Dayanand Science College, Latur

Department of Zoology and Fishery Science

“आ नो भद्रा क्रतवो यन्तु विश्वतः”

Class: B.Sc. I Year

Subject: Fresh water fish culture technology (III)

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UNIT I

3) Importance, objective and scope of aquaculture.
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1) Importance, objective and scope of aquaculture.

Since about 71% of the earth's surface is covered with water, humans have realized its importance as a resource. For this reason, one of the areas heavily exploited regarding the use of water as a resource is aquaculture.

Aquaculture can be defined as the process of cultivating, breeding and harvesting different aquatic organisms, mainly fish for human consumption. Also known as fish farming, aquaculture production can be carried out in a controlled aquatic environment like ocean waters, freshwater rivers, ponds, lakes and even in tanks. The word "aquaculture" is defined by the Food and Agriculture Organization of the United Nations (FAO) as follows "Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants.

With increasing population, economic well-being, and rapid urbanization globally, the demand for food has grown exponentially. Fish which is an integral part of the diet for people all over the world is key to food security in the future. It is an important nutrient source for people in developing countries as well.

Importance of Aquaculture

Aquaculture plays a pivotal role in addressing various challenges related to global food security, environmental sustainability, and economic growth.

Meeting Food Demand: As the world's population continues to grow, so does the demand for protein-rich foods, including seafood. Aquaculture helps bridge the gap between seafood demand and the limited supply from wild fisheries. It provides a consistent and predictable source of seafood, reducing the strain on overfished wild populations.

Conservation of Wild Populations: Overfishing has led to the depletion of numerous fish species in the world's oceans. Aquaculture offers a sustainable alternative by reducing the need to extract seafood from already stressed wild populations, thus allowing them to recover and maintain their ecological balance.

Economic Growth: Aquaculture contributes significantly to the global economy by generating employment opportunities in rural and coastal communities. It supports livelihoods for small-scale farmers, processors, distributors, and other related industries.

Resource Efficiency: Traditional fishing can result in unintentional bycatch and habitat destruction. Aquaculture systems can be designed to minimize these negative impacts, making them a more environmentally friendly option. In addition to this, aquaculture allows for efficient water use, reduced land footprint, and controlled waste management.

Benefits of Aquaculture: Aquaculture offers a wide array of benefits that extend beyond mere food production and economic growth. Some of the notable advantages include:

Sustainable Food Production: By providing a controlled environment for growth, aquaculture reduces the pressure on natural ecosystems. It also allows for selective breeding and genetic improvement of species, enhancing their growth rates and disease resistance.

Diversity in Diet: Aquaculture enables the cultivation of various species that might not be as readily available through traditional fishing. This diversification encourages a broader range of seafood consumption and promotes balanced nutrition.

Innovation and Research: The aquaculture industry drives innovation in areas such as marine biology, nutrition, and technology. Research in aquaculture contributes to the existing understanding of aquatic ecosystems and the development of sustainable practices.

Rural Development: Many aquaculture operations are located in rural areas where other forms of employment might be limited. The industry provides jobs and income, helping to uplift local communities and reduce poverty.

Reduced Pressure on Ecosystems: Overfishing can disrupt marine food chains and cause irreversible damage to marine ecosystems. Aquaculture lessens the need for excessive fishing, allowing marine environments to recover and regenerate.

Objectives of aquaculture

- Production of low cost protein rich, nutritive, palatable and easily digestible human food.
- Providing new species and strengthening stocks of existing fish in natural and man-made water-bodies through artificial recruitment
- Production of ornamental fish for aesthetic appeal.
- Effective utilization of aquatic and land resource
- Recycling of organic waste of human and livestock origin
- Providing means of livelihood through commercial and industrial aquaculture.
- Production of sport fish and support to recreational fishing.
- Production of bait-fish for commercial and sport fishery.

Scope of aquaculture

The freshwater aquaculture systems in the country has primarily confined to three Indian major carps, viz., rohu, catla and mrigala, with exotic species: silver carp, grass carp, and common carp forming the second important group. Among the catfishes, magur (*Clarias batrachus*) has been the single species that has received certain level of attention both from the researchers and from farmers due to its high consumer preference, high market value and most importantly its suitability for farming in shallow and derelict water bodies with adverse ecological conditions. Recent years, however witnessed increasing interest for farming of *Pangasius* spp., especially in Koleru lake region of Andhra Pradesh due to its higher growth potential and ready market. Other potential species include *Labeo calbasu*, *Labeo gonius Labeo bata*, *Labeo dussumeri*, *Labeo fimbriatus*, *Barbodes carnaticus*, *Puntius pulchellus*, *Puntius kolus*, *Puntius sarana*, and *Cirrhinus cirrhosa*. Some of these species are being cultured at a very low level in different parts of the country, mostly based on wild seed collection. The freshwater air-breathing and non air-breathing species, *Channa marulius*, *Channa striatus*, *Channa punctatus*, *Channa gachua*, *Channa stewartii* have not been taken up for the aquaculture activities in serious way. With the technology available for seed production and culture of air breathing (*Clarias batrachus*, *Heteropneustes fossilis*) and non air breathing catfish like (*Wallago attu*, *Mystus seenghala*, *Mystus aor*, *Horabagrus brachysoma*, *Pangasius pangasius*), scientific organized catfish farming can be taken up in extensive and semi intensive way (Ponniah and Sundaray, 2008). The giant freshwater prawn, *Macrobrachium rosenbergii* has been the principal species, adopted both under monoculture and under mixed farming of freshwater prawn production of about 43,000 tonnes in the country at present. However, *M.malcomsonii* and *M. gangeticum* have not been taken up in a big way

In the brackishwater sector, the aquaculture development is mostly contributed by shrimp, *Penaeus monodon* culture only. The other shrimp species like *Fenneropenaeus indicus*, *Fenneropenaeus merguiensis*, *Penaeus pencillatus*, *Marsupenaeus japonicus* and *Penaeus semisulcatus* are not cultured on a commercial level large-scale culture. Recently *Fenneropenaeus vannamie* culture is developing in India. The finfish species like the seabass (*Lates calcarifer*) and grouper (*Epinephelus* spp.), grey mullet (*Mugil cephalus*), pearl-spot (*Etroplus suratensis*), milk fish (*Chanos chanos*) which are promising and ideal for aquaculture has not been exploited.

In the present era of food insecurity, aquaculture shows enormous potential to feed not only the ever increasing human population but also the aquaculture products can be utilized as a feed ingredient in the diets of different domesticated animals of high commercial value. The aquaculture sector has become a modern, dynamic industry that produces safe, high valuable and high quality products, and has developed the means to be environmentally sustainable Sustainable aquaculture is currently the need in India as elsewhere. Eco-friendly aquaculture in harmony with environmental and socioeconomic needs of the society has to be evolved.

2) Introduction to types of aquaculture

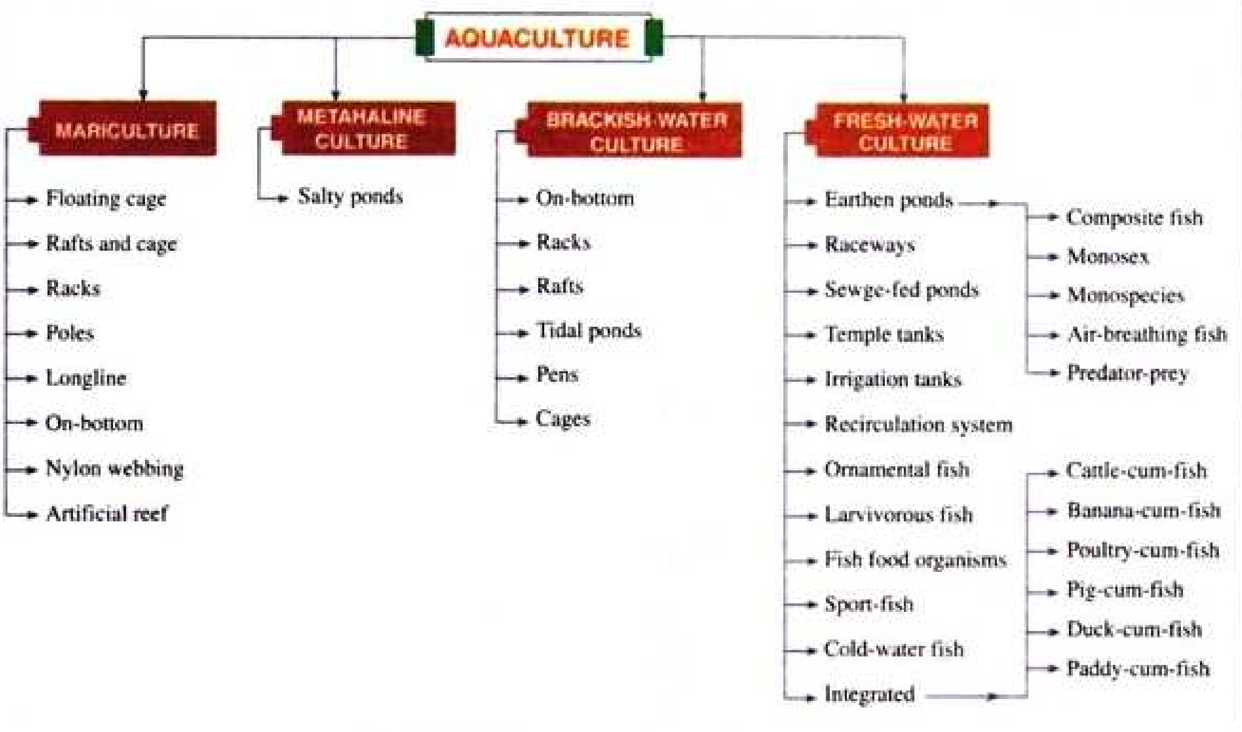


Fig. 6.5. Different types of aquaculture practices

i) Culture based on economic or commercial consideration: Extensive culture, intensive culture & semi-intensive culture

Depending upon the motive of farming, based on economic and commercial considerations, fish culture practices may be classified as under:

(i) Extensive Fish Culture:

Extensive fish farming system is the least managed form of fish farming, in which little care is taken. Large ponds, beels, etc. are brought under this culture system. Here, the yield is modest and the expenditure is less as it is raised on natural food. No supplemental feeding or fertilization is provided. Fish depends only on natural foods. Yield is poor (500 kg/ha) and survival is low. The labour and investment costs are low and this system results in minimum income. This system involves large ponds measuring 1 to 5 ha in area with stocking density limited to only less than 5000 fishes/ha.

(ii) Intensive Fish Culture:

Intensive fish farming system is the well-managed form of fish farming, in which all attempts are made to achieve maximum production of fish from a minimum quantity of water.

It is the best managed form of fish farming and the fishes are fed on artificial food in addition to the natural feed. Here the yield is very high (6000 kg/ha/year). Although the cost of investment is high, the earnings from this culture far exceed the cost, so as to ensure high profit.

This system involves small ponds/tanks/raceways with very high stocking density (50-100 fish/m3 of water). Fish are fed completely formulated feed. Good management is undertaken to control water quality by use of aerators and nutrition by use of highly nutritious feed. The yield obtained ranges 15 ton/ha or more. Although the cost of investment is high, the return from the yield of fish exceeds to ensure profit.

(iii) Semi-Intensive Fish Culture:

Intensive culture possesses certain hazards, for which a culture between the first two, called semi-intensive culture, is generally practiced. Here certain amount of management is required and the net profit is in between the above two. Semi-intensive fish culture system is more prevalent and involves rather small ponds (upto 1 hectare in area) with higher stocking density (8000 to 15000 fish/ha). In this system care is taken to develop natural foods by fertilization with/without supplemental feeding. However, major food source is natural food. Yield is moderate (3 to 6 ton/ha) and survival is high.

Table 6.2 : Comparative study of the types of farming (prawn/shrimp)

	Extensive/Traditional	Modified Extensive	Semi-intensive	Intensive	Super-intensive
Pound size	5 hectares	1 – 2 hectares	1 hectare	0.2 – 0.4 hectare	0.05 – 0.1 ha
Shape	Any	Any	Rectangular	Square	Circular
Stocking density	Mixed culture uncontrolled	$3/m^2$ Mixed culture	$8\text{-}15/m^2$ Monoculture	$50\text{-}100/m^2$ Monoculture	$100/m^2$ Monoculture
Water exchange	Sometimes with the help of pump	5%/day	5–10% per day	20-50% per day	100% flow through
Water depth	1.2–5.0 m	1.0 – 3.0 m	0.8 – 1.5 m	0.6 – 1.5 m	
Aeration	Not needed	Very less, if needed	2 HP	8–12 HP	Continuous
Production	500 kg/hectares	1000-3000 kg/ha	3000-6000 kg/ha	15000 kg/ha	25000 kg/ha
Feed used	Natural feed	Natural and formulated feed	Natural and formulated feed	Pellet feed	Pellet feed
Rate of feeding	—	1-4 times daily	3-6 times daily	—	—
Crops/year	1	2	2	Batch-wise	Batch-wise
Engineering	Not needed	Very less needed	Essential	Essential of high quality	Essential of high quality
Investment	Very less	Less	High	Very high	Very high
Care	Not much needed	Needed	Essential	Essential	Essential
Generator and current	Not needed	If needed	Necessary	Compulsory	Compulsory
Prawn/shrimp larva source	Wild	Wild	Hatchery	Hatchery	Hatchery

ii) Culture based on the types of designs of culture: Pond culture, culture in manmade reservoirs, fish culture in paddy fields, culture in bheries, culture in tanks, raceway culture, cage culture and pen culture

i) Pond Culture

It is the most common method of fish culture. In this case water is maintained in an enclosed area by artificial construction of dike/bund, where aquatic animals are stocked and grown. Ponds are usually filled by rain, canal water and by manmade bores. They differ widely in shape, size, topography, water and soil qualities.

ii) **Culture in manmade reservoirs**

Man-made reservoirs, sometimes called artificial lakes, are important water sources in many countries around the world. In contrast to natural processes of lake formation, reservoirs are artificial, usually formed by constructing a dam across a river or by diverting a part of the river flow and storing the water in a reservoir. Upon completion of the dam, the river pools behind the dam and fills the artificially created basin (UNEP 2000). Seasonal changes of runoff and precipitation feed the reservoir. There are big differences in the size of man-made reservoirs such as big artificial lakes or small pond-like water bodies. The stored water can be used for irrigation, drinking water after purification or to produce energy.

iii) Fish culture in paddy fields

Integrated Paddy-cum-Fish Culture is a system of producing fish in combination with paddy cultivation using the same resources in the same unit area. Production of fish in paddy fields is almost as primitive as the practice of paddy culture itself. Paddy farming with fish culture is a type of dual farming system in which paddy is the main enterprise and fishes are grown to obtain additional income. Paddy-cum-fish culture is practiced in many paddy-growing belts of the world including China, Bangladesh, Malaysia, Korea, Indonesia, Philippines, Thailand and India. In India it has been a traditional practice largely in the North-Eastern Region.

Paddy and fish are the staple food of India and the country is very rich in natural water resources in the form of rivers, reservoirs, lakes, flood plains, ditches and large areas of paddy fields. Paddy-fish farming involves the simultaneous culture of paddy and fish in irrigated paddy fields so as to obtain an added production of fish with paddy.

The North-Eastern Region of India has vast paddy fields both in valley and hill areas. The region is known for highest amount of rainfall (2000-4000 mm annual average) in the country and hence, the fields remain under water almost throughout the year. Moreover, there are innumerable streams and rivers that irrigate the fields. Hence, these fields offer a good scope for producing fish along with paddy with little or no additional cost or effort. Further, due to hilly terrain as well as pressure to produce rice for consumption, scope for constructing large fishponds in these regions is limited. Paddy-cum-Fish Culture is easy, cost-effective, sustainable and environmental friendly. Moreover it can increase paddy yield as a result of nutrients and pest control by fish. Besides it can enhance farmers' income and provide nutritional security.

In this system of farming fish is farmed in paddy fields, not all paddy varieties are suitable for integrated fish farming. Varieties with strong root system like Tulsi, Panidhan, CR260 77, ADT 6, ADT7, Rajarajan and Pattambi 15 and 16 are suitable for farming in combination with fish because it has strong roots to withstand flood conditions. The fish species such as Common carp, Tilapia and Murrells are most suitable for culture in rice fields.

iv) Culture in bheries

In small Bheries fish and paddy are grown alternately while in bigger Bheries only fish is grown. The sewage is let into the ponds to a depth of 90 cm along with tidal water in a ratio of 1:4, sewage to water. The water is allowed to settle for 15-20 days after which it becomes clear and odourless. Subsequently plankton will grow in the Bheries. The ponds are then stocked with fingerlings of Indian major carps of size 7.5 – 15 cm in the month of April. Some farmers also stock silver carp and common carp. Harvesting begins in September and ends in February. The weight of the stocked fish is about 500-550 kg/ha and the final yield from this system is about 3000 kg/ha/year.

Tilapia can also be grown in sewage fed ponds since they are capable of tolerating poor water quality prevalent in sewage fed ponds and production of up to 9000 kg/ha/yr of 70-200 mm Tilapia can be obtained. Raw sewage has the potential to cause human health hazard. Therefore only treated sewage should be used for fish culture. Other countries such as Far East, Middle East, Germany, Hungary and Israel use treated sewage for fish culture.

v) Culture in tanks

Using tanks allows the fish culturist to manage stocks and have a good deal of control over environmental parameters (e.g., water temperature, dissolved oxygen concentration, pH, waste) that can be adjusted to promote maximum production. In addition, feeding and harvesting operations require less time and labor than in ponds. In small tanks it is practical and economical to treat diseases with therapeutants applied to the culture water. Intensive tank culture can produce high yields, year-round, on small parcels of land.

vi) Raceway culture

Raceway culture is defined as raising of fish in running water. It is a high production system in which fishes are grown in higher stocking density. Raceways are designed to provide a flow-through system to enable rearing of much denser population of fishes. Raceway ponds are basically of two types:

Linear type: Ponds arranged in sequence. In a linear type, the volume of water entering each pond is larger and as the same water is used repeatedly from pond to pond, occurrence of disease in initial ponds may directly affect the other connected ponds. **Lateral type**: Ponds laid out in parallel and lateral or parallel type the volume of water entering each pond is smaller but a fresh supply of water is always ensured, and no transfer of disease from one pond to another.

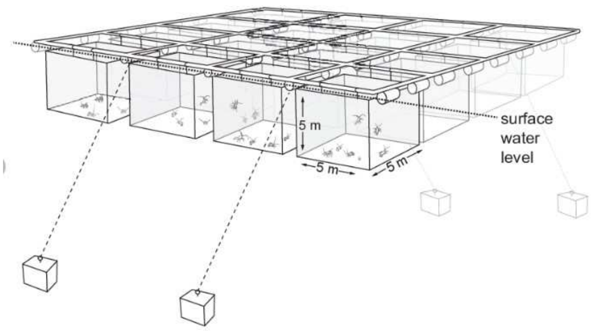
vii) Cage culture and pen culture

Cage culture is rearing of fish from juvenile stage to commercial size in a volume of water enclosed on all sides including bottom, while permitting the free circulation of water. Cage culture is readily adapted to water areas which cannot be drained. Fish culture in cage is an innovative concept to exploit the potential of lakes, reservoirs and riverine pools. Cage culture of fish and other aquatic organisms is popular in many countries. Japan, South Korea, China, Philippines, Thailand, Malaysia, Germany, Norway, USA are some of the countries where cage culture is well developed. In principle, almost every cultivable species of fish can be cultured in cages, such as carps, tilapia, trout, catfishes, etc. depending on socioeconomic, ecological and technical suitability.

Advantages of Cage Culture: Use existing waterbodies, Technical simplicity with which farms can be established or expanded, Lower capital cost compared with land-based farms, Easier stock management and monitoring compared with pond culture.

Disadvantages of Cage Culture: Stock is vulnerable to external water quality problems eg. Algal blooms, low oxygen, Stock is more vulnerable to fish eating predators such as water rats and birds, Growth rates are significantly influenced by ambient water temperatures.

Pen culture is defined as raising of fish in a volume of water enclosed on all sides except bottom, permitting the free circulation of water at least from one side. This system can be considered a hybrid between pond culture and cage culture. Mostly shallow regions along shores and banks of the lakes and reservoirs are used in making pen/enclosure using net/wooden materials where fish can be raised. In a fish pen, the bottom of the lake forms the bottom of the pen. Pen has the advantage of containing a benthic fauna which serves as food for the fish and polycultue can be practiced in pens as it is in ponds. The environment in fish pen is characterized by a free exchange of water with the enclosing water body and high dissolved oxygen concentrations.



Cage Culture **Pen Culture**

iii) Culture based on number of species: Monoculture and poly culture

Monoculture

In order to fulfill the single species based needs of food, scientific experiments and sports etc. single species of fishes are cultured in a fish farm/pond At times, single species culture is promoted because of their high demand in markets. Thus, 'monoculture' refers to the culture and breeding of a single fish species in a farm. Breeding performance of a single species can be easily observed and recorded in a monoculture system. Additionally, it doesn't involve any competition for feed and space among fishes. The culture of trout, tilapia, catfish, and carps are typical examples of monoculture. Monoculture in intensive system is commonly practiced for high value, marketable fish species. It is the only method of culture used in re-circulating system, running water system and in cages wherever the supply of natural food is limited.

Advantages of Monoculture;

1. Easy to feeding
2. Permits great control over size, age and sex
3. Easy to operate
4. Selective harvest of marketable fish can be employed
5. Suitable for farmers having limited land resources

Disadvantages of Monoculture:

1. Natural productivity of pond is not fully utilized
2. Available space in water column is not utilized
3. More chances of epizootic disease and parasites
4. More risk of water quality problem like dissolved oxygen depletion

Poly culture

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 utilize 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 zones — upper surface zone, middle column zone and bottom zone. A particular species exploits food of a particular zone. For example — *Catla catla* is a surface feeder, *Labeo rohita* a column feeder and *Cirrhinus mrigala* 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.

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.

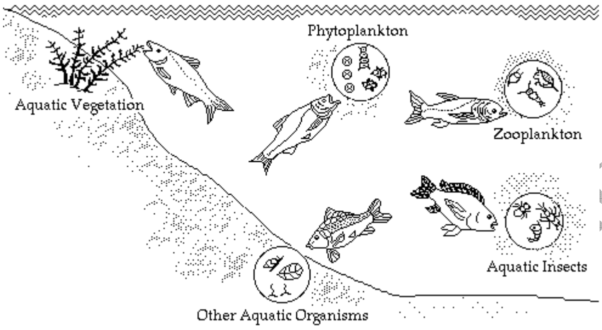
(2) To utilise all the available niches.

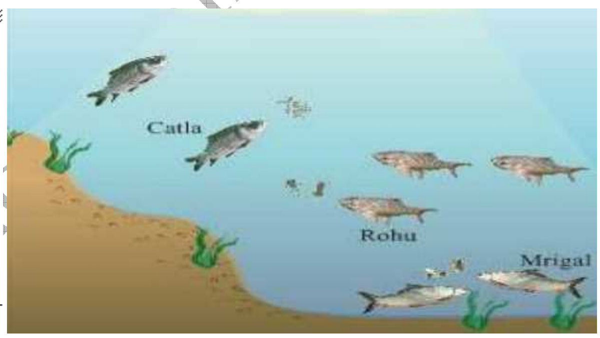
(3) The fishes cultured should not cause any ecological disbalance.

(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 fertilizes 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 utilizing those parts of the food resources that would have been wasted.





Monoclture **Polyculture**

iv) Culture based on climatic condition: Cold water fish culture, warm water fish culture

Cold water fish culture

The cold water fishes adopted to live below 10^0C to 20^0C temperature. The upland water at high altitudes of mountains and the spring water at low altitude in temperate regions remain cooler than the rest and the cold water fishes flourish in these region. Such water bodies comprising several hill streams, rapids, pools, lakes and reservoirs are abundantly found in the Himalayan region and in the Deccan plateau region of peninsular India. These are either fed by melting snow and the springs as in north or by the rain water as in Deccan plateau.

During recent years, there has been growing realization for development of cold water fisheries in India, since the production from cold water is neglisable in comparison to total inland catch. 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, Simla, Kangra, Nainital, Shilong and Arunachal. Other hatcheries constructed at Nilgiris and Kerala.

Indigenous cold water fishes:

Mahaseer, Snow trout and Indian hill trout are the principle cold water fish species inhabiting the mountain waters of India. Mahaseer fishery of cold water: It is one of the major game fishes of Himalayas. However, it has not received attention as exotic fishes in India. It is generally found in large sizes and abundant in quantities from mountain streams and rivers. Some of the important species of mahaseer are: ***Tor tor, Tor putitora***, ***Tor mosal, Tor mosal mahanadicus***, ***Tor khudree, Acrossocheilus hexagonolepis,*** **Snow trouts** and ***Schizothoraichthys***

Exotic cold water fishes:

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

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

Warm water fish culture

Warm water fisheries have many of the same concerns that cold water fisheries do, but fish that live in warm waters have lower dissolved oxygen requirements. Temperatures should be around 27° to 32° C (80° to 90° F). Warm water fish inhabit shallower, warmer waters, which are commonly found in rivers, streams, lakes, and coastal ocean areas. In contrast, cold water fish are well-suited to colder and deeper oceanic environments, though they can also inhabit certain freshwater bodies under specific environmental conditions. Warm water fishes include Indian Major Carps, Catfishes, Murrels, etc.

UNIT II

Intensive fish farming

7) Selection of site -
   i. Topography ii. Soil type iii. Water supply
8) Construction of fish farm
   a) Layout, design and construction of different types of pond
      i. Hatching pits
      ii. Nursery pond
      iii. Rearing pond
      iv. Stocking pond
   b) Physical chemical and biological factors affecting fish culture.
9) Objectives of fish culture
10) Qualities of culturable species of fishes
11) Types of cultivable fishes
12) Culture qualities & breeding habits of Indian major carps

1) Selection of site -

i. Topography ii. Soil type iii. Water supply

Selection of Site Before describing the construction of fish farm, for site following considerations are essential selection of fish farm : (1) Topography (2) Soil (3) Water supply.

i) Topography: Topography or the shape of land is the first important consideration in the selection of the site. It determines the number and the kinds of ponds to be constructed. An ideal pond following topographical features.

(1) The ground should neither be too flat no too hilly. The ideal is a slight deeper depression outlet on the fourth. Such ponds can be easily evacuated and drained dry when needed.

(2) The ground should have natural slope to evacuate the pond down the slope without any extra expenditure of energy or cost.

(3) The best place for such combination of slope and water supply are found on more or less flat ground between the hills. If the valley is wide, parallel ponds can be constructed, but when it is narrow the ponds can be made one after another in a line.

ii) Soil type: Soil plays an important role with regard to the fertility of fish ponds. Types, characteristics and chemical conditions of soil influence the pond productivity. The following features of soil should be considered before the construction of a fish pond.

(1) The soil of a fish pond must have ability to hold water. For this clay soil is suitable. Clay soil holds water and when mixed with further silt, its water holding capacity increases. Gravelly and sandy soil have poor water retaining capacity and a high rate of the soil unfit for fish culture.

(2) Sandy and rocky soils when used, need much expenditure to correct them. However, smaller ponds may be dug on such soils also.

(3) Soil should be rich in nutrient. A good soil on which the crops may grow well is considered nutrients rich. The soil on which times the crops have been grown many becomes poor nutrient contents and requires heavy fertilization.

(4) The pH of the soil should be in the range of 7.2 - 9.0 (slight alkaline). Acidic contents Of O may prove toxic to the survival of fishes. Similarly too much of alkalinity also leads to poor productivity of the pond.

(5) Depth should to about 1 - 1.5 meter.

A correct identification of soil can be done by a soil analyst and a good soil would result in a fertile pond.

iii) Water supply: Availability of adequate supply of water sufficient quantity near the fish farm is a sine qua non in the selection of site. The quality and quantity of water required for fish culture depends upon the type and amount of fish to be raised in the ponds. Certain fishes require large amount of fresh and well oxygenated water while others require less oxygen and lesser amount of water. A constant level of water in fish ponds and their temperature can be maintained by constructing the farm near Some Source of water supply. The dependable sources of water supply are: Lakes and reservoirs, Springs, Rivers, Canals, Surface run off and Wells.

Big tanks, reservoirs and lakes are perhaps the best sources of water. Dams provide the cheapest water for the fish farm. Good springs do not dry up in summer and form a dependable Source of water. Streams, rivulets and canals are also satisfactory sources, provided the flow is enough to fill the ponds, a constant water level is maintained with a little silt so that freshwater is available even during the rainy season. Small streams that are likely to be flooded during heavy rains should be avoided because the water carries heavy silt and reduce the fertility of the fish pond. The water of rivers, supplied by canals is also a satisfactory and dependable source.

Very clear water is since poor in nutrients it requires prefertilization. The muddy water has to be settled in separate ponds before it is supplied to the fish pond. Greenish water indicates a rich food for the growth of fish while the brownish water indicates the acidic character of the water. The water of latter type has to be neutralized with lime before it is supplied to the ponds.

2) Construction of fish farm

a) Layout, design and construction of different types of pond

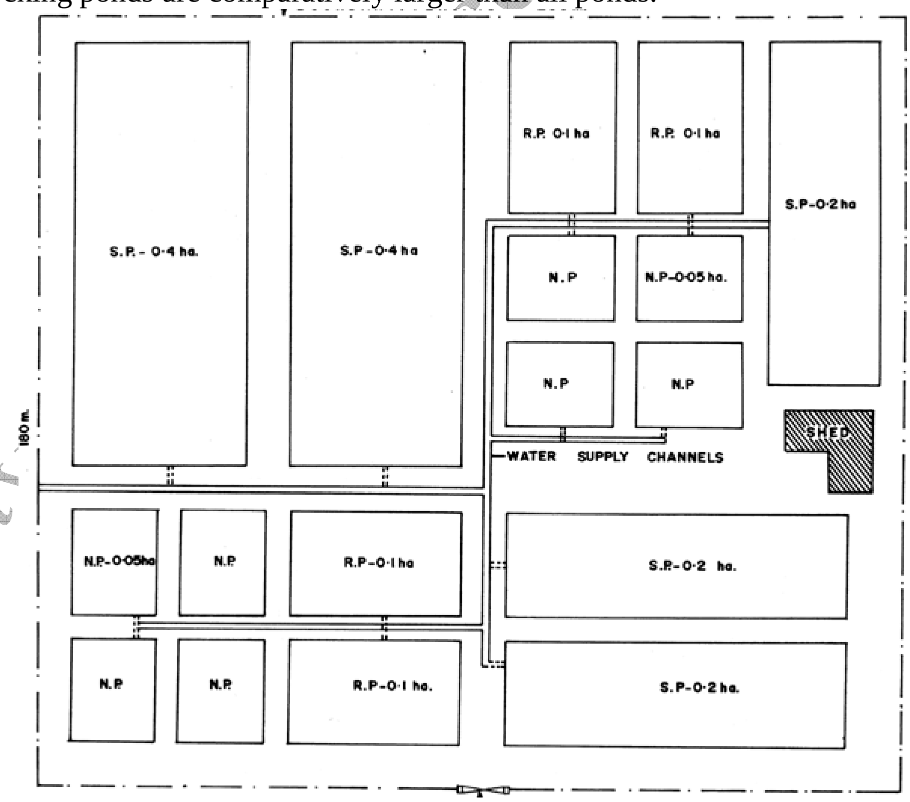
Before starting the construction, the lay out plans have to be drawn for the location, design and the number of various types of ponds. The size of the pond depends on the purpose of the farm. There are two major kinds of fish farms. In the first kind the fish farmer procures the fry and fingerlings from the hatcheries and rears them in the farm to the marketable sizes (restricted farming). In the second kind a large number of ponds are built in the farm. The fishes are bred, eggs are hatched, fry reared and the fingerlings are raised to marketable size (complete fish farming). The latter type of fish farming requires many ponds and an elaborate management.

i. Hatching pits: It is also called as spawning pond. These are the small tanks usually of 8x 4x2 feet and are used for hatching the fertilized eggs. These are located near the riverine collection grounds. Continuous but slow flowing water is desirable for aerating the eggs. The tanks are fixed up with hapa called hatching hapa made of coarse cloth or the mosquito curtain cloth. The spawn is collected in the hapa where the hatching takes place. Similar types of ponds are constructed in the fish farm, or the deeper ponds with circulating water may be utilized by fixing the hapa. In the latter case the breeders are released into the hapa after injection of hypophysial suspension. Spawning occurs within the hapa and the spent breeders are removed from it. Number of hatching ponds may be upto 6.

ii. Nursery pond (Spawn to fry): The newly hatched spawns transported from hatching hapa to nursery ponds are very tender so one should be very careful in mainaining them there. Nursery ponds should always be near the hatching hapas. Young spawn about 3 to 5 days old are transferred from Spawning ponds to nurseries, where they remain for about 30 days. The main objective of constructing nurseries is to create suitable conditions of food availability. Their number may be upto 4.

iii. Rearing pond (Fry to fingerling): For good health and growth of fingerlings the exercise is essential for them in rearing ponds. So the fingerlings are reared in longer and narrower ponds to provide them long distance for swimming. Such ponds may be Seasonal or perennial of 90x30 × 4 feet in size and are used for rearing fry for 2-3 months, These ponds are made long and narrow, gently sloping to facilitate netting. These ponds are located near the spawning and nursery ponds and their number may vary depending upon one, two or three year rotation of carp culture. Their number may be upto 12.

iv. Stocking pond (Fingerling to adult sized fish): These are fairly large perennial ponds more than, 6 feet deep. Their size may be 300 × 88 x6 feet and are so constructed that it may facilitate netting. Stocking ponds are comparatively larger than all ponds.



Layout of Nursery, Rearing and Stocking ponds

b) Physical, chemical and biological factors affecting fish culture

Water quality includes all physical, chemical and biological factors that influence the of water. beneficial use Where fish culture is concerned, any characteristic of water that affects the survival, reproduction, growth, production or management of fish in any way is water quality variable. Obviously, there are many water quality variables in pond fish culture. However, only a few of these normally play an important role. The fish culturists, therefore, should concentrate On and attempt to control to some extent by management techniques the important water quality variables. All other things being equal, a pond with "good"' water quality will produce more and healthier fish than a pond with "poor" water quality. In a nut shell, fish growth depends greatly on the quality of water used in the pond. And the quality of the water depends upon where from it comes and what kind of soil it travelled over. Testing the water quality means making sure that all the factors which relate to water are right for the fish. The principal factors necessary for fish culture are given below:

Physical factors

The important physical factors affecting fish culture are depth, shore condition, pressure and movement of water, temperature, light, turbidity and colour.

Depth: The depth of a pond has an important bearing on the physical and chemical qualities of water. On it, varying with turbidity, depends the penetration of sunlight which in turn, determines the temperature and the circulation patterns of the water and the extent of photosynthetic activity in the pond.

In shallow ponds sunlight penetrates up to the bottom, warms up the water and facilitates the increase in productivity, though, ponds shallower than 1 meter get overheated in tropical summers inhibiting survival of fish and other organisms. While depths greater than 5 meters are rare in fish ponds, a depth of about 2 meter is considered good from the point of view of biological productivity.

Temperature: Water temperature generally depends upon climate, sunlight and depth. The intensity and seasonal variations in temperature of a water body have great bearing upon its productivity. All organisms including fish, posses well defined limit temperature tolerance with the optimum somewhere in between. The temperature in fish pond is generally minimum during the early hours of morning and reaches the maximum value in the afternoon showing diurnal fluctuations. All metabolic and physiological activities and life processes such as feeding, reproduction, growth movement and distribution of fishes are great, influenced by water temperature. Knowledge of maximum and minimum water temperature of a body of water is essential for selecting suitable species of fishes for culture purposes.

Fishes are cold-blooded animals: i.e. their body temperature depends upon the temperature the water in which they live. Each fish species has a temperature range within which it grows quickly. This is called the optimum temperature range, and it means that a particular fish grows best at temperatures within that range. In a fish pond, the fish should live at their optimum to grow well. However, since fish have different temperature requirements, the farmer must choose the fish which may grow best in the temperature range of his pond.

Turbidity: Turbidity is the term for suspended dirt and other particles in water. In natural waters, it is caused by clay silt, organic matter and planktonic organisms. Turbidity of water varies greatly with the nature of basin and inflowing sediments. Ponds with clay bottom are likely to have high turbidity. Turbidity in natural water restricts the penetration of light thereby reducing the photosynthetic activity hence, acts as a limiting factor for productivity. The suspended particles causing turbidity also absorb nutrients like phosphate, potassium, and nitrogen in their ionic form making them unavailable for plankton production. Turbidity due to profusion of plankton is an indication of pond's high fertility. Turbidity can be a problem, particularly in shallow ponds. If the dirt and particles prevent sunlight from reaching to the plankton, the phytoplankton cannot produce oxygen. An aerating pond can be turbid if there are bottom feeders like common carps stirring up the bottom mud. Turbidity can also result from a water source which has a lot of silt in it. The undesirable type of turbidity is caused by suspended clay or silt particles. Turbidity due to plankton is somewhat desirable, if it does not lead to bloom. Turbidity caused by suspended silt and clay particles can be controlled by application of hydrated lime.

Chemical Factors

The productivity of a pond depends on the presence of several chemical parameters which are given below: Dissolved gases like oxygen, carbon dioxide, alkalinity, pH, total hardness, solids, nutrients etc. constitute the important chemical characteristics of a pond.

Dissolved oxygen: The pond water receives oxygen by its absorption from atmosphere, with the help of photosynthesis in day time through plants which release oxygen while consuming carbon dioxide. The animal community residing in the pond consumes oxygen at both day and night. Dissolved oxygen normally decreases during early morning; hence oxygen in a pond can be increased with the help of aerators.

Carbon dioxide: The CO_2, of natural waters is derived from various sources like a atmosphere, respiration of animals and plants, bacterial decomposition of organic matter, inflowing ground waters etc. The amount of CO_2 varies depending upon the decomposition of top soil land chemical nature to increasing pollution. The atmosphere also furnishes some CO_2, in the form of rain water due CO_2.

pH: The pH of natural waters is an important environmental factor, the variations of which are linked with the species composition and life processes of animal and plant communities inhabiting them. 43 The pH of pond water undergoes diurnal changes being most alkaline in mid afternoon and most acidic just before day break. The waters having a pH range of 6.5 to 9.0 recorded before day break are most suitable for pond culture and those having pH values more than 9.5 are unsuitable. The acidic waters reduce the fish appetite and their growth and tolerance to toxic substances. The fish gets prone to attacks of parasites and diseases in acidic waters.

Total Hardness: Hardness is due to presence of calcium and magnesium salts present in water. Hardness may be temporary caused by soluble Ca and Mg bicarbonate or permanent caused by soluble Ca and Mg carbonate and salts of inorganic acids. Based on hardness lakes were classified as soft water lakes, medium class lakes and hard water lakes.

Biological Factors

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. Photosynthesis which transforms mineral salts into carbohydrates under the influence of light given the energy necessary for the development of plants. The biomass of phytoplankton various seasonally in general reaching its highest levels in spring and summer. The density is highest in superficial layers of water (0-10m) and deceases with depth. The appearance of different populations is linked in part to the characteristics of the surrounding water temperature, turbidity and depletion of nutrient.

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. 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.

3) Objectives of fish culture

- Production of low cost protein rich, nutritive, palatable and easily digestible human food.
- Providing new species and strengthening stocks of existing fish in natural and man-made water-bodies through artificial recruitment
- Production of ornamental fish for aesthetic appeal.
- Effective utilization of aquatic and land resource
- Recycling of organic waste of human and livestock origin
- Providing means of livelihood through commercial and industrial aquaculture.
- Production of sport fish and support to recreational fishing.
- Production of bait-fish for commercial and sport fishery.

4) Qualities of culturable species of fishes

For best results in fish culture, it is necessary to make careful selection of the species, considering the climatic and physico-chemical conditions of the place. Only a few species fulfill the necessary conditions to be considered suitable for pond culture. Fish having the following characters are considered suitable:

1. It should grow fast so as to attain full size in a short time.
2. It should be herbivorous, plankton feeder or detritus feeder and should not be predaceous.
3. It should be able to grow on natural food available in the pond and should also take artificial food.
4. It should be hardy and able to survive under temporary unfavourable conditions, so that it can be easily transported to distant places.
5. It must be a prolific breeder and capable of spawning in ponds or respond favourably to induced breeding.

6. The fish should be resistant to diseases and parasites.
7. It should have good taste and flavour.
8. It should be able to live along with other species without competing with them. i.e., suitable for polyculture.

In India, carps are considered to be most suitable for pond culture as they feed on plant material or zo- and phytoplankton, decaying weeds and debris. They are resistant to relatively high turbidity and higher temperature. They are economical also, having a fast growth rate, attaining full size in a short time. They breed profusely and can tolerate low oxygen content.

To find all these qualities in one fish species would be very unlikely. Therefore, the species having maximum required traits are considered to be desirable for cultivation in ponds. Carps fit well to these criteria and hence the most widely cultivated food fishes.

The important cultivable species called the major carps are: *Labeo rohita*, (rohu), *Catla catla*, *Cirrhinus mrigala*, *Labeo calbasu*, *Labeo bata* and *Labeo flmbriatus*. Besides these indigenous species, a few exotic fishes imported into the *Cyprinus carpio* (mirror carp), country are also good for culture. These are *Cenopharyngodon idella*, (grass carp), *Hypophthalmicthys molitrix* (Chinese carp), *Osphronemus goramy* and *Tilapia nnossanbica*. A few salt water species that have become acclimatised to freshwater. e.g. *Chanos* (milk fish) and the mullets, can also be cultured in ponds.

5) Types of cultivable fishes

Cultivable fish species may be of three types:
(1) Indigenous or the native freshwater fishes viz., major carps like *Labeo rohita: Catla catla* and *Cirrhina mrigala*,
(2) A few salt water fishes acclimatized to fresh water like *Chanos chanos* and mullets.
(3) Exotic fishes imported from outside the country Viz., grass carp, silver carp, common carp, chinese carp, crucian carp, etc.

A wide variety of species are cultured in ponds and lakes in a large number of countries all over the world. Fish culture practices have been common in India. China, Indonesia since ancient times. The species that are successfully cultured in various countries are:
(A) Indigenous Carps: *Labeo rohita*, *Catla catla*, *Cirrhnus mrigala* and *Labeo calbasu;*
(B) Chinese Carps: *Ctenopharyngodon idella* (grasscarp), *Hypophthalmichthys molitrix* (Silver carp) and *H. nobilis*;
(c) Trout: *Salmo salar, Salmo truta*
(**D) Common Carp:** *Cyprinus carpio*;
(E) Tilapia: Tilapia spp.
(F) Cat Fishes: *Clarias gariepinus and Silurus spp., Pangasius spp., Clarias batrachus, , Ictalurus punctatus;*
(G) Others: *Chanos chanos* (milk fish), *Puntius javanicus*, *Mugil spp.* (mullels) *Channa spp., Anabas, Anguilla japonica* and *A. rostrata.*

6) Culture qualities & breeding habits of Indian major carps

Culture qualities of Indian major carps: None of the fish species can be said an ideal for cultural purposes as it may not possess all the aforesaid desirable qualities. However, major carps are economically the most important fishes for culture. Along with indigenous carps like Catla, Rohu, Mrigal, suitable exotic carp's are also introduced like silver carp, grass carp and common carp.

The major carps possess following qualities from pisci culture view point.

(1) Major carps feed on phyto and zooplanktons, decaying weeds and debris and other available aquatic plants.
(2) Major carps are resistant to relatively high temperature and turbid water.
(3)They can tolerate certain O, variation in water.
(4) Their growth rate is fast and may attain a seasonably large size in short duration.
(5) They breed profusely.
(6) Fecundity is high.
(7) Their flesh is palatable and much nutritive.
(8) They can be handled and netted out easily can be transported easily from one place to other.

Breeding habits of Indian major carps

Various external factors are known to influence the spawning in fishes, of which light and temperature found more significant. A number of experiments have shown that the summer breeding fishes could be bred in winter by enhancing the photoperiod. On the other hand temperature seems to be more important than that of the photoperiod in influencing reproduction in various fishes. Fishes may not breed below or above a range of optimum temperature, which varies with species. Besides these, rain water, flood, water currents, turbidity, hydrogen 10n concentration, alkalinity gases are also salinity, dissolved oxygen and other gases factors influencing reproduction in important fishes.

The Indian major carps usually breed in inundated rivers during monsoon months. When the rivers are flooded with fresh rain water, shoals of breeders of Catla, Rohu and Mrigal start the spawning migration upstream. It is believed the pituitary gets stimulated by the flowing rain water by improving several other hydrobiological factors to shallow areas The brood fishes migrate adjoining the rivers, where they indulge in sexual play and finally spawn. Spawning of major carps takes place only once 1n a year. However, Indian carps have also been successfully bred in specially designed ponds called "bundhs", where artificially a conditions akin to that of the rivers is created.

The breeding behaviour of Indian major carps is very interesting. The male and female indulge in sexual play, the male chasing the female with Vigorous splashing of water. The female is then held by a male in grip, the latter bending its body round the female. The female shakes violently, and Ova are released in enormous numbers. The male also quivers and ejects wilt over the eggs. During breeding season, the surface of the pectoral fins in males becomes rough, and possibly assists n getting a better grip of the female and exerting pressure on the abdomen of the female to excide eggs. After spawning, the breeders remain quiet for sometimes and then swim away.

The Chinese carps have more or less similar breeding habits like those of the Indian carps. They do not breed in ponds. No report of bundh breeding is available but it is possible that those exotic fishes Can also be bred in specially designed ponds.

UNIT III

Fish Pond Management

4. **Pre-stocking Management**: Drying, ploughing, liming, mannuring, watering, Eradication of aquatic weeds; Eradication of predatory fishes, weed fishes, aquatic insects, predatory animals
5. **Stocking Management**: Seed selection, acclimatization, stocking
6. **Post-stocking Management**: Feeding and Feed management, Water quality management, disease management, harvesting

Fish Pond management

1. Pre-stocking pond management

Pre-stocking management means management before stocking. Broadly it can be said that all the management practices involved in fish culture before stocking of fry in order to prepare the water body and its surrounding environment for living and growth of the fry.

Drying: The objectives of pond drying are: To kill undesirable species and predatory fishes from the pond, To help the works of dike and predatory fishes from the pond, To help for liming and fertilizing to the soil. The pond bottom should be allowed to dry in sunlight at least for 15 days.

Ploughing: When the bottom soil takes the crack after removal of the bottom silt, tilling / ploughing the bottom soil at the top 5-8 cm is done diagonally two times. Then it is dried for 3-10 days.

Pond drying and ploughing facilitate the oxidation of organic matter, degassing of Hydrogen sulphide and ammonia, kills the pathogenic microorganism, predatory and weed fishes and remove the unwanted aquatic weeds. Ponds should be dried for a minimum of 7 – 10 days or until the cracks develop on a clayey soil or until the stage when footprints do not form on a sandy soil.

Limimg: The basic objectives of liming in the pond are: To maintain the pH of soil and water above 6, To increase the function of fertilizer, To remove the turbidity of water, To control decrease and toxin gases, To make the pond environment clean, To increase the productivity.

Manuring: Zooplankton and phytoplankton are the main natural food of fish. Objective of fertilizing are: To produce natural food, To increase the amount of nitrogen, phosphorous, potassium etc.

Organic manures are directly used for the development of natural food. For the pond culture cow dung is better to use. During pond preparation poultry manure can also be used. Generally urea can be used at 20-30kg/ha. It should be dissolved in water and spread over the surface of the pond. Similarly 10-15kg/ha of super phosphate is used during preparation of pond.

Watering: When a pond is fully prepared for stocking of fish then water filling is done. Initially before manuring/fertilizing the water depth should be maintained as low as possible so that the effect of nutrients for natural food production is fully realized. After 1 to 2 weeks of manuring / fertilizing the water depth has to be raised to the required level before stocking the seeds for fish culture. The average water depth in a pond is an important factor in fish culture. This generally depends on various factors like rainfall, evaporation losses, seepage, use of water for irrigation, etc. If necessary, water may be let in from nearby available sources during summer or drained out during monsoon to maintain desirable water depth in the pond.

Eradication of aquatic weeds: Clean and excess aquatic weed free pond is very essential for getting a better production from it. All the aquatic vegetations (floating, submerged or emergent) should be removed from the pond. They hamper primary productivity by absorbing available nutrients from water and soil and hinder normal penetration of sunlight and mind action.

It is necessary to ensure the entrance of sufficient sunlight on the pond surface, to produce more natural food and to increase the fish production. Although some aquatic weeds are the source of food for some fishes such as grass carp all weeds are not necessary and beneficial for a pond. All aquatic weeds are nourished from the water and soil of a water body. It is very harmful for the reproduction and growth of plankton. More over sufficient sunlight cannot enter in to the pond because of excess aquatic weed which is also harmful for the growth of plankton. They also decrease the dissolve oxygen of water and make disturbance for the movement of fishes.

These aquatic weds can be controlled by manual (hand picking, netting, racking), mechanical (weed harvester, weed cutter), chemical (weedicides) and biological (grass carp) methods. The aquatic weeds can be controlled by manual, mechanical, chemical and biological methods. The selection of the method depends on the pond size, extent of weed infestation, availability of time and money. Manual method is generally advocated for weed removal, because it is easier, less time consuming and cost effective.

Eradication of predatory fishes, weed fishes, aquatic insects, predatory animals: Predators are those species which take pray as these foods by hunting. As for example shoal, boal, chital etc. Those species which are not expected during the culture of a specific or desirable species and those which grow naturally in a pond with cultured species are known as undesirable species or weed fishes.

The presence of predatory and weed fishes in nursery affect the survival rate. These fishes normally spawn prior to onset of carp spawning and increase their population. The larvae of predatory may compete with carp seeds for food, space, oxygen, etc that affects the growth and survival rate. Thus, eradication of weed fishes (murrel, catfishes, puntius, barbas danio and anabas) is a prerequisite before stocking the carp seeds.

Reasons for control: Predatory fishes eat the fry of cultured species as for e.g. Predators eat 10-12 kg of other fishes for their 1 kg growth. Undesirable species share the food of cultured species. Undesirable species breakout disease for other cultured species.

The dewatering and drying practices are best to remove the predatory and weed fishes. However, if dewatering is not possible, eradication can be done through the application of a pesticide. The selected pesticide should have characteristics such effective even on usage of low dose, does not affect the quality of the fish, rapidly detoxifies and economical and readily available. The physical methods of eradication include drying, usage of hook and lines and repeated netting. Certain derivatives of plant origin such as Derris root power, Mahua oilcake, Tea seed cake can be used.

All the predatory and unwanted fishes must be eradicated from the pond prior to stocking the pond with the fingerlings of desirable species. This can be done either by complete dewatering the pond or by poisoning. Some commonly used efficient fish toxicants are tea seed cake and Mahua oil cake.

Predatory insects can be controlled by using emulsion of soup and diesel. It causes the damage to respiratory system of insects. These can be killed by using different insecticides.

2. **Stocking Management**: Seed selection, acclimatization, stocking

Prior to the transfer of the spawns to the pond, stocking acclimation has to be done to prevent sudden water quality changes, which affect the survival rate. Early morning or late evening is recommended for stocking. It may be noted that there may be lower dissolved oxygen in the early morning in the ponds, if the ponds are newly fertilized ponds and have high plankton. Similarly, in the evenings the water temperature may be high in the ponds that could stress the spawns. These parameters have to be tested and taken care of before stocking to obtain higher survival. A stocking density of 3 – 5 million / ha or 300 to 500 per m^2 is recommended for earthen ponds and 10 – 20 million /ha or 1000 to 2000 per m^2 for cement cisterns.

Seed selection: For success of aquaculture quality seeds are very important. The seed should be selected according to the culture pond such as nursery pond should be stocked with spawns, rearing pond should be stocked with fry and stocking pond should be stocked with fingerlings. Fish seed should be stocked at required stocking density according to the method of culture such as extensive, semi-intensive or intensive aquaculture. Vigorous and healthy stocking material can only ensure good crop of fry/fingerling. It is advised to check condition of the fry before stocking in rearing ponds.

	Point of Observation	**Good fry**	**Bad fry**
1.	Body shape	Well formed body	Emaciated/Lean with relatively bigger head
2.	Body colour	Bright, shiny	Fade colouration
3.	Scales	No spots of missing scales	Lose scale and spots without scale
4.	Movement	Active and exhibi tnormal movement	Lethargic
5.	Reflex	Immediately react to touch and try to escape	Weak response
6.	Touch	Slippery texture of the body	Rough body

Acclimatization and stocking: The fish should be acclimatized to pond water temperature before stocking. The bag should be kept in the pond water for at least 15-30 minutes to ensure the matching of temperatures of transport water and pond water. After opening the bag water should be gently splashed over the opened bag to match up the temperature and other water qualities. After acclimatization, the bag should be opened and fish seed should be released slowly in the pond. Fish stocking is the practice of releasing fish that are artificially raised in a hatchery into a natural body of water. Stocking of fish seed is carried out different stocking density according to the method of culture. Generally fingerlings of Indian Major Carps are stocked at 10000 fingerlings/ha.

3. Post-stocking Management: Feeding and Feed management, Water quality management, disease management, harvesting

Feeding and Feed management: Soon after stocking, the fish start grazing natural food available in the pond irrespective of their stage of life cycle. Spawn feeds voraciously on plankton. Therefore, immediate steps must be taken for providing supplementary feed. In the case of nursery ponds where spawn are reared for about a fortnight up to fry stage, supplementary feed is broadcast on the pond surface in the form of fine powder daily in the morning hours. The availability of natural food is insufficient to rear the spawn in ponds due to higher stocking density. The requirement of artificial feed is hence necessary. Artificial feed comprises of groundnut oil cake and rice bran at 1:1 ratio.

The form in which the supplementary feed is given is also important. In the nursery ponds the feed should be provided in finely powdered form and may be broadcast over the pond surface. In the case of rearing, stocking and brood stock ponds, the supplementary feed mixture should be mixed with enough water to make a dough and applied into feeding trays fixed in the ponds. Better results can be obtained if the feed mixture is pelletized and fed to fish. The pellets may be of the sinking or floating type, but both types should be water stable. The sinking type of pellets are put in feeding trays fixed in the pond.

The standing crop of fish is estimated every month on the basis of sample netting for growth and health check and feeding schedule is adjusted accordingly. Periodical netting should be done strictly on a monthly basis and with the help of hand nets and spring balance, the average weight of each species should be recorded. The average weight of individual species, monthly increment in weight, total standing crop and amount of feed to be given should be estimated on the basis of data thus available. The feeding tray should be cleaned daily before the application of fresh feed. Fish normally stop feeding if they are sick or the temperature is far below normal. In such situations a proper health check is required and the feeding rate is adjusted. Grass carp should be fed until they stop eating. Usually they consume aquatic vegetation, about 50% of their body weight on a daily basis.

Water quality management:

The fish farmer should also monitor the following parameters on a routine basis.

Water colour: The visual colour of the pond water is a simple but important reflection of the basic production processes.

Water transparency: Water transparency measured with a Secchi disc is intended to quantify the result of those processes which determine and modify the visual colour. However, a low transparency may result either from high turbidity alone or from dense algal population and thus cannot reflect the correct tropic or production level of the water. However, the Secchi transparency readings together with the visual colour provide valuable information on the productivity of the water.

Water depth: The primary water source is usually the rainfall during the monsoon. After the rainy season the water level gradually decreases which results in a very shallow water column by the end of the dry season. The water depth should be maintained upto 2m depth and can be measured with a 4–5 m long bamboo pole fitted at its base with a wooden disc of 25 cm dia.

Dissolved oxygen: Fish ponds usually exhibit wide fluctuations in the dissolved oxygen content from day to night. This diurnal oxygen fluctuation is normally measured to calculate the community metabolism of the whole pond while quantifying the production and respiration processes in the ecosystem. A single measurement just before sunrise would be an important indicator of the risk of fish kill due to oxygen depletion. If the oxygen is depleted aerators can be used. Desirable ranges of various pond environment parameters are presented in Table.

Desirable ranges of pond water quality parameters

Parameters	**Desirable range**
Water colour	Greenish brown
Transparency	25 – 50 cm
pH	7.0 – 8.5
Dissolved oxygen	5.0 ppm
Free carbon dioxide	15.0 ppm
Inorganic nitrogen	0.2 ppm
Inorganic phosphorus	0.2 ppm

Disease management:

In most of the situations, cultured fish are healthy even in the continuous presence of pathogens. However, when environmental stresses occur and the balance shifts in favour of the disease, the characteristic pathogens flourish. Under such circumstances if the fish fail to adjust adequately or if corrective measures are not taken timely, outbreak of diseases may occur. By resolving environmental problems and applying effective therapeutics, the original balance between the host and the pathogen may be restored. Thus a disease outbreak may often be a symptom of environmental imbalance and it gives a distress signal so that the adverse environmental conditions may immediately be corrected to prevent fish losses.

It is always advisable to stock the pond only with healthy and genetically vigorous fry and fingerlings so that they may have better growth rate and resistance towards diseases. Prior to stocking, samples of the stocking material should be examined to check their health status. Overstocking may lead to biological crowding resulting in waste build up, decreased availability of natural food, depletion of dissolved oxygen, deterioration of water quality, etc., and hence it is advisable to follow the recommended stocking density for nursery, rearing and stocking ponds.

Harvesting:

Harvesting of fish means the complete removal of fish from the pond at the end of production. A single stocking and a single harvesting are the common practice in existence. However, the technique of partial harvesting and restocking is now being practiced and has been found to yield better results in terms of fish production per unit area. Bigger size fishes should be harvested and sold in batches and the pond should immediately be restocked with the same number of fishes of such species.

Harvesting of fingerlings is done when it reaches about 80 – 100 mm length which generally takes around 2 – 3 months. Rearing of fingerlings duration can be extended when advanced size fingerlings are required. If the fingerlings are needed to be transported, the feeding should be stopped one or two days before harvest to improve conditioning. A minimum of 60 – 70 percent of survival is attained if best practices are adopted.

Benefits of partial harvesting & stocking rate:

- Allow smaller fish to grow faster.
- Increase carrying capacity of a pond and thus the total production become higher per unit area.
- Farmers some cash return from the pond within a short period of 4-5 months. This encourages them to reinvest the money in Improving his production capacity
- All the tropic and special niches of the pond are fully utilized throughout the culture period maximizing production.
- Harvesting of fish is related to biological productivity and carrying capacity of the pond, when the pond is overcrowded and the productivity of pond cannot support further growth of fish biomass. In rearing pond, relatively bigger sized fishes must be harvested in order to leave available space and food for smaller fish to growth further. Thus, partial or total harvesting of fish can be done at any time when the carrying capacity of a pond is saturated.
- Harvesting should be done by seine net preferably in the morning, when pond environmental conditions remain good. During harvesting, marketable fish should be sorted out first and then small size fish should be returned to the pond. The total operation should be done as possible so that the fishes returned back to pond are not stressed.

UNIT IV

1) **Composite fish farming**
   i. Principle of composite fish farming
   ii. Objectives of composite fish culture
   iii. Composite fish culture in India
   iv. Stocking density
2) **Integrated fish farming**
   i. Principle of Integrated fish farming
   ii. Paddy cum fish farming
   iii. Poultry cum fish farming
   iv. Cattle cum fish farming

1) Composite fish farming

i. Principle of composite fish farming

Stocking of cultivable fishes of which differ different species in feeding habits in called same pond is Composite Fish Culture or Mixed Fish Polyculture or Farming. In other words, combined or mixed farming of compatible fish species is called Polyculture or Composite Fish Culture. When several species belonging to different ecological niches of a pond are cultivated together, the available food in the pond is utilized most efficiently leading to maximum production of fishes. The stocking is done in such a way that towards the end of vegetative period, marketable fishes of all the species are obtained.

The scientific based technology of composite fish culture aims at maximum utilization of the pond's productivity. Fast growing, non-predatory, non-competable species of food fishes are cultured together with complementary feeding habits and capable of utilizing both the natural and supplementary fish food. At the same time one fish is useful to the other. For example the excreta of grass carp is useful for growing fish food organisms, on which other fishes feed. The fishes never face any competition for space and food. Bottom feeders like common carp and mrigal subsist partly on the faecal matter of grass carp. If the bottom feeders are absent in a culture pond the excessive faecal matter of the grass carp may pollute the water. Stocking optimum number of each kind of fish adequately utilizes the different ecological niches. The productive potential or carrying capacity of the pond can be increased by stimulating natural fish food production through fertilization and the use of supplementary feed to provide adequate food for the large number of fish stocked.

ii. Objectives of composite fish culture

- All available niches are fully utilized.
- Composite fish species do not harm each other.
- No competition among different species is found.
- The entire type of food supply is utilized.
- Production increases five to eight times than monoculture.
- Fishes may have beneficial effect on each other.

iii. Composite fish culture in India

Most Asian and Far Eastern countries have taken up composite fish culture mostly on the line of Chinese system of mixed fish farming, though, with certain modifications, so as to suit the local demands. The composite cultures of four species of Chinese carps is still being practiced by Chinese fish farmers.

A fully fledged co-ordinated research project of I.C.A.R (CIFRI) on composite fish culture was started in (1971) with one centre in six major states engaged in fish culture. These centers are in (i) Andhra Pradesh (i) Haryana (iii) Maharastra (iv) Tamilnadu (v) U.P., and (vi) West Bengal.

Mixed farming involves rational manuring and fertilization of pond, as well as feeding the fish with supplementary food consisting of oil cakes, groundnut cakes, rice bran, wheat bran, etc. In India, mixed fish culture is an old practice and species like *Catla catla* (surface feeder), *Labeo rohita* (column feeder), and *Cirrhinus mrigala* or *Labeo calbasu* (bottom feeder) are generally stocked together in the same pond.

Now-a-days in India polyculture is progressing well in larger ponds on commercial scale. Hora and Pillay (1962) proposed culture of Catla, Rohu, Mrigal and Calbasu in proportion of 40: 50 : 10 : 10. Composite fish culture at Cuttack involved a maximum of 7 species viz., the Grass carp, Silver carp, Catla, Rohu, Scale carp, Mirror carp and Tilapia in proportion of 25 : 15 : 15 : 30: 40 : 10: 15 respectively. Many more experiments conducted at Central Inland Fisheries Research Institute (CIFRI) and by ICAR (Indian Council of Agricultural Research) have indicated possibilities of high yield and income. Various combinations selected for composite experimentation chiefly include:

(1) Grass carp, Silver carp, Scale carp and mirror carp in ratio of 5: 3 : 8: 2.
(2) Grass carp, Silver carp, Rohu, Scale carp and Mirror carp in ratio of 5 :3:6:8 :2.
(3) Grass carp, Silver carp, Catla, Rohu, Scale carp, and Mirror carp in ratio of 5: 3:3. 6: 8: 2.
(4) Grass carp, Silver carp, Catla, Rohu, Scale carp, Mirror carp and Tilapia in ratio of 5:3: 3:6: 8: 2: 3.

However, experiments conducted at various stations of CIFRI involved mixed farming of 3 indigenous major carps and 3 exotic carps. The feeding behaviour and type of food consumed by these three indigenous and three exotic carps are given below.

Indigenous major carps

1. *Catla catla* (Catla): It is a surface feeder consuming zooplanktons.
2. *Labeo rohita* (Rohu): It is a column feeder consuming algal forms, decaying plants and macrophytes.
3. *Cirrhinus mrigala* (Mrigal): It is a bottom feeder consuming decaying plants and detritus.

Exotic carps

(1) *Cyprinus carpio* (Common carp). Omnivore and scavanger, feeding on both animals and plants.
(2) *Ctenopharyngodon idella* (Grass carp). It feeds On Coarse macrovegetation, viz; Spirodela, Lemna, Azolla, Hydrilla, Ceratophyllum, etc.
(3) *Hypophthalmichthys molitrix* (Silver carp). A surface feeder on phytoplankton.

iv. Stocking density

Generally fish production increases with the increase in the number of fish stocked per unit area to a maximum and then starts decreasing. There is always an optimum stocking rate in a particular situation, which gives the highest production and largest fish. Under crowded condition at a higher stocking density fish may compete severely for food and thus suffer stress due to aggressive interaction. Fishes under stress eat less and grow slowly. By increasing the stocking density beyond the optimum rate the total demand for oxygen increases with obvious dangers, but no increase of the total yield of the fish is obtained. Stocking density and stocking ratio of fishes should be on the basis of the quantity of water and the amount of oxygen production. The above six varieties of Indian and Chinese major carps should be stocked at a rate of 5000 fingerlings of 75-100 mm size/ha. The percentage of stocking of the above fishes can be as follows:

Catla and silver carp – 30 – 35 %
Rohu – 15 – 20 %
Mrigal and common carp – 45 %
Grass carp – 5 – 10 %

In the 5 – species combination excluding grass carp, the optimal stocking ratios are catla 6(30%) : rohu 3(15%) : mrigal 5(25%) : common carp 4(20%) : silver carp 2(10%).

In a 4 – species combination excluding silver carp and grass carp, the optimal stocking ratios are – catla 6(30%) : rohu 3 (15%) : mrigal 6(30%) : common carp 5(25%).

In a 3 – species combination excluding exotic carps, the optimal ratios are – catla 4 (40%) : rohu 3 (30%) : mrigal 3 (30%).

An 8 – species combination is also possible for composite fish culture, where milk fish and fringe-lipped carps are included in the culture system along with Indian and Chinese major carps. But the growth of the additions is not satisfactory. The milk fish is a brackish water fish. Usually the stocking ratio is catla 2 : rohu 2 : mrigal 4 : common carp 3 : silver carp 5 : grass carp 2 : fringe-lipped carp 1 : milk fish 1.

Stocking ratio with three indigenous and three exotic carps is as follows:

Indigenous fishes			**Exotic fishes**		
Catla	Rohu	Mrigal	Silver carp	Grass carp	Common carp
1	1	1	2	2.5	2.5
1	1	1	3	1.5	2.5
1.5	3	1	3.5	1.5	2.5

The factors which are considered useful for purpose of complete utilization of natural/supplementary food and higher productivity are given below:

- Selection of suitable combinations with respect to food and feeding habits and their tolerance limit to various physicochemical and biological factors.
- Stocking densities of fingerlings stocked per hectare area of the pond.
- Initial total weight of fingerlings being released in the pond.
- Rate, kind and frequency of fertilization of pond.
- Rate, kind and frequency of artificial food being supplied.
- The abiotic and biotic characteristics of the pond.
- Fish production including the gross weight of fish harvested per hectare area of the pond.
- The cost of production, based on expenditure increased and the net profit.

2) Integrated fish farming

Integrated fish farming systems refer to the production, integrated management and comprehensive use of aquaculture, agriculture and livestock, with an emphasis on aquaculture. Asia has a long and rich history of integrated fish farming. Written records from the first and second centuries B.C. documented the integration of aquatic plant cultivation and fish farming. From the ninth century, records showed fish farming in the paddy field. From the fourteenth to sixteenth centuries, there were records of rotation of fish and grass culture; and by the 1620s, the mulberry-dike fishpond, the integration of fish and livestock farming and complex systems of multiple enterprises integrated with fish farming were developed. Integrated fish farming is the methods by which fish is cultured along with paddy, piggery, poultry or any livestock, or flower culture.

i. Principle of Integrated fish farming

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 (FAO, 1977). In integrated farming, the basic principles involve the utilization of the synergetic effects of inter-related farm activities and the conservation, including the full utilization of farm wastes. It is assumed that all the constituents of the system would benefit from such a combination. However, in most cases, the main beneficiary is the fishes which utilises the animal and agricultural wastes directly or indirectly as food. As integrated farming involves the recycling of wastes, it has been considered an economic and efficient means of environmental management.

Integrated fish farming is a system of producing fish in combination with other agricultural/livestock farming operations centered around the fish pond. The farming sub-systems e.g. fish, crop and livestock are linked to each other in such a way that the byproducts/wastes from one sub-system become the valuable inputs to another sub-system and thus ensures total utilization of land and water resources of the farm resulting in maximum and diversified farm output with minimum financial and labour costs.

In a proper fish, crop and livestock integrated farming system, the possible inter sub-system interactions are - excreta and waste feed from livestock sub-system act as manure and feed for fish as well as can be used as manure for crop land. By-product/wastes of crop can be used as feed, manure for the fish pond and as feed for livestock. Nutrient rich bottom silt and water of pond can be a good source of fertilizers for the crop land. It thus appears that the different sub-systems in an integrated system are beneficially inter-linked to each other in a limited area, minimizing the production costs but resulting in a diversified outputs viz. fish, meat, eggs, vegetables, fruits, fuel wood and fodder which are the basic need of a farm family.

ii. Paddy cum fish farming

In areas where paddy fields remain water for 3 to 8 months in a year, paddy cum fish culture can provide an additional supply of fish crop. The culture of fish in fields, which remain flooded even after the paddy is harvested, might also serve as an off-shore occupation for farmers. Rice fields which are water-logged for 3-8 months in a year, there is always small population of fishes that gain access to such waters. This probably had given rise to the practice of deliberate stocking of fishes and harvesting. The trapping of prawns and fishes with the help of 'gamcha or dhoti' in fallow paddy-fields has been an age old practice in India.

Objectives of Paddy-Field Aquaculture:

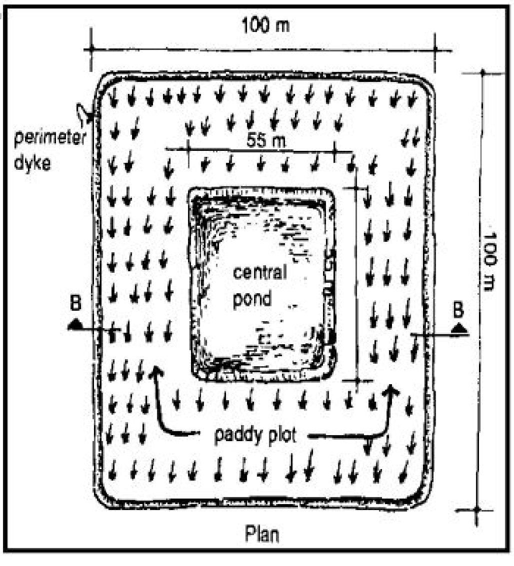
- Paddy-field aquaculture provides additional income to the farmers.
- In areas where rice and fish form the staple food, paddy-field aquaculture makes available an essential diet for the people.
- As paddy and fish can be grown either simultaneously or alternately in the same water mass, it requires very little extra input by way of additional costs, particularly in management and labour.
- It provides off-season employment to the farmers and farm labours.
- Combination of paddy and fish farming is mutually beneficial. Fish cultivation promotes better paddy production by way of exercising an effective control on unwanted weeds, molluscs, noxious insects and their larval stages.

Fishes Suitable for Paddy-Cum-Fish Culture: 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.

Fishes having the following criteria are generally selected for paddy-cum-fish culture:

- Fishes that can adapt to shallow waters necessary for paddy crops.
- Fishes that can tolerate high temperature.
- Fishes that can thrive on low dissolved oxygen, which is the characteristic of paddy-fields especially in tropical countries.
- Fishes that can tolerate fairly high turbidity.
- As the duration of culture is quite short, fishes that have high growth rate is to be selected, so that it can reach marketable size within these few months.
- Fishes that can live in confinement and do not tend to escape from the cultivated area.

Fishes that are cultured in such waters in India are *Mugil sp*., *Mystus gulio*, *Haplochromis mellandi* (mollusc eating fish), *Lates calcarifer*, *Mugil parsia*, *Puntius sp*., *Channa sp*., prawns and shrimps. In India, limited experimental works have shown the suitability of Indian carps for such integrated farming.



iii. Poultry cum fish farming

In this system fish farming is integrated with poultry farming where poultry droppings or deep litter materials are utilized by fish as feed materials. In India, this system of freshwater fish culture has assumed greater significance in view of its potential role in recycling of organic wastes and in integrated rural development.

Advantages of fish cum poultry farming:

- save fertilizer cost
- save supplementary feed cost (account 60%)
- Chicken get its required quantity of water from the fish pond
- from the same places at the same time chicken meat, eggs and the fish can be produced

In poultry farming along with fish the following management practices are followed:

- Construction of poultry house
- Housing system of birds
- Selection of birds
- Feeding
- Egg laying
- Health care

1. Construction of Poultry House: A low cost house can be constructed near the pond embankment using locally available materials like- bamboo, wood, etc.

2. Housing System: The poultry house can be constructed over the pond or on the embankment of pond. The height of the poultry house should be 2.1-2.4 m at side well and 3.0-3.3m at the centre to provide slope on the either side. The roofing materials like tins, asbestos sheets, tiles or thatches may be used for construction. The width of poultry house should not exceed 9 m to have effective cross ventilation and length of the house may be as per the requirement. The droppings of the birds fall on the floor from where these are collected and applied to the pond.

The birds are confined to the house entirely, with no access to the land outside. This housing system is of two types, viz. Battery system (Cage system) and deep litter system. The deep litter system is preferred over the cage system due to higher manorial value of the built up deep litter. In this system, the poultry birds are kept in pens up to 250 birds per pen on floor covered with litter. For starting the deep litter system, the floor of the pen is covered with dry organic material. The chopped straw, dry leaves, hay, saw dust etc. to a depth of about 6 inches. 1 sq. feet floor space is required per bird. The dropping of the birds which fall on the litter gradually combine with the litter material due to bacterial action. When the depth of litter becomes less, more organic matter is added to maintain sufficient depth. In case the litter becomes damp superphosphate or lime is added to keep it dry. The litter is regularly stirred for aeration. In about 10-12 months, it becomes fully built up litter, having very high manorial value. The shed should be thoroughly cleaned, disinfected and rested before chicks are placed.

3. Selection of Birds: The dual purpose bird for meat and egg are Vanaraja, Gramapriya or Kuroiler and for egg purpose bird is white leghorn suitable for this integration. About 500 to 600 birds are required for one hectare water spread area. About eight week old chicks, after vaccination against viral diseases and providing other necessary prophylactic measures as a safeguard against epidemics are kept in poultry house near the pond.

4. Feeding: Grower mash is provided to the farmed birds during the age of 9-20 weeks @ 50-70 gm/bird/ day. Whereas, a layer mash is provided to the birds above 20 weeks @ 80-120 gm/bird/day. The feed is provided to the birds in feed hoppers to avoid wastage. An ample supply of water is made available to all the birds at all the time. Egg-type birds are fed with starter 0-8 weeks, grower 8-20 weeks and brooder feed 20 weeks onwards, while broilers are fed 0-4 weeks with starter and 4-6 weeks with finisher feed.

5. Egg Laying: Each pen of laying birds is provided with one nest for 5-6 birds. Egg production commences at the age of 22 weeks and then gradually decline. The Vanaraja and Gramapriya and Kuroiler lay from 140–160 eggs and white leg horn lays egg 240- 300 per year. After the age of 18 month birds are disposed.

6. Health Care: The poultry house and equipment must be disinfected at least 30 days prior to bringing in the new flock. The birds are to be vaccinated against diseases like infectious bronchitis infected laryngo trancheitis, Marak's diseases, Ranikhet diseases, fowl pox, etc. at the appropriate age. Some of the bacterial diseases viz. Salmonellosis, Coryza, fowl cholera, etc. can be kept under control by maintenance of proper hygienic conditions. Broad spectrum antibiotics may be added to the water in case the infection is mild. In severe cases, veterinary expert should be consulted. The fully built up deep litter removed from poultry pens is stored in suitable place and supplied to the pond @ 50 kg/ha/day every morning after sunrise. The application of this is deferred on the days when algal bloom appears in the pond.

Production: Fertilization with poultry manure results in a production of 3000-4000 kg fish, 60,000-100,000 eggs and over 3,500 kg meat/ year can be obtained from a hectare of pond area in one year. A fish production of 10 tonne/ha could be obtained by culturing tilapia, common carp and murrels with a stocking density of 20,000 fingerlings/ha and chick density of 4,000/ha. No chemical fertilizers or supplemental feeds have to be given at any stage.

iv. Cattle cum fish farming

Fish farming by using cattle manure has long been practiced in our country.The cow excreta is most abundant in terms of availability and a healthy cow may excrete over 4000-5000kg dung and 3500-4000 litre urine on an annual basis.

- This promotes the fish-cum-cattle integration and is a common model of integration.
- Cattle farming can save more fertilizers, cut down fish feeds and increase the income from milk.
- The fish farmer not only earns money but also can supply fish, milk and beef to the market.

Pond management practices

- Cow dung is used as manure for fish rearing.
- About 5,000 - 10,000 Kg/ha can be applied in fish pond in installments.
- After cleaning cow sheds, the waste water with cow dung, urine and unused feed, can be drained to the pond.
- The cow dung promotes the growth of plankton, which is used as food for fish.

Cattle husbandry practices

- The cow sheds can be constructed on the embankments of the fish farm or near the fish farm.
- The locally available material can be used to construct the cow shed. The floor should be cemented.
- The outlet of the shed is connected to the pond so that the wastes can be drained into the pond.
- Cultivable varieties of cows are black and white (milk), Shorthorn (beef), Simmental (milk and beef), Hereford (beef), Charolai (beef), Jersey (milk and beef) and Qincuan draft (beef).