other biological and physiological processes. Due to their neutral buoyancy and the fact that maintaining their body temperature requires no energy, fish have low energy needs. Fish's energy needs are influenced by a number of elements, including temperature, size, growth rate, species, and diet, as well as physical activities like swimming and evading predators.

Vitamins and Minerals: Vitamins are required in trace amounts; are essential for fish growth and to fight against diseases. They are necessary for the tissue components' metabolism of other nutrients. Numerous water-soluble vitamins function as coenzymes as well. Thiamine, riboflavin, pyridoxine, pantothenic acid, inositol, folic acid, choline, biotin, ascorbic acid, and vitamin B12 are just a few of the eleven well-known water-soluble vitamins. There are also four fat-soluble vitamins, including A, D, E, and K. When consumed in excess over what the body can store, water-soluble vitamins are expelled after being converted to fish-necessary vitamins. Vitamins A (retinol), D (cholecalciferol), E (alpha-tocopherol), and K are all fat-soluble vitamins. Fish can live for lengthy stretches without these vitamins in their diet before showing symptoms of insufficiency because these fat-soluble vitamins are digested and stored in conjunction with body lipids. Extra dietary fat-soluble vitamins cause improper development and liver problems.

S. No.	Vitamin	Catla	Rohu	Mrigal	Common carp	catfish	Seabass	Rainbow trout
1.	Thiamin	-	-	-	2-3	1-3	R	1-12
2.	Riboflavin	-	-	-	7-10	9	R	3-30
3.	Pyridoxine	-	-	-	5-10	3	5-10	1-15
4.	Pantothenic acid	-	-	-	30-40	25-50	15-19	10-50
5.	Niacin	-	-	-	30-50	14	-	1-150
6.	Folic acid	-	-	-	NR	R	-	5-10
7.	Vitamin B12				NR	R	R	0.02
8.	Myo-inositol	-	-	-	200-300	R	R	200-500
9.	Choline	-	-	-	1,500-2,000	400	-	50-3,000
10.	Biotin	-	-	-	1-1.5	R	-	Na
11.	Ascorbic acid	-	-	650-700	30-50	60	700*, 25-30**	100-500

12.	Vitamin A (IU)		2,000		1,000-2,000	1,000-2,000	-	2,000-15,000
13.	Vitamin D (IU)	-	-	-	NR	500-1,000	-	2,400
14.	Vitamin E (IU)	98.4	131.19	99	80-200	30	-	30-50
15.	Vitamin K (IU)	-	-	-	R	R	-	10

Table1. Vitamin requirements (mg/kg dry diet) of certain fish species

Minerals are necessary for fish structural functions and the osmotic balance of several metabolic processes. While some elements, like calcium, are absorbed by fish directly from their gills and skin, or both, other minerals can be found in natural food sources and swallowed debris. There are 20 identified inorganic needs that carry out crucial bodily processes. Iron, manganese, selenium, zinc, aluminium, chromium, vanadium, calcium, chlorine, magnesium, phosphorus, sodium, and other minerals are needed for fish. In metabolism, calcium and phosphorus are tightly connected. Calcium and phosphorus are necessary for the development of bones. Calcium is essential for healthy muscular contraction, blood coagulation, and nerve signal transmission.

10.2.2 Feed and feed formulation

Nutrition is crucial in aquaculture, the production of fish. Recent years have seen a significant advancement in fish nutrition thanks to the creation of new, balanced commercial diets that support ideal fish growth and health. In the aquaculture sector, feeding artificial food that is balanced in all nutrients has taken on top priority. Over 60% of all input costs in an aquaculture business go toward artificial feeding, making it a crucial technique.

Prepared or synthetic foods come in complete or supplemental varieties. Complete diets give fish all the nutrients they need for optimum growth and health, including protein, carbs, lipids, vitamins, and minerals. Supplemental (i.e., incomplete or partial) diets, on the other hand, are solely meant to complement the natural food that fish in ponds or outside raceways often have access to. Supplemental diets are often used to assist strengthen the naturally available diet with additional protein, carbohydrate, and/or lipids. They do not, however, provide the full complement of vitamins and minerals.

Feed formulation entails choosing an ingredient combination that will result in a mixture with critical nutrient levels at or above the minimal requirements of the fish. Applied nutrition is essentially what feed formulation is. Feeds should never be kept on hand for longer than three months and should always be maintained in a cold, dry place. The high moisture level in that climate makes it unwise to refrigerate dry foods. An acceptable method of extending shelf life is freezing. Commercially produced milled fish food is typically offered as flakes, pellets, or semi-moist pellets. The most complete diets are often boiled pellets. Negative aspects include the possibility of rapid sinking if the pellet isn't extruded. The size of the pellets is also crucial. Some fish, particularly young fish of many species, may not be able to consume a particle that is small enough to be manufactured. A very little pellet may not be appropriate for larger animals.

Diets that are semi-moist are fluffy and little. Although many of them are pricey, they frequently consist of high-quality diets and might be a great option for some species. Since they are soft enough for extremely small fish to ingest, flakes have long been used widely in the ornamental fish market. Additionally, they sank slowly. Unfortunately, the volume needed to satisfy the animals' nutritional needs could be overly large. A diet should only contain ingredients that have a defined purpose, such as being a great source of energy or having a high concentration of an amino acid that is a dietary limit. Each feed component in a particular diet formulation should also be the least expensive one available for the diet's intended usage. The assumption that any nutrient available in a particular feed, like an amino acid, is equally helpful to that nutrient present in any other feed, which is what this leads to, is another presumption in feed design. This makes it possible for feed formulators to switch out various feedstuffs when availability and pricing change.

Fish meals primarily consist of byproducts from the manufacture of food for humans made from plants and animals. Since they have restricted nutrient levels or potentially feature antinutritional qualities, the majority of these ingredients are employed in diet formulations only within specific constraints. However, it is possible to combine complementary elements to meet the nutritional requirements of fish.

Supplements for energy and protein make up the majority of the ingredients in prepared fish diets. Mineral and vitamin supplements are two additional categories of feedstuffs that are frequently bought as premixes and added to nutritionally complete diets to make sure that all nutrient requirements are met. Additives make up the last category of feedstuffs. Antioxidants, binding agents, enzymes, immunostimulants, flavour enhancers, prebiotics, and probiotics are some examples of substances that can be added to fish meals at relatively low quantities to provide specific benefits.

Energy concentrates have less than 20% crude protein and less than 18% crude fibre than protein supplements, which have more than 20% crude protein. Energy concentrates contain mill wastes like wheat middling and rice bran as well as feed-grade cereal grains including corn, wheat, and sorghum. Fats and oils are the other concentrated energy source for fish diets.

A pellet binder is often added to the mixture to boost pellet durability, even though heating of the components and gelatinization of starch do occur during the pre-conditioning and pelleting process. In order to expose the feed mixture to heat and moisture from steam, extrusion processing also uses a preconditioning chamber. However, as the feed mixture descends the extruder barrel and is forced out the other end through a die, it is exposed to higher moisture (roughly 25 percent) and much higher temperatures (190 to 300 °F). Both pressure and heat are generated significantly as the mixture slides down the extruder barrel.

Part of the moisture vaporises when the mixture leaves the die due to an abrupt drop in pressure, which causes the pellets to expand and lose density. Extruded pellets must be dried in a dryer to a moisture content of 8 to 10% in order to be maintained without refrigeration. Pellets may only contain a certain amount of fat due to frictional losses during processing. Extrusion offers some advantages over pelleting, one of which is that bigger pellets will absorb more lipid when they are coated with it using a fat coater. Fat is frequently supplied after drying and just before the feed is put into storage bins. Food with a fat coating has more energy and may taste better as well as produce less feed dust. The finished feed is taken out of the storage bins and either loaded onto a truck for distribution in bulk or packaged for delivery to a single customer.

It is possible to produce food for small fish in a variety of methods. Using methods for micro binding, micro coating, and microencapsulation, larval meals with diameters ranging from 25 to

400 microns will be created. Pellets are reduced in particle size and filtered into predetermined size ranges to create conventional meals and crumbles. The processing techniques and diet types used to feed microscopic fish of a particular species may be influenced by the physical properties of a fish and the requirements of the culture system for effective dispersion.

Major cultured fish species have well-established dietary requirements. When comparing animals with similar natural food habits and habitat requirements, these estimates are remarkably consistent. The information also includes the typical feeds used in fish diets' nutritional composition and suitability. This knowledge has inspired the creation of food formulations and feed management strategies that support efficient and successful production while preserving the wellbeing of the cultivated species.

Steps in feed formulation:

The first step in diet formulation is balancing the crude protein and energy levels. Trial and error, the square approach for calculating crude protein or energy levels and then correcting, or the solution of simultaneous equations can all be used to achieve this. When first balancing the levels of protein and energy, it is helpful to utilise at least three feedstuffs: one high in protein and high in ME, one low or intermediate in protein and high in ME, and one low or intermediate in both protein and ME. Any number of feedstuffs can be used once diet formulation is mastered via practise. It's important to keep in mind to leave space in the recipe for any feed additives, like a vitamin or mineral premix.

To ensure that the dietary levels fulfil the needs of the animal to be fed, the second step in diet formulation is to evaluate the levels of essential amino acids in the formulation. Fish's essential amino acid needs are represented as a percentage of the diet's total calories or as a percentage of the protein in the diet. Divide the dietary level of each amino acid by the dietary protein level to convert an amino acid level from the percent of diet to the percent of protein.

Calculating the dietary intake of each essential amino acid may be interesting, but it is not always practical to do so. The levels of the other six essential amino acids will most likely be above necessary levels if the levels of arginine, lysine, methionine, and tryptophan satisfy the nutritional needs of the fish to be fed. It is important to monitor the amounts of all ten essential amino acids when utilising unusual protein supplements.

If any of the amino acids in the diet formulation are low, the diet must be supplemented with a feed that has high levels of that amino acid at the expense of another ingredient. Following the fulfilment of the amino acid requirements, the diet's protein and calorie levels must be evaluated again to determine whether any ingredient substitutions resulted in an unbalanced formulation.

A diet mixing sheet should be constructed to standardize diet formulation. A sample sheet is shown in table 2.

Table 2:Some feed formulations for fry and fingerlings of Indian major carps

Feed	Fry		Fingerlings and growers	
	Ingredients	**Composition (%)**	**Ingredients**	**Composition (%)**
1.	*Azolla* powder	60.0	Rice-bran	35.0
	Soybean meal	19.0	Groundnut oilcake	25.0
	Groundnut oilcake	13.9	Roasted soybean meal	25.0
	Sesame oilcake	4.0	Fish meal	7.0
	Rice-bran	2.0	Vegetable oil	5.0
	Vitamin mineral mix	1.0	Fish oil	2.0
	Attractant (Seeds of *Trigonella* and *Murraya*)	0.1	Vitamin-mineral premix	1.0
2.	Groundnut oilcake	26.0	Groundnut oilcake	28.0
	Soybean meal	23.0	Soybean meal	20.0
	Rice-bran	33.0	Rice-bran	30.0
	Fish meal	16.0	Meat-cum-bone meal	20.0

	Vitamin mineral mix	2.0	Vitamin-mineral premix	2.0
3.	Groundnut oilcake	28.0	Soybean meal	7.0
	Soybean meal	20.0	Groundnut oilcake	30.0
	Rice-bran	30.0	Mustard oilcake	35.0
	Meat meal	20.0	Rice-bran	26.0
	Vitamin mineral mix	2.0	Vitamin-mineral premix	2.0
4.			Groundnut oilcake	40.0
			Soybean meal	20.0
			Fish meal	8.0
			Rice-bran	30.0
			Vitamin-mineral premix	1.5
			Vegetable oil	0.5
5.			Fermented silkworm pupae	6.7
			Rice-bran	19.3
			Ground nut oilcake	62.0
			Groundnut oil	5.0
			Binder mix (tapioca flour, maida and rice flour in 6:3:1 ratio)	5.0
			Vitamin-mineral premix	2.0

10.2.3 Different type of feed:

There are different types of fish food in the water such as dissolved nutrients and different types of plants and animals. Some fish have been observed to directly absorb glucose from water, while specifics on direct food intake are unknown. There are numerous primary and secondary ingredients and ions that are dissolved in water and absorbed by fish directly through the gills or with food to the digestive tract. Different kinds of food are consumed by various fish. Some fish only consume plant matter, but others rely on animal sources of nourishment. The majority of fish need nutrients from both plant and animal sources, including protein, carbohydrates, lipids, vitamins, and other nutrients for development and health.

Fish need to eat organic things like plants, animals, or prepared meals that incorporate plant and/or animal material in order to survive, grow, and reproduce. Therefore, it is crucial for you to make sure your fish receive the food they need in both quality and quantity.

These fish foods come from two main sources, namely-

(1) The environment in which fish live, i.e., from the aquatic environment and

(2) Outside the aquatic environment i.e., from the land surface of the earth.

Selecting fish foods:

According to this difference in food sources, fish food can be mainly divided into two types, viz

1. Natural food
2. Supplementary feed

1. Natural Food: Natural fish food is defined as foods that are naturally created in reservoir water. Fish naturally eat plankton, aquatic plants and insects, aphids, organic materials at the bottom of the reservoir, etc. The quality of the water has a big impact on their quantity. For fish to thrive, natural food is their primary source of nutrition. Liming and fertilisation, especially organic fertilisation, can assist you in giving your fish a plentiful supply of natural food.

2. Supplementary Food:

Some food is provided from outside the reservoir in addition to the natural food that is provided to promote higher output. Supplemental food refers to certain foods provided from outside sources. Supplemental food for fish includes things like rice husk, wheat bran, mustard oil cake, etc.

In addition to the above methods, fish food can also be classified in the following ways, viz.

1. Plants food
2. Animal food
3. Mixed food
4. Prepared food

Plants Food: Foods obtained from plants or vegetable sources are called vegetable foods, such as phytoplankton, grasses, soft aquatic plants, rice husk, cornmeal, mustard oil cake, wheat bran, etc.

Animal Food: Animal food includes items like zooplankton, tiny aquatic insects, calf blood, silkworms, fish dinners, etc. that are produced from animals or animal sources.

Mixed Food: Food that has been combined from both plant and animal sources, such as rice husk, cow blood, and decaying organic debris at the bottom of a pond, is known as mixed food.

Prepared Food: A balanced diet formed from combining various food elements called prepared food. Food is made in pellets, tablets, or granules. Today's market offers a variety of prepared food options. Such as- starter, grower etc.

Different species of fish have different diet and food intake. Nikolsky (1983) divided fish food into four categories, viz

Basic Foods: Basic foods are the foods that most fish eat. It typically appears in the majority of fish diets.

Secondary Foods: Fish occasionally eat tiny amounts of food that is connected to basic dietary components. Such foods make up fish's secondary diet.

Incidental Foods: An ingredient that rarely enters the digestive tract to form such food.

Obligatory Foods: Compulsory foods are those that fish must eat in poor settings because they lack access to fundamental nutrition.

The *system of production* can be defined according to the type of food given to the fish.

1. Extensive*:* All natural foods are required for fish production.

2. Semi-intensive*:* A greater number of fish may be raised in the pond depending on the availability of natural food and supplemental feed.

3. Intensive*:* Fish productivity is solely dependent on full feed, and the stocking rate is now influenced by other elements, such as water quality, rather than the availability of food.

10.2.4 Artificial feeding

Fish, like all other living things, need food to eat and grow in order to survive. For a range of essential life processes, such as blood circulation, respiratory control, hypertension management, suspension, and submersion, fish need a lot of energy. Fish use food to produce energy. Fish food is the food that fish consume in order to grow, produce energy, and reproduce. When they consume a healthy diet, fish grow more quickly and reach sexual maturity earlier. The fish's reproductive organs fully develop as a result, and their egg and sperm production are increased. When supplied as a natural dietary supplement, artificial fish food aids in the growth, control of health, production of heat and energy, and reproduction of fish or shrimp. Modern aquaculture relies heavily on fish feed as a source of nutrients and energy for fish growth, reproduction, and health.

Artificial Fish Feed Types

Artificial fish food is often manufactured as food that floats, or sinks. Both types of food help fish grow, while some fish species prefer floating food and some prefer drowning food. Shrimp don't eat floating food, but the majority of fish species are rather adept at doing so. It is very expensive because creating floating food is very expensive. This type of food has the advantage that the fish farmer can easily monitor the fish's direct food consumption and can modify the feeding rate as necessary. It is essential to determine whether the rate of food intake is too high or too low in order to maximise fish development and food consumption.

It is noted that the fish diet varies in size. It varies from a small particle to a huge pellet, in particular. The size of the pellet is typically 20–30% of the fish species' mouth. The fish must spend a lot of time and energy searching for several small-sized pellets in order to devour them. Consequently, the pellets are often of medium size.

Fish farming that is both intensive and semi-intensive uses a variety of artificial foods. The most frequent fake food varieties are:

1. **Dry Feeds**

2. **Non-dry feeds**

1. Dry Feeds

Dry food ingredients or a combination of dry and moist ingredients are used to make this kind of cuisine. Depending on the environmental factors, this sort of food typically contains 8–10% water and is not fully moisture free. Typically, this kind of food is devoid of bacterial diseases.

Such food is divided into two types, viz

(A) Mashes or Meals: Foods that are made with very common dry food ingredients are called Mashes or meals.

(B) Pellets: Foods that are dry and have a certain size are called pellets.

2. Non-dry Feeds

Non-dry meals often come in two varieties, such as wet or moist. Wet cuisine typically consists of a variety of wet elements, such as non-dry vegetable ingredients, fresh or frozen fish, whole, shredded, or abandoned fish, as well as other wastes like cow slaughter blood, etc. Wet meal is made from a variety of fish, including herring, caplin, mackerel, blue whiting, and sand lance. Squid or other aquatic animals make up a big portion of this dinner. Moisture levels in this type of food range from 47% to 80%. Due to the increased production and consumption of tailored foods, the use of such foods has greatly declined.

Wet food is primarily used by a number of aquatic animals. Such food contaminates the water, which is a bad thing. By consuming such food, several disease-causing microorganisms are transmitted. Due of the wide variety in size of such food, the use of such food is restricted in several countries, especially on freshwater farms, which increases food waste and causes water contamination.

Wet and dry components are combined to make moist food, or water is added to dry ingredients. These foods are all between 18 and 40% moist. Certain fish species prefer wet meals to dry ones. In salmon hatcheries, this type of feed is frequently used. Non-dry foods, especially moist and wet, tend to be pellet, ball or cake shaped. Both kinds of food are produced using a mixture of additives, oils, vitamins, and minerals.

Commercial Fish Feed Types

According to the stages of the fish's life cycle, food is categorised. Starter feed, fry feed, fingerling feed, grow-out feed, brood stock feed, etc. are examples of these food kinds. The production of cultivable species is increased using the five food categories mentioned above. Grow-out and brood stock food are both essentially the same type of food as starter and fry feed. To boost fish output and quality, various nations utilise a variety of feeds, including medicated feed, low pollution feed, high energy feed, pigmented feed, etc.

Starter Feed: This type of food is nutritious, easily digestible and of suitable size. Depending on the fish's size and nutritional requirements, different types of feeds are available, each with a different set of ingredients. This kind of meal typically consists of tiny pieces. Such meal is offered to fish while they are larvae or when they first eat.

Fry Feeds: This type of food contains high levels of protein (50-55%). The meal in question is also cut into little bits. When a fish is in the fry stage of its life cycle, this kind of diet is employed. High protein and calorie intake is necessary at this time for the fish's quick physical development.

Fingerling feeds: These foods contain less protein (45-50%) than fry and starter feeds. These foods come in a variety of sizes, from tiny bits to round pellets. These formations often depend on the species that can be cultivated and their size.

Grow out feeds: This type of food is used during the growth of fish. These foods have high sugar and protein content. Such foods contain protein for both metabolic and physical growth purposes. These foods typically cut into small pieces.

Brood stock feeds: This type of food contains only high levels of protein. These commercially available foods typically include substances like colour, vitamin C, and vitamin E. During sexual activity, the rate of bodily growth slows down, while the genital growth quickens up till conception. These feeds are used to satisfy the nutritional requirements of fish that are in the reproductive stage.

Product quality feeds: This type of food is used to increase the quality of the fish produced. These foods are utilised near fishing areas to improve consumer acceptance. Carotenoids are used in some dishes to improve the colour of the meat. Feeds of high product quality are typically utilised for highly prized species.

Medicated feeds (Product quality feeds): It should be obvious that anything is wrong when the fish starts to eat less or stops altogether. Disease or water pollution are the causes of this type of behaviour. In this instance, the FDA has given approval to various sorts of medications. Additionally, a variety of medicated fish foods are readily available on the market in appropriate amounts. While treating fish with such food is fairly simple, it must be done immediately and early because ill or weak fish typically cease eating rapidly.

Antibiotics are used in medicated feeds to treat bacterial diseases of fish and shrimp. Several guidelines for the use of medicated diets in fish farming are provided by Scott (1993), among them:

1. Use antibiotics only if the bacterial infestation of fish is high;
2. To start treatment as soon as possible after taking a bacterial test sample;
3. The use of antibiotics to preserve the common bacterial environment;
4. Avoidance of antibacterial treatment;
5. To ensure the appropriate tissue level and apply the correct dose at the appropriate time;
6. To apply prevention policy based on the type of antibacterial agent.

Pigmented feeds: Carotenoid dyes are used in pigmented feeds to make the color of fish flesh pink-red. To produce shrimp shells with the proper colour, this kind of meal is also utilised in shrimp farms. Food contains 100 mg/kg of synthetic carotenoids, such as astazanthin and canthazanthin.

High energy feeds: These foods contain 15-30% protein which increases the total energy of the food and increases the physical growth of the fish. These foods are more expensive since they include a lot of protein and fats. When such food is consumed more frequently, the fish's quality often suffers as a result of an increase in muscle fat content.

Low pollution feeds: This type of food is prepared in a special way where the water holding capacity of the food is high and the digestion of sugars is increased. This kind of meal uses top-notch food components that are fully digestive, excrete very little stool, and cause the least amount of contamination.

10.2.5 Feeding devices

In fish and shellfish farming, feed accounts for more than 60% of the operational cost and thus different feeding methods can be adopted to avoid wastage of feed. Numerous varieties of automated systems for distributing fish feeds have been developed as a result of the widespread availability of robust dry feeds and the quick advancements in control technology.

Traditional hand feeding techniques and mechanised, computer-controlled technologies are both available to fish growers. Fish producers must first decide whether to hand-feed their fish or employ labor-saving mechanical or mechanised systems. This choice is dependent on a number of factors, including labour costs, the size of the farm operation, the species being raised, the types of holding systems, hatchery or grow-out operations, etc.

Feeding Methods

Cultured fish may be fed by one of two ways:

1. By broadcasting or hand feeding or manual feeding.

2. By feeders (mechanized)

Handfeeding

Hand feeding is the practise of hand distributing food to fish that actively feed at the surface and are raised in clear water systems, allowing researchers to observe their appetites and feeding habits. If food waste is to be prevented, effective hand feeding requires some early training and expertise. For fish, dry pellets, granules, and crumbles could be dispersed. Broadcasting is quite suitable for tiny ponds (less than 0.50 hectare). Broadcasting should be complemented for larger ponds with distribution utilising a small boat in slightly interior locations.

Avoid broadcasting damp or semi-moist materials; instead, keep them in plastic trays or earthen pots and arrange them along the edges of the pond's bottom. 30–40 feeding trays are sufficient per ha to provide fish with the most opportunity.

Advantages: Behaviour of fish is regularly observed.

Disadvantages:

1.Labourintensive

2.Moretimeconsuming

3. Limited in application on large farms

MechanizedFeeding

Different types of feeding equipment are now in use. There are two main categories of fish feeders, as follows:

(a) Stationary feeding equipment

1. Without supplied energy - Example: demand feeders

2. With supplied energy -Example: automatic feeders (electric, pneumatic, hydraulic)

(b) Mobile feeding equipment

1. feeding carts

2. feeding boats.

Demand feeder

Demand feeders come in a variety of forms, but their fundamental idea remains the same. The fish themselves regulate demand feeders based on their appetite.

Demand feeders are typically inappropriate for small fish because they cannot operate them, however some species of fish may learn to utilise them very quickly.

1. The fish make contact with the rod that is attached to a plate or plug at the feed hopper's base.
2. Typically, this stopper seals the hopper to prevent feed from spilling out. A modest amount of feed is released whenever the bait rod is moved.
3. The plug's shape and design can be used to regulate how much feed is released each time.

The plug typically has a spherical or an inverted cone shape.

10.3 FISH DISEASES AND THEIR CONTROL

Fish in aquaculture are considered to be healthy due to their physical well-being. Two factors-one related to the aquatic environment and the other to the fish's cold-bloodedness-lead to abnormal changes in the body. All aquatic creatures, including fish, are susceptible to a number of diseases that are brought on by inadequate diet, dirty water, or parasite infestations. One of the major issues that fish farmers deal with is this.

Fish living in tropical waters are more susceptible and prone to diseases than fishes living in temperate waters, because the former provides favorable conditions for introduction and spread of diseases. Such waters are easily contaminated by discarded food and biodegradable materials, which quickly create unclean conditions. Fish in ponds may become ill from a lack of food, a sudden change in the water's physico-chemical characteristics, such as pH, temperature, or oxygen deprivation, or from overcrowding.

Disease defenses in fish can be either particular or general. Non-specific defenses include skin and scales as well as the mucus layer released by the epidermis that traps germs and stunts their growth, while specific defenses are tailored reactions to certain diseases that the fish's body has identified.

10.3.1 Different fish pathogens: Viral, Bacterial, Fungal and parasitic

A sick fish is typically unable to maintain its balance in the water and will typically lie on one side, either at the bottom of the tank or floating above it. The skin loses its natural colour, the gills turn pallid, and the body is covered in a grey slime. Disease-causing pathogenic bacteria, viruses, fungi, protozoans, worms, helminths, and crustaceans can infest any species of fish.

Diseases caused by Viruses:

A virus is a tiny organism that can only procreate by residing in host cells and utilising the genetic material of the host.

Their size ranges from 10 nm to 500 nm, which is smaller than the light microscope's resolution. RNA or DNA, a specific type of nucleic acid, is how viruses transport their genetic material. Typically, a protein coat that closely resembles the protein "albumin" surrounds the genetic material. As a result, viruses are sometimes known as "nucleoproteins."

Viruses are referred to as "obligate intracellular parasites" because they cannot reproduce outside of a host cell and must utilise the components of the host cell to create their genetic material. Although many viruses have so far been discovered, only a small number have been proven to cause serious illnesses in fish. Since viral infections are difficult to treat, it is crucial that they be kept under control using preventative medications.

Some of the viral diseases of fish are discussed below -

1. Viral Hemorrhagic Septicemia (VHS) of Rainbow Trout: Schaperclaus (1941) made the initial discovery, which was later validated by Zwillenberg (1965). Egtved sickness is another name for VHS, and Egtved virus is another name for VHSV. The death rate for this illness is significant. A virus with the shape of a bullet, similar to the IHN virus, is the cause. The signs include general anaemia, pale gill discolouration, eye and belly edoema, intestinal inflammation, etc.

The emergence of this disease and its dissemination in the fish farm are significantly influenced by high population densities and high feeding practises. The viral disease known as viral haemorrhagic septicemia (VHS) affects rainbow trout and is extremely infectious. Salmonids in freshwater and saltwater are both impacted by VHS.

Freshwater fish have been reported to have clinical illness, and occasionally marine species as well. The majority of epizootics in rainbow trout occur in freshwater farms, although outbreaks have also been documented in fish raised in brackish or salt water. Age, water temperature (9–12 degrees Celsius), and stressful situations are a few of the variables that increase the risk of this infection.

The rhabdovirus that causes VHS has a bulletlike form. The illness results in a significant mortality rate in fingerling rainbow trout. Older fish are susceptible to chronic illness if they are exposed for the first time. Both infected eggs and water transfer between fish are ways that VHSV can transmit from one fish to another.

Fish that are afflicted exhibit high death rates. The body develops a dark hue. Internal organs, eyes, skin, muscles, serosal surfaces of the gut, and other tissues bleed out in diseased fish. The organs most commonly impacted are the kidney and liver. The most significant signs are bleeding in the air bladder, renal edoema, blood in the gills and fins, liver discolouration, etc.

The fins started to fray, and skin sores started to appear.

The fish gradually disappear over a few months. Fish become drowsy and occasionally hyperactive. They change how they swim and almost completely blacken in hue. The fish gets acute anaemia, which is shown by a lower haemoglobin level.

Laboratory testing or a clinical examination can be used to make the diagnosis. The possibility of viral hemorrhagic septicemia should be considered in rainbow trout, turbot, Japanese flounder, and other sensitive species with haemorrhages, exophthalmia, neurological signs, or other symptoms suggestive of this condition. Expected water temperatures range from 1 to 18°C (34 to 64°F). At temperatures exceeding this range, disease has not been linked to any cases. Among the probable diagnosis are infectious hematopoietic necrosis, enteric red mouth disease, and furunculosis.

Viral isolation in cell cultures can be used to identify viral hemorrhagic septicemia. Immunofluorescence, immune-histochemistry, or ELISA can also be used to detect viral antigens directly in tissues, particularly the kidney and spleen. PCR is another option. Although it has not yet been proven to be reliable for routine diagnosis, serology by virus neutralisation or ELISA may be useful in identifying carriers.

The VHS illness has no recognised treatment. As with other viral infections, prevention is the best form of control. The impact of viral hemorrhagic septicemia can be lessened in endemic areas by hatchery disinfection, the adoption of specific-pathogen-free (SPF) stock, spring or well water, and management measures that lower physiological pressures.

HSV is sensitive to many common disinfectants including formalin, iodophor disinfectants, sodium hydroxide and sodium hypochlorite. Disinfectants lose some of their virucidal effects when diluted in seawater. VHSV is highly sensitive to UVC (280–200 nm wavelength) irradiation, which can be utilised to treat water in recirculation systems or for hatcheries' input water. Fish that are sick or dead need to be removed right away. High stocking densities are to be avoided at all costs. Ponds with clear bottoms and no infection should be chosen.

It is not recommended to co-cultivate flatfish and salmonids, especially rainbow trout, because VHSV can transmit across species and non-virulent isolates have the potential to virulent. There are no effective antiviral drugs or commercially available vaccines to treat this condition.

2. Papillomatosis: Diverse fish species from freshwater and marine settings can develop benign epithelial tumours known as papillomas in remote geographic zones. It is considered that the majority of papillomatous epithelial lesions are entirely or partially viral in origin. It has been discovered that environmental factors affect the illness. Examples include the papilloma in Atlantic salmon, cauliflower illness, and "carp pox."

The papilloma virus, a halophilic virus, is the disease-causing agent in eels and cyprinids. It is a contagious illness. The disease's progression seems to follow a pattern similar to that of metastasis-followed cancer. The condition first manifests as minute skin folds that are around 1 mm in size and that proliferate and replicate over the lower jaw and nasal orifices. Large papillomas may develop as a result of anastomosis between these basic centres of development. Several papillomas appeared all over the afflicted fish's body. Three to six months after the disease initially manifests, eating becomes increasingly challenging. Finally, the papillomatosis causes mortality from full emaciation.

The fish that have been assaulted exhibit a growth in skin proliferation throughout, but especially on the upper and lower jaws. Because of how much these growths resemble cauliflower, the condition is known as cauliflower disease. The cauliflower-like papillomonous that affects the fin, body, and tail may be white, pale red, or dark grey in colour.

Affected fish's skin and jaws also exhibit lesions. The pectoral fins, the back, the belly, the sides, and the caudal area all exhibit proliferations. Fish that were ill could not eat adequately. Significant alterations can be seen in the internal organs, particularly the liver and intestine. The fish rapidly loses weight and becomes more and more malnourished.

Diagnosis is usually made based on clinical signs. Histopathology will reveal epithelial hyperplasia. Electron microscopy may reveal viral particles or viral inclusion bodies, but this does not occur in all cases by far. There is no known cure for papillomatosis. To stop the sickness from spreading, the sick fish must be removed and destroyed. It is advised to take a bath containing soluble quinine sulphate at a dosage of 60 mg/lit for roughly 40–50 days.

3.Infectious pancreatic necrosis (IPN) of salmonids:

Infectious pancreatic necrosis (IPN) is a severe viral disease of salmonid fish.IPN symptoms are also seen in other fish species, including carp, eel, and Atlantic salmon. It is also a virus that kills young fish in large numbers. Fish fry and immature fish frequently contain it. In addition to being a severe issue in North America and Europe, this fish sickness has now been identified in Japan. When it affects trout fingerlings and fry, it manifests as an acute illness.

IPN virus, a member of the Birnaviridae family, is the disease's primary cause. Since the virus causes gastrointestinal and pancreatic damage in infected fish, it is known as IPN. Eggs are a normal method of disease transfer from parents to offspring, and this is probably one of the main causes of IPN's geographic spread.

Fish that are affected turn their bodies while swimming and turn a dark colour. Death occurs within an hour or two of this whirling movement, which is a terminal symptom. Individual fish exhibit a generally pale colouring, exophthalmia, stomach distension, and haemorrhages in the ventral regions. Fish that are infected frequently have poor hematocrits and stomach haemorrhages, mainly in the pyloric region. The intestines are stuffed with mucus. The liver and spleen are both pale, and there are signs of necrosis in the gall bladder. There is an anaemic state.

Clinical signs of the illness include spiral swimming, darkening of the skin, enlarged eyes or abdomen. The disease can be diagnosed by ELISA, the typical histological pancreatic lesion, indirect fluorescent antibody tests, and virus culture. Fish that make it through should recover in one to two weeks. There are no effective treatments for this illness, but providoneiodine has been recommended by Economon (1963) as a potential treatment option.

4. **Channel catfish virus (CCV):** The Alloherpesviridae family of viruses, which includes the channel catfish virus, is responsible for catfish illness. A herpes virus is what causes CCVD. A 100 nm-long DNA genome virus is the source of this illness. Fish less than a year old (fry and fingerlings) or shorter than 15 cm in length are most commonly affected by the sickness.

The channel catfish virus is believed to mostly propagate vertically, via the egg, from brood stock to young fish. Additionally, the virus shed in water and the virus transmitted by animal vectors both directly cause horizontal spread of the illness. This illness may cause visceral organs to bleed.

A fish that is unbalanced hangs vertically in the water. The intestine is filled with a yellow mucous fluid with bleeding from the muscles, air bladder, and internal organs. Enlarged abdomen. Additionally, fish may exhibit signs like irregular swimming and a loss of appetite.

By using virus neutralisation, fluorescent antibody testing, ELISA, or PCR, CCV can be found in water containing damaged fish organs and infected fish. While virus neutralisation or PCR should be used to detect carrier fish, FAT and ELISA should be used to diagnose fish that are clinically affected.

There is no cure at this time. To lower illness occurrence, stress and excessive stocking densities should be avoided. To stop the spread of disease, appropriate quarantine and hygiene precautions should be taken. The virus is inactivated by pond mud and sea water but is susceptible to heat, UV light, and an acidic pH.

5. Lymphocystis: Both freshwater and saltwater species exhibit it. Irido virouses are the lymphocystis' etiological agent. Fish to fish transmission is how it spreads. Two months after infection, the first nodules are seen. On the skin, fins, and gills of the infected fish, little to variable-sized white to yellow nodules or lumps appear clinically. This virus can occasionally spread throughout the body and cause peritoneal and mesentery white nodules.

The illness has a self-limiting course and is resistant to therapy. Fish with nodules may be susceptible to subsequent bacterial infections for several months after becoming ill. The entire affected stock should be destroyed because there is no cure. Draining the contaminated pond will then disinfect it. It is advised to apply lime at a rate of 200–300 kg/ha after drying. Fresh fish culture should begin following cleanings.

Bacterial Diseases: Bacteria are responsible for many fatal diseases in fishes like furunculosis, Columnaris, fin and tail rot, vibriosis, dropsy, cotton mouth disease and tuberculosis. Bacteria are fairly common in the aquatic environment. The majority of bacterial disease pathogens are frequently found in the flora of water. The only time fish become unwell is when they are under stress from unfavourable environmental factors, insufficient nutrition, and poor husbandry techniques.

Similar to viruses, bacteria can cause significant losses in aqua forms. This disease's onset might not be as abrupt. Most bacterial illnesses are brought on by hot water. Under these conditions, a rapid loss of appetite is a sign that the fish needs immediate diagnosis, treatment, and care; otherwise, severe losses could result. Dropsy disease, Lymphocystis, bacterial haemorrhagic septicemia, fin and tail rot disease, Columnaris, and bacterial gill disease are a few of the bacterial infections that affect fish.

Dropsy: Aquarium fish frequently have dropsy, which is typically recognised as a symptom rather than a disease. Fish-borne dropsy is a sickness. caused by a fluid buildup in the tissues or organs of the body. It can signify a number of underlying conditions, such as bacterial infections, parasite infections, or liver failure, but it is not a disease in itself.

Both *Aeromonas hydrophila* and *Pseudomonas punctata* are bacteria that induce dropsy in fish. Bacterial haemorrhagic septisemia is more likely to develop in areas with high population density, overfed fish, and overfertilized water. One of the illnesses most dreaded in carp culture is infectious dropsy.

Bloating is the recognisable sign of dropsy. Originally, the word "swelling" was used to denote swelling brought on by a buildup of fluid, primarily in body cavities and tissues. Although it is frequently the case, the swelling is primarily in the abdomen.

Accumulation of body fluid or water in the cavities of the body or in the pockets of the scales, the scales becoming loose, the abdomen bloating noticeably, and when pressed, water flows out of the mouth, etc. Other symptoms include eye edoema and gill haemorrhages. The fish respond more frequently by jumping when ulcerative dropsy—a condition in which the skin develops ulcers, the fins stretch, and the backbone is deformed—occurs. The epidermis and muscle of the diseased fish exhibit sores. The color of the ulcers may be black, white or red. At some times the protrusion of the scales and loss of scales occur.

Chloromycetin, which is dissolved in water at a concentration of 60 mg per gallon, can be used to treat fish. The fish are left in the solution for 3 to 7 days. The fish are not fed while they are receiving treatment. To stop the disease from spreading, it is recommended that the fishpond be completely drained, dried out, and disinfected with quicklime.By dipping the sick fish for two minutes in a solution of 5 mg/l $KMnO_4$, the fish can be treated. Use of chloromycetin or streptomycin is required for preventive therapy. Sanitation and disease management are both possible uses for glutaraldehyde. Penicillin, tetracycline, and naladixic acid are only a few of the available medicines.

3. Columnaris Disease: It is caused by*Flexibacter columnaris.*The primary symptom is the development of tufts that resemble fungi around the mouth. On the head, fins, gills, and lateral sides of the body, there are grey patches that are pale in colour. These spots develop ulcers and a reddish rim surrounding the lesion.

Regular water changes and gravel sweeping can help to control it. The fish won't become stressed and vulnerable to illness if they are fed properly and the water is generally kept in good condition. Utilize 2-3 ppm of $KMnO_4$ in the fishpond. In a solution of 1-2 ppm $KMnO_4$, soak the fish. Inject 25 mg of streptomycin and 20 000 IU of penicillin per kilogramme of larger fish that weigh more than 1 kg. Provide 6.5 g of Nitrofurazone per 100 kg of fish each day in fish feed.

4. Bacterial Hemorrhagic Septicemia (BHS):

Pseudomonas flurescense, Aeromonas hydrophila, and Aeromonas liquefaciens typus (or forma) ascitae. Red fluid builds up inside the body cavity; other signs include the death of lesion cells, a green or yellow liver, skin necrosis, and blood vessel inflammation. Exophthalmia (bulging eyes) (bulging eyes). Use $KMnO_4$ at 2-3 ppm in the fish pond and Terramycin at 65-80 mg/kg of fish for 10 days. Only for larger fish weighing more than 1 kilogramme, administer an injection with 25 mg of streptomycin and 20 000 IU of penicillin.

5. **Furunculosis**: This is one of the most serious bacterial illnesses that affects wild and farmed salmon, especially those who dwell in contaminated water that is high in decomposing debris. Aeromonas salmonicidae, a rod-shaped bacterium with a length of around 2-3 m, is the causative agent for this disease.

Hemorrhagic septicemia causes ulcerative skin lesions caused by the release of blood-tinged fluid into the water. Fish should be fed logical, vitamin-rich food. The fishponds and hatcheries shouldn't be able to contain foreign substances. Use oxytetracycline and chloramphenicol at 5-8 g/100 kg of fish per day with feed, as well as sulfonamide at 5g/100 kg fish per day.

6. **Fin rot:**

Water contamination in the environment and unsanitary conditions in fishponds are associated to fin and tail rot. *Aeromonas salmonicid* and *A. liquefaciens* are the culprits behind the fin and tail rot disease. Protozoans and fungi, however, might also be implicated.

The appearance of white lines around the fin edges is one of its defining features. Typically, erosion and bleeding occur when the opacity extends towards the base of the fins. The fin rays initially become brittle before fracturing, which causes the fins to be destroyed. The skin's surface could also become contaminated. The outer edges of the fins develop a minor cloudiness, and as the condition progresses, the tissues of the tail and fins become necrotic and eventually vanish.

Use a dip therapy with emequil @ 10 ml/100 lit for 24-48 hours; use a lengthy bath in acriflavine @ 10gm/100-liter water or sulfonamide @ 10gm/100-liter water. Give larger fish (20 mg/kg body weight) an injection of the antibiotic kanamycin, then clean the tanks and raceways with chlorine and copper sulphate (1:2000).

7. Gram-positive Bacterial Infections of Fish

Although these infections are rare, when they do happen, they can have a significant fatality rate (>50%). Only a few fish every day may die as a result of chronic infections, which might last for weeks. All fish species are susceptible, however some are more vulnerable than others, such as salmonids, a variety of marine fish (such as mullet and sea bass), tilapia, sturgeon, and striped bass. Rainbow sharks, red-tailed black sharks, rosy barbs, danios, and various tetras and cichlid species are among the aquarium fish that are susceptible. In cyprinids like tiger barbs (Puntigrus tetrazona), pink barbs (Pethia conchonius), and tetras, rostral ulceration and stomatitis are usually linked to the gram-positive bacterium Erysiopelothrix sp. Fish that are infected with the disease frequently survive for several days.

Streptococcus and allied genera Lactococcus, Enterococcus, and Vagococcus may be responsible for these infections. Neurologic illness, which frequently presents as spinning or spiralling in the water column, is a defining symptom of Streptococcus infection.

Suspect fish should have their brain and kidney cultures cultured on blood agar for 24-48 hours at 25°C. Gram stains of specific bacterial colonies show gram-positive cocci in characteristic chains, enabling a tentative identification. Confirmation needs the organism to be positively identified.

The environment or live foods, such as amphibians, fish that have already contracted the virus, or tubeficid worms, may be the source of an infection. If the source of infection is found and removed, future epizootics can be avoided. Antimicrobial susceptibility testing should serve as the foundation for antimicrobial therapy. Although erythromycin is frequently used, the FDA has not approved it for this use. Facilities for aquaculture can employ autologous vaccinations.

Fungal diseases:

Among the most prevalent ailments affecting temperate fish are fungi. A rise in fungal infections in a fish population that is otherwise healthy might also be caused by poor water quality. Only a few numbers of fungi can infect a fish's interior organs; the majority of fungi only affect the exterior tissues. When a fish sustains a mechanical injury or when parasite infections result in significant fish mortalities, fungus develops as a secondary infection. The spores that are produced by all fungus are what easily spread disease. Like a seed, the fungal spore is resistant to heat, drying, cleaning agents, and the natural defensive mechanisms of fish. It has been established that the fungi, which are common in the natural environment, can infect fish eggs, fry, fingerlings, and adults. They thrive very well where there isn't much slime.

Various kinds of fungal diseases in fishes are illustrated below:

1. **Saprolegniasis**: Freshwater fish are susceptible to the illness saprolegniasis (winter fungus), which affects their skin and gills. Young and adult fish both frequently contract this sickness. A superficial, cotton-like growth on the skin or gills is the most typical manifestation of this condition. These lesions typically start as little, localised infections that have the potential to spread quickly across the surface of the body. Lesions are initially white, but they eventually turn red, brown, or green. Fish's exterior surfaces can become infected with the common fungal disease known as saprolegiasis. Once the fundamental source of the ailment has been found and addressed, it is simple to eradicate. Saprolegniasis is brought on by saprolegnia fungus, sometimes known as "water moulds."

Direct contact between unhealthy and sick fish or fish eggs. Indirect interaction resulting from a variety of factors, such as the water supply, transport vehicles, workers moving between aquaculture plants, and farm machinery like nets.

The diseased fish first have muted body colours. the appearance of a white to grey or cotton-like growth on the eyes, gills, fins, or skin of fish. In some instances, fungus growth may cover 80% of the body. Skin lesions are grey or white in appearance during early infections. The respiration is obstructed by the growth of fungus in the gill lamella. The diseased fish becomes lethargic and frail. The skin of the sick fish may also develop ulcers, and it will eventually pass away.

A clinician may suspect saprolegniasis if they notice a cottony, proliferative growth on the skin or gills. The diagnosis of saprolegniasis is aided by direct smears from fungal growth and the presence of long, branched non-septate hyphae.

The first step in illness control should be avoiding the underlying causes, such as improper handling, injuries, inadequate sanitation, infection of feeding bags, and low water quality. Preventing skin harm while transporting fish. Fish must be given plenty of the proper kind of food. Fish overcrowding must be avoided. Cleaning the tools and utensils to stop the infection from spreading. Potassium permanganate (1 g per 100 litres of water for 60–90 minutes) and ordinary salt baths are used to cure sick fish (10 g per litre of water for 20 minutes for young fish and 25 g per litre of water for 10 minutes for older fish).

2. **Branchiomycosis or gill rot**: It is a fungus that affects the gill tissues of most freshwater fish species, including cyprinids and catfish. Branchiomycosis is a relatively recent issue that has killed a lot of cultured fish and is challenging to control.

The causative agent of this disease are two fungi namely, *Branchiomyces demigraus* and *B. sanguinis* belonging to Phycomycetes and Archiomycetes respectively. Fish that are under stress due to environmental factors including low pH (5.8 to 6.5), low dissolved oxygen, or a strong algal bloom have both types of fungal. Although they thrive between 77° and 90°F, Branchiomyces species can grow at temperatures as high as 95°F. It mostly develops in the gill lamellae, filaments, and blood vessels of the gill arches. The parenchymal tissues of the gills contain this fungus species. The primary sources of infection are debris on pond bottoms and fungal spores conveyed in the water.

In the beginning of the infection the fish shows pale gills with deep red patches. Fish start to move more sluggishly. Fish can be caught by hand and don't respond when a man approaches them. Infected fish experience respiratory discomfort and are unable to consume air. Gills may look red due to poor circulation. When fungus grows on or inside the gill tissue or enters the blood vessels, the gill tissues become obstructed, congested, and necrotic. Study of a moist preparation made from an infected gill under a microscope. Finding and separating the responsible agent.

The impacted fish must be taken out of the pond and put to death. Avoid wearing dense stockings. For the management of diseases, strict sanitation and disinfection are necessary. Dead fish should be gathered each day, burned, or buried deeply. By supplying clean, fresh water, high quantities of organic matter in the water supply should be avoided. To assist reduce deaths, formalin and copper sulphate have been utilised. Branchiomycosis-affected ponds should be dried up and treated with copper sulphate or 2-3 kg of calcium oxide per hectare. Malachite green can be used to cure sick fish for extended periods of time (0.1 mg/l) or for a 12-hour period (0.3 mg/l). Transfer of diseased fish from infected to uninfected areas needs to be stopped. Adjusting the feeding rate when it's warm outside.

3. Ichthyophonosis: Both freshwater and saltwater fish are affected by the fungus disease. Skin that is rough or granulomatous, internal organ lesions that are white to grey-white, and other physical manifestations of the disease. There is no treatment for the systemic fungal disease known as ichthyophonus once it has infected a fish.

Ichthyophonus hoferi, which enters the host fish's body with food, is the fungus that causes this sickness. It is a spherical or oval-shaped, yellowish-brown, obligatory parasite with granulated cytoplasm. The tissues of different organs are home to the fungus, which exists as an intercellular parasite. A temperature of 10^0 C is ideal. Seven to ten days following the inoculation, growth started to show.

Consuming raw or processed fish that has been contaminated with illness spreads it. Infections can spread more easily when there are skin wounds or damaged gills. By faecal excretions, carriers aid in the infection's transmission. When a sick fish comes into contact with a healthy one, the sickness is spread.

Fish with a mild to moderate illness show no outward symptoms. In severe cases, infection under the epidermis and in muscular tissue may give the skin a "sandpaper texture." The spine of some fish might curve. The internal organs could swell and have white to grey-white lesions. The condition is known as swinging disease because such fish exhibit peculiar swinging movements.
When this fungus's viable spores are consumed along with tainted food, they spread throughout the fish's visceral organs, infecting the liver, brain, kidney, gonads, and other areas. In severe situations, the infection extends to the skin, which may break and release spores that can cause many ulcers.
Study of afflicted tissues under a microscope to find the fungi. Locating and identifying the responsible party. Examination of the histopathology. The ichthyophonus disease cannot be treated using therapeutic methods. The best way to control the condition is to avoid infection. Avoid feeding raw fish or contaminated food. At the same time, all nets, brushes, and utensils used near contaminated fish must be cleaned and disinfected.

Parasitic Diseases

Parasitic diseases are among the most serious problems in farmed fish, though not of much concern among the wild fish. The three main types of fish parasites are protozoa, helminths, and arthropods, which are dominated by crustaceans.

Protozoan diseases in fishes:

Single-celled organisms known as protozoans are only visible under a microscope. They come in a variety of sizes and shapes and feed primarily on the skin and gills of fish. A small number of them can also infect internal organs and cause serious illnesses. The fishes' bodies are covered in a variety of protozoan parasites. They may reside outwardly on the body's surface, inwardly in the visceral organs, or both. The following is a list of significant diseases brought on by protozoan parasites:

1. **Ichthyophthiriasis**: The visible and recognisable white spots that are a symptom of ichthyophthiriasis, also known as the "white-spot illness," are quite common. Young parasites that are in the water cling to the fish's skin. When they reach a certain size and are large enough, they fall to the pond's bottom.

The ciliated protozoan *Ichthyophthirius multifillis* is responsible for the deadliest protozoan illness. Ich illness is another name for this condition. The disease can affect any type of pond-cultured fish, including trout, Chinese carp, and common carp.

The presence of white patches on the host's skin and fins serves as the primary diagnostic indicator. A single Ichthyophthirius, or spot, is a unicellular creature. These organisms have a rounded form and stick out from the surface. The interior epithelial tissue is destroyed. Fish retaliate by leaping into the water and rubbing their bodies on the items in the water. Moreover, breathing is impacted, and a strong attack may lead to the extinction of all the fish in a pond. In mild infections, the epidermis may separate in some places as a result of apparent skin and fin damage. Other severe signs, such as acute restlessness and fish weakness brought on by an osmoregulation imbalance, can be seen in severe infections.

Liming and draining the pond are beneficial. Malachite green, at a concentration of 1 g per square metre in the culture, treats carps' illness. The ponds can be dried out to destroy the ciliated bodies as well. It has been suggested that treating the pond once, twice, or three times with 0.1 ppm malachite green and 15 ppm formalin is effective.

2. **Costiasis**: The severe disease costiasis, often called ichthyobodosis, affects several fish species, including young trout and common carp. A parasite on the skin is the cause of costiasis. Mastigophora pathogen *Costiasis necatrix* is often referred to as *Ichthyobodo necatrix*. The parasite embeds itself in the host's skin. At the place of attachment, its anterior end develops finger-like structures that pierce the host cell and suck out its contents. Transmission happens over water.

The increased mucus secretion causes the affected fish to develop dull patches on its sides and fuse into a continuous greyish film. The tissue in the fins is frequently corroded; this corrosion begins in the space between the rays. The gills turn pallid and mucus-covered. The fry gathers around the intake, rise to the surface, and ingest the oxygen present in the air. Fish eventually deteriorate, lose interest in food, and perish.

During 10-15 minutes, sick fish are kept in either a 3-5% sodium chloride solution or a 1-2500 ppm formalin solution. Young fish should be fed nutritious food and should not be kept in spawning and rearing ponds for too long if the disease is to be avoided. Before adding spawners, quicklime should be used to sanitise carp spawning ponds.

3. Whirling disease: In the 1950s, whirling illness was discovered for the first time in Pennsylvania; it probably arrived with shipments of frozen fish from Europe. One of the well-known salmonid diseases, whirling disease has been documented throughout the world. All trout and salmon species are affected, especially the young ones.

Myosoma cerebralis, parasitic protozoans, are the cause of this illness. The condition gets its name from the *Myxosoma cerebralis* spores, which also produce the rapid-whirling movements. Contaminated salmonid fish, either alive or dead. Transplanting sick fish is the main method of transmission between rivers. Spores are spread within a river system by water currents, contaminated tools, boats, and birds that have eaten contaminated fish.

There is no reliable technique to get rid of the infection of whirling illness once it has entered a stream. There are, however, steps that can be taken to lessen the disease's effects. As the parasite invades cartilage and harms the neural system, a distinct "whirling" swimming movement may be seen. Skeletal deformation linked to spine curvature can be seen in later stages of the illness. Nerve compression causes colour alterations, causing the tail to seem dark or even black. Mass deaths among fry. Trout that recover from the condition have faulty opercula, mandibular and vertebral malformations, and depressions in the skull, especially posterior to the eyes. Increased breathing rate. Skin discoloration from the vent to the tail.

Fish raised in water free of the infectious stage are protected against this disease (nematode worms in the mud of the pond). The best way to manage this illness is to control tubifex worms. Before moving from one body of water to another, clean and dry your equipment. Transferred fish stocks have undergone a whirling disease quarantine inspection. Instead of throwing out leftover bait into the water, do so in the garbage or on dry land. Never move live fish between different bodies of water. Take out all the diseased fish. Restock only fish that have been proven to be free of surface-infected eggs or whirling disease.

Metazoan Parasitic diseases of fish:

Metazoan parasitic diseases are less pathogenic than protozoan parasitic diseases. Despite having a multicellular structure, they can rarely reproduce themselves inside of their hosts' bodies. Hence intensity of infection depends on the number of initial infective stages. This category includes illnesses brought on by myxozoans, parasitic helminths, crustaceans, and leeches. Members of the phyla Platyhelminthes and Nematohelminthes are referred to as helminthes.

1. **Gyrodactylosis**: The skin of cyprinids, notably the common carp, gets infected with gyrodactylosis. Salmonids in both freshwater and saltwater are impacted by it. Young common carp are troubled by the virus.

Gyrodactylus sp. is the responsible party for the disease gyrodactylosis. Although it rarely affects the eyes or gills, it frequently affects the skin. It is a tiny monogenean fluke that is infrequently visible to the unaided eye. It is abundant on the skin of freshwater and saltwater salmonids.

Gyrodactylus elegans is a widespread parasite that can be found on the skin, gills, and fins of trout and carp. The increased mucus secretion causes the affected surface to become covered in bluish slime. The infected fish's colour fades and turns pale when the infection is severe. The skin grows slimier, and the fin progressively rips and frays.

By scraping mucus, *G. elegans* is easily visible under the microscope. Fish with this parasite are frequently observed rubbing their bodies against the pond's sides or bottom or any other objects in the water in an effort to get rid of the parasite.

Gill epithelial hyperplasia and gill lamellae distortion are brought on by infection. This injury is particularly serious in young fish and causes respiratory failure. The attachment sites where adult flukes adhere, where necrotic foci develop, are also damaged. The likelihood of subsequent infections rises as a result.

The most common form of treatment is a potassium permanganate bath. It is typically advised to do a 3–5-minute dip treatment in a 5-5000 ppm formalin solution or a 5% Nacl solution. Alternately, they could be kept for two to three days in water tanks with 2-4 ppm of methylene blue dye or 10 ppm of acriflavine.

2. **Dactylogyrosis**: Other significant sources of infection in aquaculture are trematode larvae. Dactylogyrosis is a disease that mostly parasitizes the gills of other fish, including Chinese carp and common carp. The term "dactylogyrosis" refers to the illness this parasite causes.

Dactylogyrosis symptoms include rapid breathing, irritated gills, and clawing on the bottom. Later on, the gills are entirely damaged, which causes a high rate of carp death. The gill fluke, or dactylogyrus, is the cause of dactylogyrosis. Dactylogyrus is a tiny organism that lives on the fish's gill filament.

The gill epithelial cells are the primary food source for the fluke, which lives between the secondary lamellae. Gill epithelial hyperplasia and gill lamellae distortion are brought on by infection. This injury is particularly serious in young fish and causes respiratory failure. As the host becomes older, the illness becomes more severe. The gills are harmed and covered in mucus, which prevents regular breathing.

The common hygienic procedures in pond farms help control the diseases. For treatment, ammonia baths with a concentration of 2 ml of 25% ammonia solution per litre of water for 30 to 60 seconds are advised. The quick development of fingerlings depends on proper pond management. It is as a result of Dactylogyrus susceptibility to fingerlings. The suggested chemical treatment is the same as for Gyrodactylus.

3. **Diplozoon disease**: The organism Diplozoon paradoxum, sometimes known as "Twin worm," is the cause of this sickness. It is a single-celled trematode that lives on the gills of several different fish species, including *Carassius, Gobio, Phoinus, Rhodeus, Rutilus*, and others.

After hatching, the larvae freely navigate the pond's water until they come across a fish. Twin worms are created when the young become attached to each other in pairs by sucking discs. At the point of touch, the bodies merge and cannot be separated. Larvae that are unable to mate pass away. They can be discovered on gills. By administering a very diluted solution of either picric acid or the methylene blue dye to the fish, the twin worm can be eliminated. By treating the fish with diluted NaCl solution, it is simple to get rid of.

Fish diseases caused by Copepod parasites:

1. *Lernea* (Anchor worm): Because to its extreme specialisation and worm-like appearance after losing all of its limbs, this copepod is known as a "anchor worm."It preys on a variety of freshwater fish species, including trout, Indian carp, silver carp, and goldfish. The female possesses hook-like appendages on the front end that are used to firmly adhere to the host after the parasite has made sores and holes in the host body by penetrating deep into the fish tissue. The fish perishes when the wounds are infected by germs and fungi. The male anchor worm is distinct in shape and does not attack the fish. At her posterior end, the female has two egg sacs. After eggs hatch, nauplius larvae emerge, swimming freely and developing.

The parasite is removed from the diseased fish and killed by touching it with a brush dipped in a potent potassium permanganate solution. Within 30 minutes of exposure to acidic water, the parasites are dead. After the fish have been transferred to another pond, the pond water can be sanitised using a potassium permanganate solution.

2. Fish louse (*Argulus*): The huge, well-known fish parasite Argulus preys on a variety of fish species, including carps. It can be attached to the host using two enormous suckers. The female louse then perishes after laying eggs on rocks or the aquarium wall. When the eggs hatch, the larvae go through four to five moults before attaching to the skin of a host. A forcep is used to remove the parasite after paralysing it with a strong salt solution. Fish with louse infestations experience secondary bacterial infection. With a weak potassium permanganate solution, large ponds can be cleaned.

10.3.2 Different fish diseases: Pathogenic, Nutritional, Parasitic and Environmental

Pathogenic:

The number of new pathogenic bacterial species identified from fish has been constantly growing along with the rapid expansion and development of aquaculture, increased usage of water bodies, pollution, globalisation, and transboundary migration of aquatic fauna. Researchers studying fish health face a significant challenge as a result of the growing virulence and host range of known pathogens. These researchers are actively searching for more effective vaccines and therapeutic medications to tackle bacterial fish disorders. The existing therapeutic approaches are inefficient and fraught with problems.

Both wild fish and fish raised in aquaculture facilities are susceptible to infectious illnesses brought on by a variety of phylogenetically distinct bacterial pathogens. Drug and vaccine-based methods of prevention and therapy are either ineffective, impractical, or inadequate. The traditional method for examining fish bacterial infections has been to focus on a single or small number of virulence variables. Our knowledge of the biology, host adaptation, and virulence traits of these significant infections has recently been greatly expanded by the genome sequencing of numerous bacterial fish pathogens. Comparative genomics has made it possible to locate distinct gene clusters that are exclusive to particular pathogens. Also, the genome sequencing has revealed a number of intricate adaptive evolutionary methods that operate in fish pathogens that are mediated by horizontal gene transfer, insertion sequence elements, mutations, and prophage sequences.

Infectious illnesses and death in wild fish stocks and fish raised in cramped settings are primarily caused by bacterial infections. It is the main factor causing the most economic losses in aquaculture. Together with aquaculture's rapid growth and development, greater use of water resources, pollution, globalisation, and the transnational movement of aquatic life, the number of novel pathogenic bacterial species found in fish has been steadily increasing. The therapy methods now in use are ineffective and problematic. To combat bacterial fish illnesses, researchers are continually looking for more potent vaccinations and treatment drugs.

Nutritional: The most crucial prerequisite for fish's appropriate growth, wellbeing, and brain development is nutritionally sound diet. Fish kept in captivity are unable to choose a balanced diet. Full rations, often known as aquafeed, must be created to satisfy all dietary needs.

Fish nutritional problems can arise from a lack (undernutrition), an abundance (overnutrition), or an imbalance (malnutrition) of nutrients in their diet. Some essential elements for healthy fish growth include lipids, carbohydrates, proteins, vitamins, and mineral salts. Because animals have body reserves that can partially compensate for dietary deficiencies, the sickness typically takes time to manifest. Only when the availability of any food component falls below a threshold level do disease symptoms appear. When there is an abundance of food, the extra can be turned to fat and stored in the tissues and organs of fish, which can have a negative impact on their physiological processes.

Aquaculture nutritional disorders are a serious threat to food production because they are hard to detect, which can increase production costs, lead to lost investments, increase fish mortality, increase susceptibility to infectious diseases, and ultimately decrease yield quality and quantity.

In order to boost fish supply through aquaculture production, it is crucial to regulate nutritional illnesses since a lack of certain nutrients will make the immune system less able to defend the body against an outside intruder. It is well known that, in addition to nutrient inadequacies, excess nutrient supply compared to what is needed for optimum growth also has a substantial impact on immune responses and disease resistance.

A diet that is too high in protein causes the fish to excrete more protein, which raises the level of ammonia in the environment. For the communities who live on farms, a change in the water's composition has major health implications.

While deciding on fish feed, some aspects to consider include:

Due to the possibility of *Aspergillus flavins* growing on mouldy feed and producing aflatoxins, feed should be stored correctly in a dry, cold, and covered area. Adding stabilised vitamin C (l-ascorbyl-2-polyphosphate) during the production process will lengthen the shelf life of fish food. Don't feed food that is more than 90 days old. Directly adding vitamin C to the water can offer the required complement. Nutritional disorders with vitamin B deficiency are widespread. During lengthy antibiotic therapy, specific B vitamin requirements significantly increase, thus patients in this situation may want to think about taking supplements.

Within 30 seconds of contact with water, up to 90% of the water-soluble vitamins in fish flakes are lost. To maximise the benefits of vitamins, owners should feed their animals more frequently and in smaller portions. Many advantages of eating live food include improved colour. Wild-caught live food should never be consumed, and live foods from controlled artificial cultures should always be used instead. Increased vitamin intake is said to assist tissue regeneration after injury or tissue damage caused by low temperatures as well as offer some protection against disease. It is generally accepted and performed to employ vitamins as preventative measures in animal feeding.

Aquatic animals' health may be improved through the use of high-quality, contaminant-free feed ingredients, a balanced diet, the prevention of micronutrient loss during feed processing, better handling, storage, and feed management. Because they include high levels of iron that may make fish more susceptible to common bacterial infections, feed formulations based on blood and fish meal should be regularly monitored. Anti-vitamin factors in feed can cause deficiencies that can be remedied through heat processing, cooking, or other heat treatments.

Don't feed the animals with waste fish that can't give a healthy diet. Fish with less natural resistance are more susceptible to pathogenic infection due to this sort of feed. Utilize dry pellet feed that is healthy, bacteria-free, and hygienic. Fish immunity can be further boosted by adding vitamins and minerals to dry pellet diet.

Parasitic: Fish are susceptible to illnesses and parasites much like people and other animals.Specific and non-specific disease defenses are present in fish.Skin, scales, and the mucus layer released by the epidermis-which traps germs and prevents their growth-are examples of non-specific defenses.Fish can produce inflammatory reactions that increase blood flow to contaminated places and deliver white blood cells that try to kill the viruses if pathogens manage to get past these defenses.

Fish parasites are a frequent occurrence in nature. It is possible to learn about the ecology of host populations through parasites. For instance, in fisheries biology, different populations of the same fish species that coexist in one area might be distinguished using parasite communities. Parasites also have a number of specialised characteristics and life-history techniques that allow them to inhabit hosts. Studying these intriguing elements of parasite ecology can shed light on how hosts protect themselves against parasites.

Normally, parasites (and pathogens) must refrain from killing their hosts because the absence of hosts may result in the parasite's extinction. The natural variation in host defence tactics may be sufficient to maintain host populations in a viable state, or evolutionary restrictions may operate to prevent parasites from killing their hosts.

Several external parasites that are linked to fish gills but live outside of them choose to live in the gills as their preferred habitat. Monogeneans and specific types of parasitic copepods, which can be quite numerous, are the most prevalent.Leeches and gnathiid isopod larvae, which live in seawater, are two additional external parasites that live on gills. The majority of isopod fish parasites are external and eat blood. The Gnathiidae family larvae and adult cymothoidids have clawed limbs and piercing and sucking mouthparts designed for attaching to their victims. Many marine fish are hosts to the parasite *Cymothoa exigua*.

In what is thought to be the first instance of a parasite replacing an animal host structure functionally, it causes the fish's tongue to atrophy and takes its place. Other parasitic diseases include Glugea, Ceratomyxa shasta, Kudoa thyrsites, Tetracapsuloides bryosalmonae, Cymothoa exigua, Gyrodactylus salaris, Ichthyophthirius multifiliis, cryptocaryon, velvet disease, *Brooklynella hostilis*, Hole in the head, leeches, nematodes, flukes, carp lice, and salmon lice. Internal or exterior parasites, protozoan parasites have a direct lifecycle. They can be found in great quantities in the internal organs, gills, or skin of fish. In fish culture systems, ciliates are the most prevalent protozoan parasites seen, however certain obligatory amoebic, flagellate, and microsporidian (sporozoa) parasites are also present.

Metazoan parasitic diseases are less pathogenic than protozoan parasitic diseases. Despite having a multicellular structure, they are largely unable to proliferate inside the body of their hosts. Hence, the number of initial infective phases affects how severe an infection is. This category includes illnesses brought on by myxozoans, parasitic helminths, crustaceans, and leeches.

There have been numerous reports of parasitic organisms producing serious issues in grouper farming. Protozoans, particularly ciliates, are the main source of grouper parasite illnesses in the hatchery and nursery phases.

Environmental:

Aquatic species are crucial to maintaining the ecological equilibrium. They are particularly vulnerable to chlorine and chloramine, which are frequently added to city water and are among a wide range of toxicants. Moreover, tanks and other equipment are cleaned with chlorine. Amination has stabilised chlorine into the substance chloramine. Ammonia is released into the system when the chlorine molecule is removed during treatment. Even at chlorine concentrations as low as 0.02 mg/L, both substances are extremely harmful to fish, with mortality occurring at

0.04 mg/L. To assess chlorine and chloramine in aquatic systems, a straightforward colorimetric technique is available.

At all times when live animals are present, no chlorine or chloramine should be found. If on-site testing of water samples for chlorine is not possible, the samples may be transported in glass bottles. A negative test result may not entirely rule out some contamination in the system being assessed because the chemical can be transitory and challenging to detect.

A regular and consistent supply of nutrients is necessary for the sustained generation of organisms that serve as fish food in proper pond management. Nutrients may come from outside sources or from the pond itself. Also, the pond ecosystem's physico-chemical characteristics must be regulated to stay within the safe tolerance ranges for the type of farmed fish. This calls for regular pond environment monitoring and prompt corrective action. While some of the characteristics necessitate laboratory facilities, the majority of them can be simply monitored at the pond site. The monitoring provides fish producers with trustworthy recommendations for maximising fish production.

Following water characteristics may be tracked from environment perspective -

*Water colour:*A straightforward but significant reflection of the fundamental production processes is the visual colour of the pond water.

*Water transparency:*A Secchi disc is used to quantify the outcome of the processes that define and alter the appearance of colour in water. However, a low transparency may be caused by either a high turbidity level alone or a dense algae population, and as a result, it may not accurately reflect the water's trophic or production level. Nonetheless, the Secchi transparency readings and the visual colour offer useful data on the water's productivity.

*Water depth:*Rainfall that occurs during the monsoon is typically the main supply of water. After the rainy season, the water level progressively drops, resulting by the end of the dry season in a very shallow water column.

*Chemical environment in the water column:*By measuring the pH, alkalinity, NH4-N, NO3-N, and PO4-P according to accepted procedures, the water is chemically classified. Typically, on the same types of mother soil, the pH and alkalinity do not vary from pond to pond. The basic inorganic nutrient condition of the pond is shown by the measurements of NH4-N and PO4-P. With the aid of field kits, simple chemical parameters like pH and dissolved oxygen can be tested. The ideal conditions are indicated by slightly alkaline water (pH 7.0–8.5) and oxygen concentrations of 6–9 ppm.

*Dawn oxygen:*The dissolved oxygen level in fishponds typically varies greatly from day to night. In order to determine the community metabolism of the entire pond and to quantify the production and respiration processes in the ecosystem, this diurnal oxygen fluctuation is typically observed. A single measurement taken right before sunrise would be a crucial predictor of the likelihood of fish kills caused by low oxygen levels.

10.3.3 Prophylactic measures to control fish diseases

Maintaining good health of aquatic animals is the key to the economic sustainability of the industry. Losses due to diseases and environmental stress have become a major impediment to the economic sustainability of the industry. Prophylactics and therapeutics are the major approaches for effective health management both in human and veterinary medicine. Application of drugs and medicines has become inevitable to maintain the health of the cultured animals and the environment. Prophylactic approach in aquaculture will reduce our dependence on antimicrobials, disinfectants, anti-parasitic drugs which are known to be harmful to the host and the environment in the long run. Prophylaxis refers to all the preventive steps such as vaccination, immuno-stimulation and use of probiotics including group improve routine husbandry practices that are taken during a hatchery and farming operation to minimize the load of pathogen and to prevent the occurrence of disease.General prophylactic measures followed in aquaculture operations are-

1. Following Best management practices (BMPs) for optimum culture environment: maintain the optimum water and soil quality parameters like, pH, transparency, hardness, ammonia, nitrite, nitrate, sulphur, etc.

2. Using probiotics: a live microbial feed supplement which beneficially affects the host animal by improving its intestinal balance [Fuller]. In hatcheries probiotics can be applied directly into the rearing waters, through live feed like artemia and rotifer or by immersion treatment.

3. Improving immunity using immunostimulants: Immunostimulants are dietary additives that enhance the innate (non-specific) defense mechanisms and increase resistance to specific pathogens.Immunostimulants are of various types - Synthetic chemicals, bacterial derivatives, animal and plant extract, nutritional factors, antimicrobial components and nucleic acids.

4. Immunization of the host against specific pathogens using vaccines: Fish vaccination has a clear advantage of reducing the impact and loss due to diseases, reducing the use of chemotherapeutants and provide long-term protection. Hence vaccination of fish is an important tool in health management.

5. Nutritional interventions with nutraceuticals: Nutraceuticals refer to a food (or a part of food) that provides medical or health benefits, including the prevention and or treatment of a disease. They may contain dietary fiber, anti-oxidants & pre/pro-biotics.

6. Selective breeding to support genetic resistance: These programs are costly & targeted towards such diseases that cause most economic harm. It involves selection of most healthy fish for further progeny so that the next generation of that breed carries their genetic traits.

10.4 SUMMARY

Aquaculture has seen a lot of developments in the last few decades and is currently the fastest growing agricultural sector in the world. Fish nutrition, feeds, and feeding management play important roles in increasing the productivity of aquaculture farms and to prevent nutritional diseases. Feed represents the largest variable cost in most fish production.

Nutrition plays a critical role in intensive aquaculture because it influences not only production costs but also fish growth, health and waste production. Different kinds of nutrients are necessary for the growth, health, and maintenance of fish.

Proteins are large, complex molecules that play many critical roles in the body.The lipids are a heterogeneous group of substances found in plant and animal tissues, which share the property of being relatively insoluble in water, and soluble in organic solvents, such as ether, chloroform and benzene etc. Lipids are an important source of energy, essential fatty acids, and phospholipids. Lipids provide a vehicle for absorption of fat-soluble sterols and vitamins.

Sugars, starches, gums, and celluloses are all included in the large category of compounds known as carbohydrates. The only elements found in carbohydrates are carbon, hydrogen, and oxygen, and when they are burned, they produce carbon dioxide and one or more molecules of water. Energy is not a nutrient, but is a property of nutrients, which is released during metabolic oxidation of proteins, lipids and carbohydrates.Vitamins are required in trace amounts; are essential for fish growth and to fight against diseases.

There are different types of fish food in the water such as dissolved nutrients and different types of plants and animals. Different kinds of food are consumed by various fish. The majority of fish need nutrients from both plant and animal sources, including protein, carbohydrates, lipids, vitamins, and other nutrients for development and health.

Feed formulation entails choosing an ingredient combination that will result in a mixture with critical nutrient levels at or above the minimal requirements of the fish.Supplements for energy and protein make up the majority of the ingredients in prepared fish diets.

Fish in aquaculture are considered to be healthy due to their physical well-being. Two factors-one related to the aquatic environment and the other to the fish's cold-bloodedness-lead to abnormal changes in the body.

A sick fish is typically unable to maintain its balance in the water and will typically lie on one side, either at the bottom of the tank or floating above it. The skin loses its natural colour, the gills turn pallid, and the body is covered in a grey slime. Disease-causing pathogenic bacteria, viruses, fungi, protozoans, worms, helminths, and crustaceans can infest any species of fish.

A virus is a tiny organism that can only procreate by residing in host cells and utilising the genetic material of the host. Since viral infections are difficult to treat, it is crucial that they be kept under control using preventative medications.The viral disease known as viral haemorrhagic septicemia (VHS) affects rainbow trout and is extremely infectious. Salmonids in freshwater and saltwater are both impacted by VHS.

Diverse fish species from freshwater and marine settings can develop benign epithelial tumours known as papillomas in remote geographic zones.Infectious pancreatic necrosis (IPN) is a severe viral disease of salmonid fish.IPN symptoms are also seen in other fish species, including carp, eel, and Atlantic salmon.The channel catfish virus is believed to mostly propagate vertically, via the egg, from brood stock to young fish.Irido virouses are the lymphocystis' etiological agent. This virus can occasionally spread throughout the body and cause peritoneal and mesentery white nodules.

Bacteria are responsible for many fatal diseases in fishes like furunculosis, Columnaris, fin and tail rot, vibriosis, dropsy, cotton mouth disease and tuberculosis. Aquarium fish frequently have dropsy, which is typically recognised as a symptom rather than a disease.

Both *Aeromonas hydrophila* and *Pseudomonas punctata* are bacteria that induce dropsy in fish.Columnaris disease is caused by*Flexibacter columnaris.* The primary symptom is the development of tufts that resemble fungi around the mouth. On the head, fins, gills, and lateral sides of the body, there are grey patches that are pale in colour.

Among the most prevalent ailments affecting temperate fish are fungi. A rise in fungal infections in a fish population that is otherwise healthy might also be caused by poor water quality. Only a few numbers of fungi can infect a fish's interior organs; the majority of fungi only affect the exterior tissues.Various kinds of fungal diseases in fishes are illustrated, Saprolegniasis**,** branchiomycosis or gill rot and ichthyophonosis etc.

Parasitic diseases are among the most serious problems in farmed fish, though not of much concern among the wild fish. The three main types of fish parasites are protozoa, helminths, and arthropods, which are dominated by crustaceans.

Single-celled organisms known as protozoans are only visible under a microscope. They come in a variety of sizes and shapes and feed primarily on the skin and gills of fish. A small number of them can also infect internal organs and cause serious illnesses.

The following is a list of significant diseases brought on by protozoan parasites, Ichthyophthiriasis, costiasis, whirling disease etc.

Metazoan parasitic diseases are less pathogenic than protozoan parasitic diseases. Despite having a multicellular structure, they can rarely reproduce themselves inside of their hosts' bodies.

The number of new pathogenic bacterial species identified from fish has been constantly growing along with the rapid expansion and development of aquaculture, increased usage of water bodies, pollution, globalisation, and transboundary migration of aquatic fauna.

Fish nutritional problems can arise from a lack (undernutrition), an abundance (overnutrition), or an imbalance (malnutrition) of nutrients in their diet. Some essential elements for healthy fish growth include lipids, carbohydrates, proteins, vitamins, and mineral salts.

Fish are susceptible to illnesses and parasites much like people and other animals. Specific and non-specific disease defenses are present in fish. Skin, scales, and the mucus layer released by the epidermis-which traps germs and prevents their growth-are examples of non-specific defenses.

Aquatic species are crucial to maintaining the ecological equilibrium. They are particularly vulnerable to chlorine and chloramine, which are frequently added to city water and are among a wide range of toxicants. Moreover, tanks and other equipment are cleaned with chlorine.

Maintaining good health of aquatic animals is the key to the economic sustainability of the industry. Losses due to diseases and environmental stress have become a major impediment to the economic sustainability of the industry.

Prophylaxis refers to all the preventive steps such as vaccination, immuno-stimulation and use of probiotics including group improve routine husbandry practices that are taken during a hatchery and farming operation to minimize the load of pathogen and to prevent the occurrence of disease.

10.5 TERMINAL QUESTIONS AND ANSWERS

Q1.Give a detail account of nutritional requirements of fish.

Q2. Explain fish nutrition, feeds and feeding.

Q3. What is a feed and feed formulation? Explain.

Q4. Give a detain account of different types of food.

Q5. Give an account of signs of sickness and defensive devices in fishes against diseases.

Q6. Give an account of protozoan diseases in fishes and their possible treatment.

Q7. Give an account of fungal diseases in fishes and also add their control measures.

Q8. Write a short note on parasitic and nutritional fish diseases.

Q9. Write an essay on viral fish diseases.

Q10. Define bacterial diseases.

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