AmbujaNeotia

THE NEOTIA UNIVERSITY

THE NEOTIA UNIVERSITY

A Lab Manual On:

Principles Of Aquaculture

The School of Agricultural and Allied Sciences.

Prepared By:

Animesh Ankuria

Department of Fishery Sciences

Index

1. Aquaculture production statistics- World and India.

WORLD Scenario

According to the latest worldwide statistics on aquaculture compiled by FAO, world aquaculture production attained another all-time record high of 114.5 million tonnes in live weight in 2018 (Figure 8), with a total farmgate sale value of USD 263.6 billion.

The total production consisted of 82.1 million tonnes of aquatic animals (USD 250.1 billion), 32.4 million tonnes of aquatic algae (USD 13.3 billion) and 26 000 tonnes of ornamental seashells and pearls (USD 179 000).

The farming of aquatic animals in 2018 was dominated by finfish (54.3 million tonnes, USD 139.7 billion), harvested from inland aquaculture (47 million tonnes, USD 104.3 billion) as well as marine and coastal aquaculture (7.3 million tonnes, USD 35.4 billion).

Following finfish were molluscs (17.7 million tonnes, USD 34.6 billion) – mainly bivalves – crustaceans (9.4 million tonnes, USD 69.3 billion), marine invertebrates (435 400 tonnes, USD 2 billion), aquatic turtles (370 000 tonnes, USD 3.5 billion), and frogs (131 300 tonnes, USD 997 million).

Marine capture production

Global total marine catches increased from 81.2 million tonnes in 2017 to 84.4 million tonnes in 2018, but were still below the peak catches of 86.4 million tonnes in 1996. Catches of anchoveta (Engraulis ringens) by Peru and Chile accounted for most of the increase in catches in 2018, following relatively low catches for this species in recent years.

In 2018, the top 7 producers were responsible for over 50 % of the total marine captures China accounted for 15 % of the world total followed by Peru (8 %), Indonesia (8 %), the Russian Federation (6 %), the United States of America (6 %), India (4 %), and Viet Nam (4 %).

In 2018, catches of anchoveta once again made it the top species, at over 7.0 million tonnes per year, after relatively lower catches recorded in recent years. Alaska pollock (*Theragra chalcogramma*) was second, at 3.4 million tonnes, while skipjack tuna (*Katsuwonus pelamis*) ranked third for the ninth consecutive year, at 3.2 million tonnes.

Inland waters capture production

Global catches in inland waters have increased steadily year on year, reaching over 12 million tonnes in 2018, the highest levels recorded. Similarly, the share of inland waters in the total for global captures also increased from 8.0 % in the late 1990s to 12.5 % in 2018.

Inland water catches have been relatively stable in China, the top producer, averaging about 2.1 million tonnes per year over the last 20 years, while the increase in total inland water catches has largely been driven by a number of other major producing countries – notably, India, Bangladesh, Myanmar and Cambodia. Most of the countries reporting declining catches represent a relatively low contribution to global production of inland water captures, although some of these are locally important food sources in the national or regional diets – in particular, Brazil, Thailand and Viet Nam.

The top six producers are all located in Asia and accounted for 57 % of total inland water catches in 2018.

Africa accounts for 25 % of the global inland captures, where they represent an important source of food security, particularly in the case of landlocked and low-income countries. The combined catches for Europe and the Americas account for 9 % of total inland captures, while in Oceania catches are negligible.

Four major species groups account for about 85 percent of total inland water catches. The first group "carps, barbels and other cyprinids" has shown a continuous increase, rising from about 0.6 million tonnes per year in the mid-2000s to over 1.8 million tonnes in 2018.

Catches of the second-largest group "tilapias and other cichlids" have remained stable at between 0.7 million tonnes and 0.85 million tonnes per year, while catches of freshwater crustaceans and freshwater molluscs have also remained relatively stable at from about 0.4 million tonnes to 0.45 million tonnes per year.

Dowmload Link:

http://www.fao.org/3/ca9231en/ca9231en.pdf

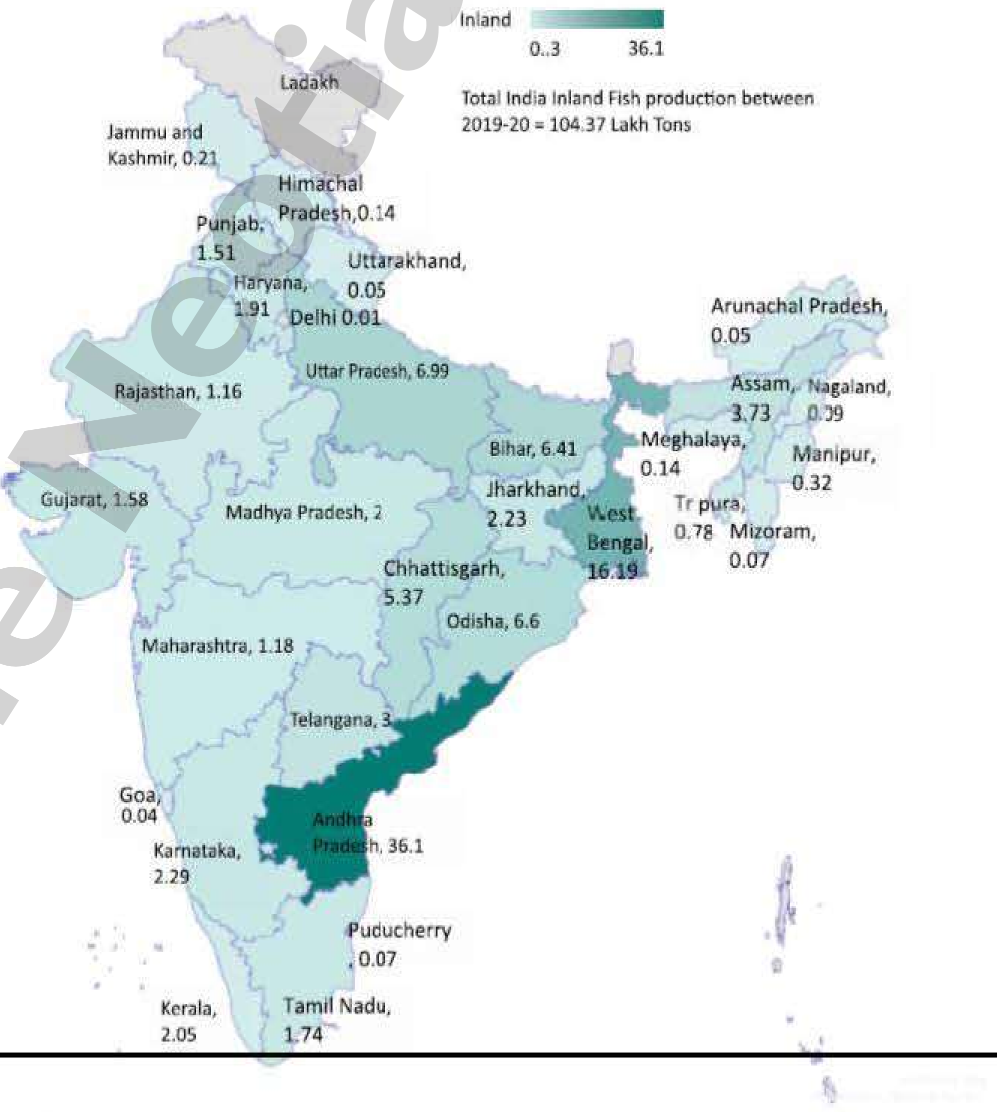
https://www.ceicdata.com/en/chad/agricultural-production-and-consumption/td-total-fisheries-production

2. Aquaculture production statistics- India.

INDIA

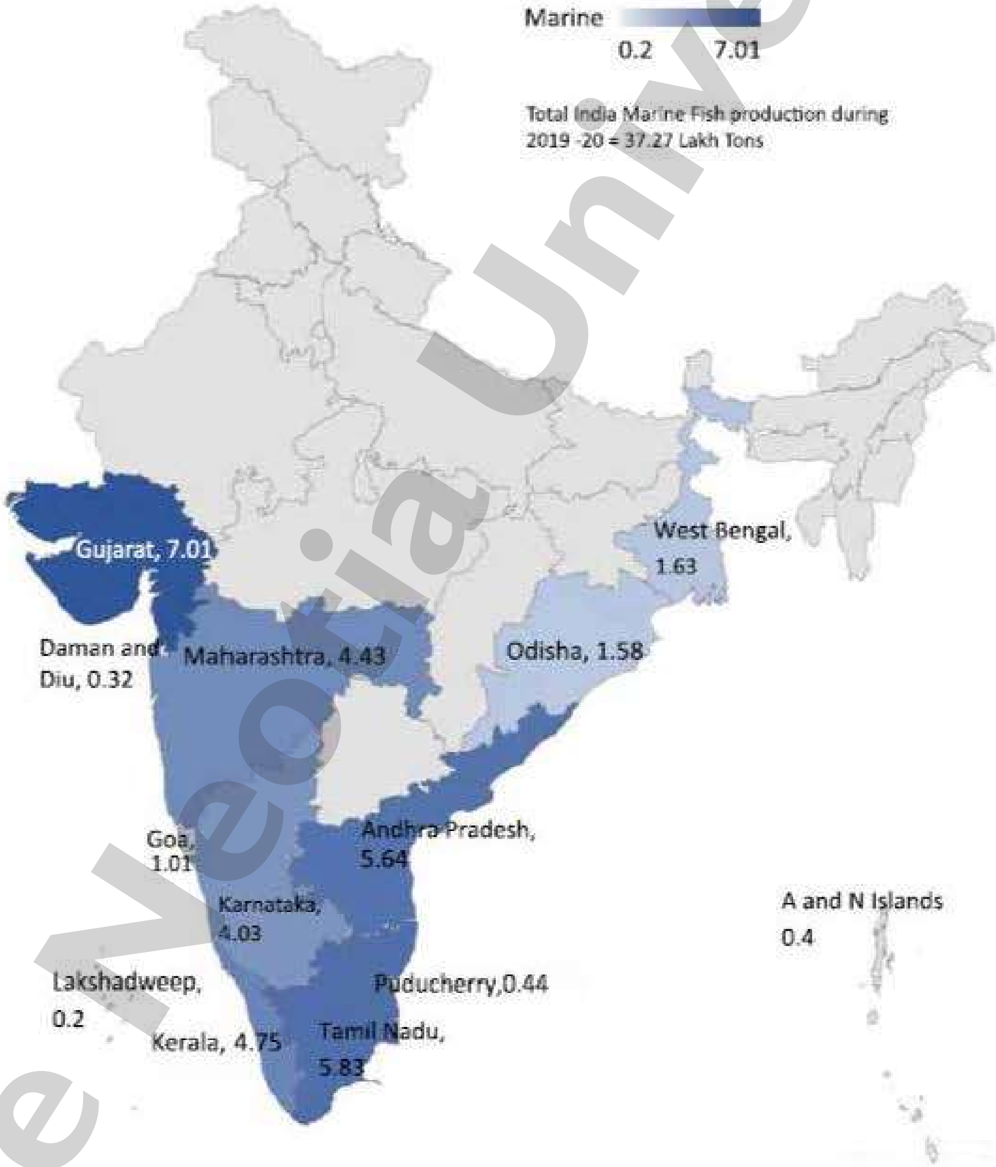
Fish Production data was reported at 13,340.860 Ton in 2019. This records an increase from the previous number of 12,590.290 Ton for 2018. Fish Production data is updated yearly, averaging 5,656.000 Ton from Mar 1981 to 2019, with 39 observations. The data reached an all-time high of 13,340.860 Ton in 2019 and a record low of 2,367.000 Ton in 1983.

Inland waters capture production



Inland data was reported at 9,627.110 Ton in 2019. This records an increase from the previous number of 8,902.420 Ton for 2018. Fish Production: Inland data is updated yearly, averaging 2,823.000 Ton from Mar 1981 to 2019, with 39 observations. The data reached an all-time high of 9,627.110 Ton in 2019 and a record low of 887.000 Ton in 1981.

Marine capture production



Marine data was reported at 3,713.750 Ton in 2019. This records an increase from the previous number of 3,687.860 Ton for 2018. Fish Production: Marine data is updated yearly, averaging 2,816.000 Ton from Mar 1981 to 2019, with 39 observations. The data reached an all-time high of 3,713.750 Ton in 2019 and a record low of 1,427.000 Ton in 1983

3. Aquaculture resources of India.

Fisheries are an important source of food, nutrition, employment and income in India. The sector provides livelihoods to about 16 million fishers and fish farmers at the primary level and almost twice the number along the value chain. Fish being an affordable and rich source of animal protein, is one of the healthiest options to mitigate hunger and malnutrition. The sector has immense potential to more than double the fishers and fishfarmers' incomes, as envisioned by the government.

India has rich and diverse fisheries resources ranging from deep seas to lakes, ponds, rivers and more than 10% of the global biodiversity in terms of fish and shellfish species. The marine fisheries resources are spread along the country's vast coastline and 2.02 million square km Exclusive Economic Zone (EEZ) and 0.53 million sq.km continental shelf area. The inland resources are in the form of rivers and canals (1.95 lakh km), floodplain lakes (8.12 lakh hectares), ponds and tanks (24.1 lakh hectares), reservoirs (31.5 lakh hectares), brackish water (12.4 lakh hectares), saline/alkaline affected areas (12 lakh hectares) etc. The unutilized and underutilized vast and varied inland resources offer great opportunities for livelihood development and ushering economic prosperity.

The total fisheries potential of India has been estimated at 22.31 million metric tons (in 2018), of this, the marine fisheries potential stands at an estimated 5.31 million metric tons and the inland fisheries potential has been estimated at 17 million metric tons. In the recent years, the fish production in India has registered an average annual growth rate of more than 7%. The fish production in the country has shown continuous and sustained increments since independence. The total fish production in the country rose from 0.752 million metric tons in 1950-51 to 13.42 million metric tons (provisional) during FY 2018-19. Of this, the marine fisheries contributed 3.71 million metric tons and the inland fisheries contributed 9.71 million metric tons. During FY 2018-19, 71% of marine fisheries potential has been harnessed and the inland fisheries potential harnessed during the same period stands at 58%.

Dowmload Link:

http://www.fao.org/3/ca9231en/ca9231en.pdf

https://www.ceicdata.com/en/chad/agricultural-production-and-consumption/td-total-fisheries-production

4. Components of an Aquaculture Farm

In a farm the various technical components included in a system can be roughly separated as follows:

I. Production units
II. Water transfer and treatment
III. Additional equipment (feeding, handling and monitoring equipment)

To illustrate this, two examples are given: a land-based hatchery and a juvenile farm.

Land-based hatchery and juvenile production farm

Land-based farms normally utilize much more technical equipment than sea cage farms, especially intensive production farms with a number of tanks. The major components are as follows:

- Water inlet and transfer
- Water treatment facilities
- Production units
- Feeding equipment
- Equipment for internal fish transport and size grading
- Equipment for transport of fish from the farm
- Equipment for waste and wastewater treatment

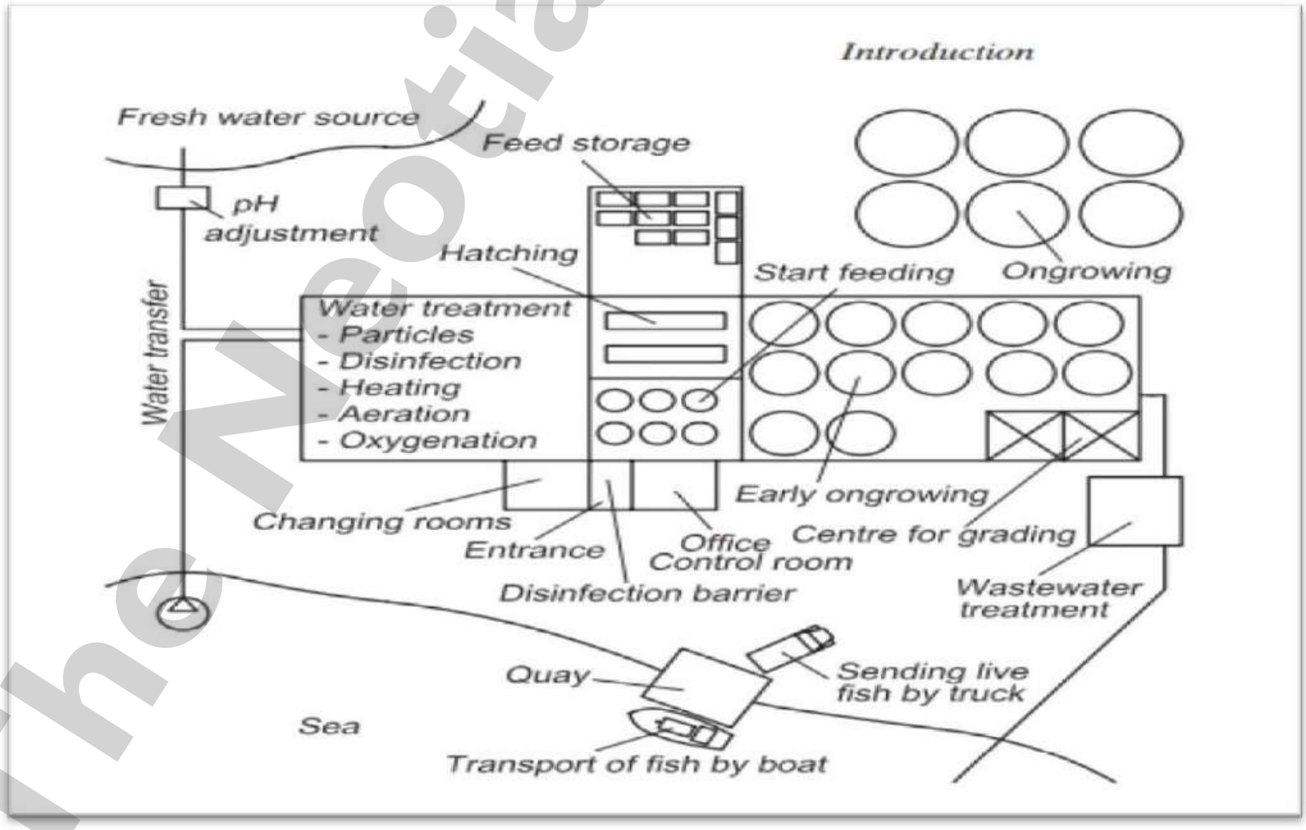
- Instrumentation and monitoring systems

Water inlet and transfer

The design of the inlet depends on the water source: is it seawater or freshwater (lakes, rivers), or is it surface water or groundwater? It is also quite common to have several water sources in use on the same farm. Further, it depends whether the water is fed by gravity or whether it has to be pumped, in which case a pumping station is required. Water is normally transferred in pipes, but open channels may also be used.

Water treatment facilities

Usually water is treated before it is sent in to the fish. Equipment for removal of particles prevents excessively high concentrations reaching the fish; additionally large micro-organisms may be removed by the filter. Water may also be disinfected to reduce the burden of micro-organisms, especially that used on eggs and small fry. Aeration may be necessary to increase the concentration of oxygen and to remove possible supersaturation of the gases nitrogen and carbon dioxide. If there is lack of



water or the pumping height is large pure oxygen gas may be added to the water. Another possibility if water supply is limited is to reuse the water, however, this will involve much water treatment. For optimal development and growth of the fish heating or cooling of the water may be necessary; in most cases this will involve a heat pump or a cold-storage plant. If the pH in a freshwater source is too low pH adjustment may be a part of the water treatment.

Production units

The production units necessary and their size and design will depend on the species being grown. In the hatchery there will either be tanks with upwelling water (fluidized eggs) or units where the eggs lie on the bottom or on a substrate. After hatching the fish are moved to some type of production tank. Usually there are smaller tanks for weening and larger tanks for further on-growing until sale. Weening start feeding tanks are normally under a roof, while on-growing tanks can also be outside.

Feeding equipment

Some type of feeding equipment is commonly used, especially for dry feed. Use of automatic feeders will reduce the manual work on the farm. Feeding at intervals throughout the day and night may also be possible; the fish will then always have access to food, which is important at the fry and juvenile stages.

Internal transport and size grading

Because of fish growth it is necessary to divide the group to avoid fish densities becoming too high. It is also common to size grade to avoid large size variations in one production unit; for some species this will also reduce the possibilities for cannibalism

Transport of fish

When juvenile fish are to be transferred to an on-growing farm, there is a need for transport. Either a truck with water tanks or a boat with a well is normally used. The systems for loading may be an integral part of the farm construction.

Equipment for waste handling and wastewater treatment

Precautions must be taken to avoid pollution from fish farms. These include legal treatment of general waste. Dead fish must be treated and stored satisfactorily, for example, put in acid or frozen for later use. Dead fish containing trace of antibiotics or other medicine must be destroyed by legal means.

Whether wastewater treatment is necessary will depend on conditions where the effluent water is discharged. Normally there will at least be a requirement to remove larger suspended particles.

Instrumentation and monitoring

In land-based fish farms, especially those dependent upon pumps, a monitoring system is essential because of the economic consequences if pumping stops and the water supply to the farm is interrupted. The oxygen concentration in the water will fall and may result in total fish mortality. Instruments are being increasingly used to control water quality, for instance, to ensure optimal production.

Video Link:

https://www.youtube.com/watch?v=jgtVg0oaKn8&ab_channel=i-AGRIbySIRDAN

5. Estimation of carrying capacity.

Concepts of carrying capacity

Carrying capacity for any sector can be defined as the level of resource use both by humans or animals that can be sustained over the long term by the natural regenerative power of the environment. This is complementary to assimilative capacity, which is defined as "the ability of an area to maintain a healthy environment and accommodate wastes" (Fernandes et al., 2001), and to environmental capacity, which is defined as "the ability of the environment to accommodate a particular activity or rate of activity without unacceptable impact" (GESAMP, 1986). Davies and McLeod (2003) defined carrying capacity as "the potential maximum production a species or population can maintain in relation to available food resources". Assessment of carrying capacity is one of the most important tools for technical assessment of not only the environmental sustainability of aquaculture as it is not limited to farm or population sizes issues, but it can also be applied at ecosystem, watershed and global scales. Although these general views of carrying capacity for aquaculture are based solely on production, they have been developed further into a more comprehensive four-category approach based on physical, production, ecological and social carrying capacity (Inglis, Hayden and Ross, 2000; McKindsey et al., 2006).

Types of Carrying Capacity

Physical carrying capacity

Physical carrying capacity is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system. In its simplest form, it determines development potential in any location, but is not normally designed to evaluate that against regulations or limitations of any kind. In this context, this can also be considered as identification of sites or potential aquaculture zones from which a subsequent more specific site selection can be made for actual development. This capacity considers the entire waterbody, or waterbodies, and identifies the total area suitable for aquaculture. Inglis, Hayden and Ross (2000) and McKindsey et al. (2006) note that physical carrying capacity does not indicate at what density cultured organisms are stocked or their production biomass. Physical carrying capacity is useful to quantify potential adequate and available areas for aquaculture in the ecosystem, but it offers little information on aquaculture's limits at the waterbody or watershed level within the EAA. In terrestrial aquaculture, it can define the capacity of the area for the construction of ponds or the availability of water supply.

Production carrying capacity

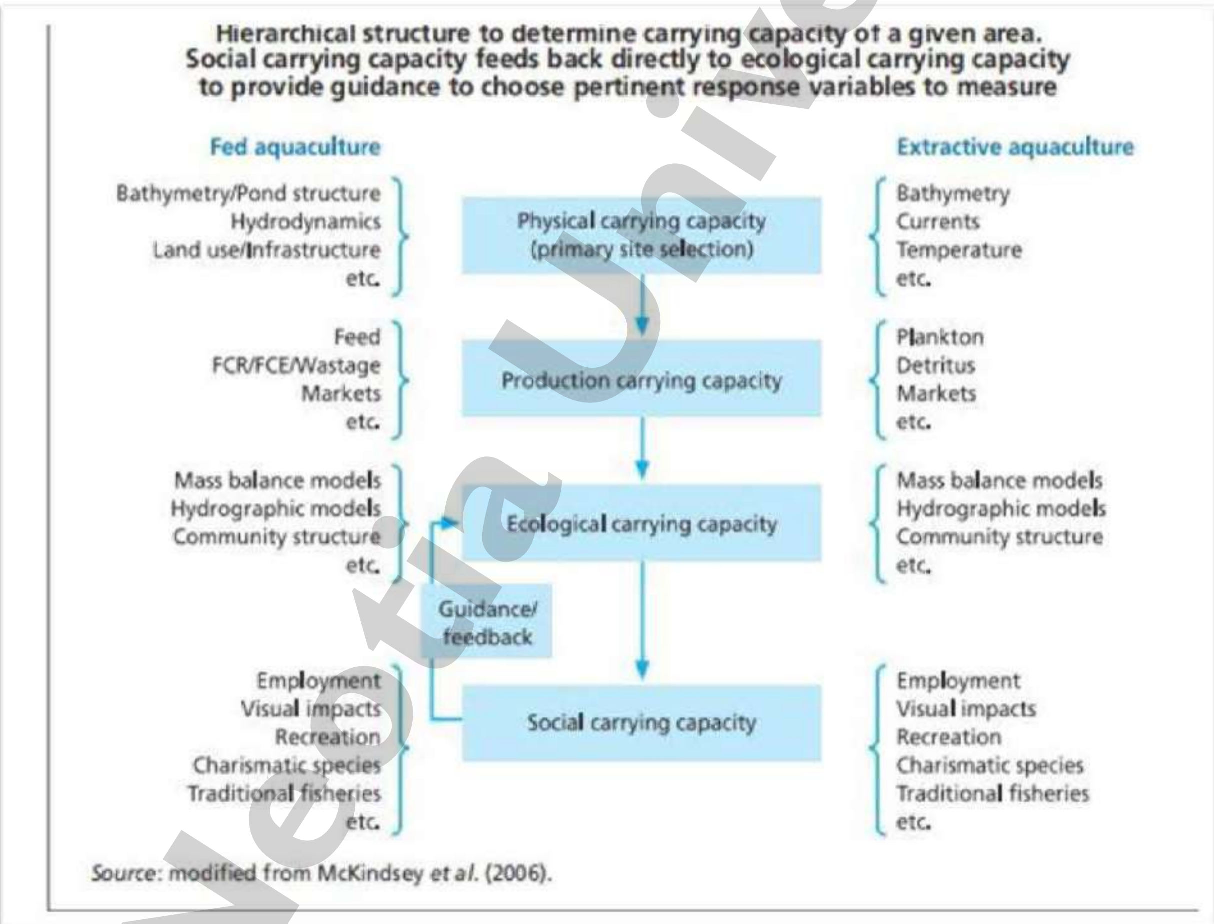
Production carrying capacity estimates the maximum aquaculture production and is typically considered at the farm scale. For the culture of bivalves, this is the stocking density at which harvests are maximized. However, production biomass calculated at production carrying capacity could be restricted to smaller areas within a water basin so that the total production biomass of the water basin does not exceed that of the ecological carrying capacity, for example, fish cage culture in a lake. Estimates of this capacity are dependent upon the technology, production system and the investment required, with investment being defined by Gibbs (2009) as an "economic" capacity, being the biomass at a particular location for which investment can be secured.

Ecological carrying capacity

Ecological carrying capacity is defined as the magnitude of aquaculture production that can be supported without leading to significant changes to ecological processes, services, species, populations or communities in the environment. Gibbs (2007) discussed a number of issues pertaining to the definition and calculation of ecological carrying capacity, and highlighted the fact that bivalve aquaculture can have an impact on the system because bivalves are both consumers (of phytoplankton) and producers (by recycling nutrients and detritus) with the concomitant ecosystem impacts of both. In determining ecological carrying capacity, he has urged caution when attributing cause of change (and partitioning impacts) between bivalve culture and other activities in the ecosystem. On the other hand, fish cage culture, for example, uses ecosystem services for the degradation of organic matter and nutrients and provision of oxygen, but a certain level of fish biomass may exceed the system capacity to process nutrients and provide oxygen, thus generating eutrophication.

Social carrying capacity

Social carrying capacity has been defined as the amount of aquaculture that can be developed without adverse social impacts. Byron et al. (2011) have stated that the ultimate goal of determinations of social carrying capacity is to quantify the value of the involvement of stakeholders in a science-based effort to determine the proper limits to aquaculture in their local waters. Ecological degradation or adverse changes to ecosystems attributed to aquaculture may inhibit social uses. According to Byron et al. (2011), the point at which alternative social uses become prohibitive due to the level, density or placement of aquaculture farms is the social carrying capacity of aquaculture. Angel and Freeman (2009) refer to social carrying capacity as the concept reflecting the trade-offs among all stakeholders using common property resources and as the most difficult to quantify, but as the most critical from the management perspective. For example, if there is widespread opposition to aquaculture in a particular place, the prospects for its expansion will be limited.



FACTORS AFFECTING CARRYING CAPACITY

- Food availability
- Water supply
- Environmental conditions
- Living space

- Disease
- Predator – prey interaction

Ecosystem approach to Aquaculture as a framework for carrying capacity

In 2006, the FAO recognized the need to develop an ecosystem-based management approach to aquaculture to strengthen the implementation of the FAO Code of Conduct for Responsible Fisheries (FAO, 1995).

Ecosystem Approach to Aquaculture (EAA)

EAA includes the strategy for the integration of aquaculture within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems.

Modeling / calculation of CC

Ecopath is static, mass-balance, ecosystem-based modeling software that focuses on energy transfer between trophic levels and is widely used in fisheries management. It is used for modeling a wide range of systems and management scenarios including the carrying capacity of bivalve aquaculture. Most other shellfish carrying capacity models are at the production or farm scale (Nunes et al. 2003) which neglects all trophic levels equal to and higher than the bivalves .

Input parameters:

1. Biomass (B)
2. P/B
3. C/B

Video Link:

https://www.youtube.com/watch?v=O9_gi3AMcok&ab_channel=By%3ARachelTaylor

6. Practices of Pond Management (Pre-Stocking Management).

POND MANAGEMENT

Carp culture in ponds is basically a three-tier culture system where the first step begins with the rearing of spawn up to fry (2–3 cm) stage for 2–3 weeks in nursery ponds followed by rearing of 2–3 weeks old fry for about 3 months up to fingerling stage (8–12 cm) in rearing ponds before they are finally released in stocking ponds for growing up to table size fish. To ensure high rate of survival and growth during all the three stages of rearing, a package of management practices should be strictly followed, and slackness at any stage of the management procedure may affect farm productivity and profitability adversely. Techniques of management involve

(i) manipulation of pond ecology to ensure optimum production of natural fish food while maintaining the water quality parameters within tolerance limits of the stocked fish species; and
(ii) the husbandry of fish through stock manipulation, supplementary feeding and health care.

Broadly, the various steps involved in the management of ponds at all the three stages of culture may be classified as

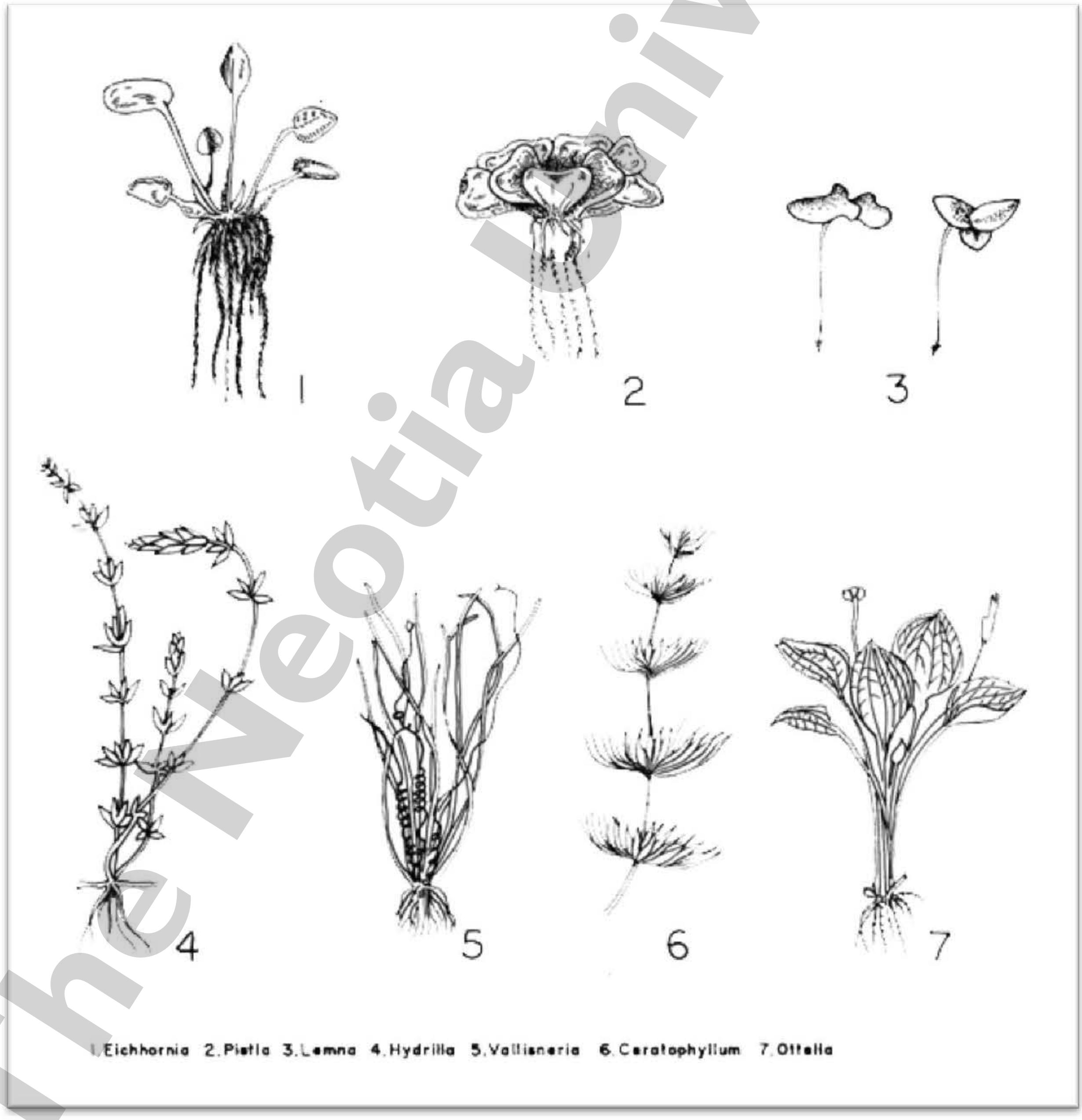
(i) pre-stocking,
(ii) stocking and
(iii) post-stocking management operations.

Pre-stocking management

Pre-stocking management aims at proper preparation of ponds to remove the causes of poor survival, unsatisfactory growth, etc., and also to ensure ready availability of natural food in sufficient quantity and quality for the spawn/ fry/fingerlings to be stocked. Pre-stocking part of the management involves the following sequential measures.

Eradication and control of aquatic weeds and algae

Aquatic weeds are unwanted plants that grow within the water body and along the margins. Unlike in temperate climate, the pond fish culture in tropics face serious problems due to weed infestation and frequent appearance of algal blooms. They remove a large quantity of nutrients from the water, which otherwise would go into the production of planktonic growth. Even the poor fish crop that is produced in weed chocked water is difficult to harvest. The fishes are subjected to stress due to dissolved oxygen depletion and wide fluctuation between the dissolved oxygen values of the day and night. Decomposition of the dead aquatic weeds further creates the oxygen problem. Dense growth of the submerged weeds restrict fish movement and interfere with fishing operations. Filamentous algae often get entangled in the gills of the fish and suffocate them to death. Floating weeds such as water hyacinth, pistia, etc., very often cover the entire water surface cutting off light drastically, thus resulting in critical reduction in primary productivity of the pond. Common aquatic weeds creating problems in fish culture ponds (Fig. 34) are broadly classified according to their nature of occurrence, into four major groups. They are floating, emergent, submerged and marginal. In addition, algal blooms and mats also create serious problems in terms of dissolved oxygen and production of certain toxic materials in some cases. Aquatic weeds of common occurrence in undrainable ponds are grouped in the following Table.



Common Aquatic Weeds in Underainable Ponds

Table 20

Groups of commonly occurring aquatic weeds, algal bloom and algal mats in un-drainable ponds

(Aquatic weeds, algal bloom and algal mats)

Groups	Scientific name	Common name
Floating	*Eichhornia crassipes*	Water hyacinth
	Pistia stratiotes	Water lettuce
	Salvinia cucullata	Water fern
	Spirodela polyrrhiza	Duck weed
	Lemna minor	Duck weed
Emergent	*Nymphea mexicana*	Banana water lily
	Nymphea tuberosa	Fragrant water lily
	Nelumbo spp.	Lotus
	Nymphoides spp.	Floating heart
Submerged	*Hydrilla verticillata*	Hydrilla
	Najas marina/minor	Najas
	Potamogeton crispus	Curly leaf pondweed
	Vallisneria spiralis	Eel grass
	Ottelia spp.	
Marginal	*Ipomea aquatica*	Ipomea
	Jussiaea spp.	Water primrose
	Typha angustata	Cat-tails
	Cyperus spp.	Cyperus
Algal blooms	*Microcystis aeruginosa*	Microcystis
	Anabaena	Blue green algae
Algal mats	Pithophora	Horse hair clump
	Spirogyra	Filamentous algae

Control measures for all the above mentioned classes of weeds and blooms fall into four major categories, viz. preventive, manual and mechanical, chemical and biological. Any of these methods or at times a combination of methods may be taken up depending on the nature of infestation, pond condition, cost involvement and availability of required inputs.

Preventive control

Taking into consideration the high cost of controlling aquatic weeds, certain preventive measures are to be followed to reduce the chances of their infestation.

The preventive measures have to be taken well in advance. The measures include trimming of pond margins, dewatering and desilting of old ponds, uprooting or burning of dried marginal weeds during the summer and providing barriers to prevent the entry of floating weeds.

Manual and mechanical control

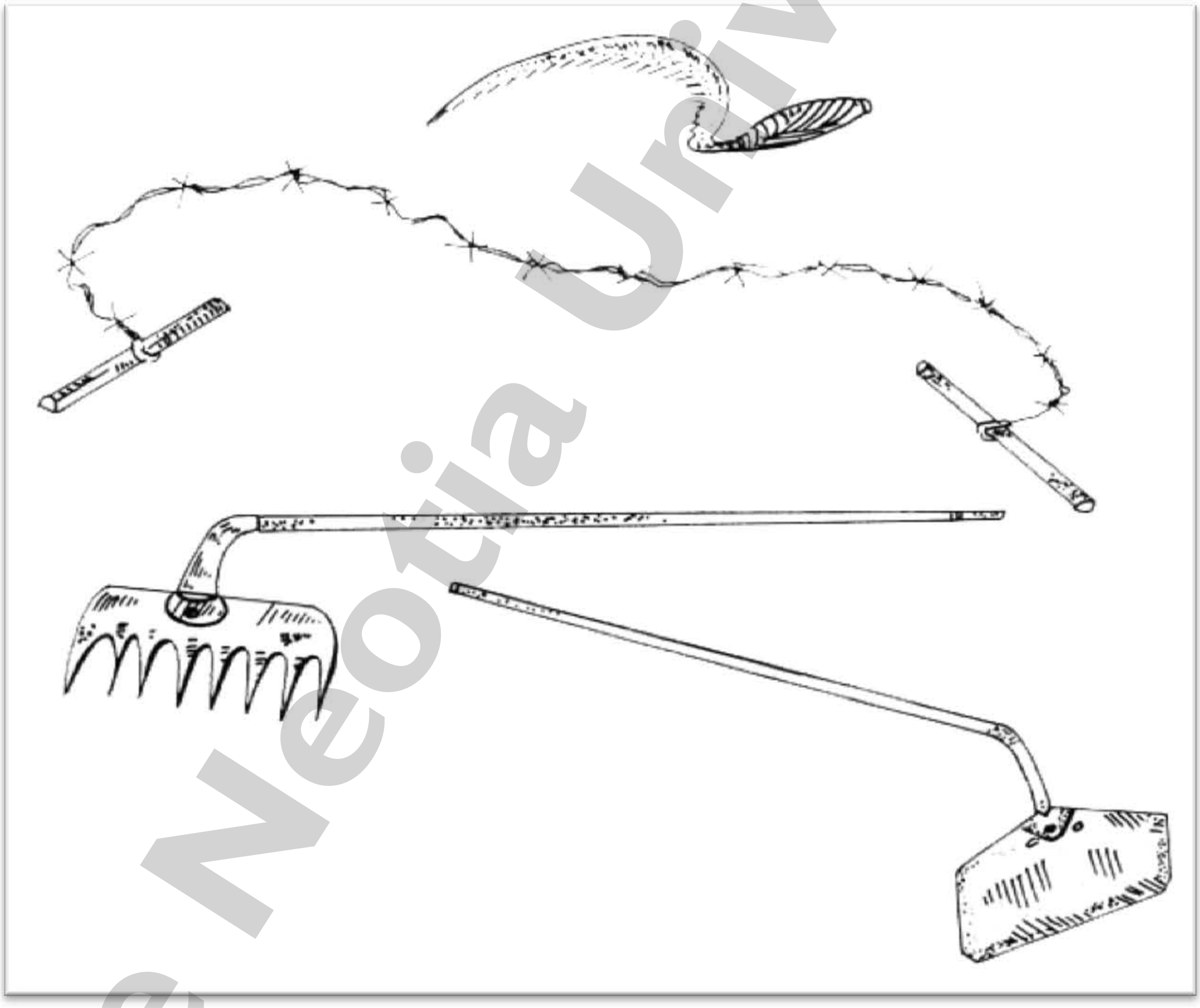
Manual removal of aquatic weeds is an age-old practice and holds good even today in rural areas. The free floating groups of weeds are either hand picked or dragged by wire or strong coir rope nets. In bigger ponds they should be removed part by part from the marginal areas and finally the centrally located weed mass is dragged towards the banks and lifted out. Certain small and light floating weeds such as spirodela, lemna, azolla, wolffia, etc., are easily skimmed out by twisted straw ropes or fine meshed nets. The manual removal of submerged weeds from a heavily infested water body is relatively much more difficult. They are either pulled by hand or hand-drawn bottom rakes or uprooted with bamboo poles having a cross piece tied strongly at the terminal end. Repeated cutting of the aerial shoots and leaves of rooted emergent plants are also useful. Implements used for manual control are mostly hand scythes for cutting, and hand forks, strong nets and bamboo poles with terminal cross piece for twisting and uprooting.

Mechanical devices used for clearance of rooted submerged weeds are steel cables, cutting chains and diesel operated winches (Mitra, 1956).

Chemical control

The manual removal of weeds from heavily infested large water bodies is difficult and time consuming. Under such conditions certain commercially available chemicals (herbicides) can provide an efficient means of eradication of undesirable aquatic plants. Total kill and disintegration of weeds can be achieved by this method ensuring full return of the nutrients back to pond soil and water for production of natural fish food. As a matter of fact there is not a single chemical known so far which can eradicate all types of weed infestation. Therefore, one must know the weeds and its species, appropriate herbicide and its rate and time of treatment. In larger ponds where dense infestation covers a substantial portion of the water, the herbicide should be applied part by part if the pond is already stocked with fish. As discussed earlier most herbicides are selective in nature and when applied to a mixed population of weeds, growth of some tolerant weeds may be encouraged at the cost of susceptible ones; likewise, when surface or floating weeds are destroyed, the submerged weeds develop. Under such conditions subsequent application of appropriate herbicide should be taken up.

Floating weeds: Water hyacinth is one of the most important weeds of this group. Depending on its degree of infestation, they are categorized in three groups, viz. small, medium and big, based on their wet weight per unit area. The recommended doses of the herbicide 2–4-D are 2,7 and 12 kg/ha for small (13 kg/m^2), medium (23 kg/m^2) and big (35 kg/m^2) (Ramchandran, 1969; Patnaik and Das, 1983). Addition of a detergent (0.2 % concentration) to the aqueous solution gives better results. The dilution for better coverage has been estimated at 400 l/ha. The foliar spray (spraying over the leaves) is undertaken with the help of a foot pump/hand pump sprayer with a three-action nozzle. Field application of herbicide, especially towards the interior of thick water hyacinth infestation, is a difficult task. In such cases a pair of stout bamboo poles should be laid on the top of the infestations so that the operators can walk over them. Normally, the complete kill of plants takes around 25 days. This chemical is available in two suitable forms as sodium and amine salt.



Hand tools Used for Manual Control of Aquatic Weeds

Water lettuce which often causes a serious problem in fish ponds can be controlled with 0.1–0.2 kg of paraquat/ha. This infestation could also be controlled by foliar spray of aquous ammonia (1%) at the rate of 50–75 kg/ha along with 0.2 % of any commercially available detergent as a wetting agent.

The aqueous ammonia is broadcast as foliar spray over the infestation with a foot pump sprayer and a small funnel–shaped sprinkler 3–4 cm in diameter, provided with 10 pin-sized holes pierced on the diaphragm covering the mouth of the funnel. The stem of the sprinkler is connected to the sprayer through a 30 m long polyethene tube, so that the sprayer is kept on the shore and only the sprinkler is taken inside the infested area in a boat.

The area to be treated inthe field is divided into small plots (20–30 m^2size) and solution is sprayed at the rate of 5 000 1/ha.

Salvinia forms a thick surface mat in ponds and can be conveniently controlled by the application of foliar spray of paraquat at the rate of 1 kg/ha. Usually it takes 30–40 days for the weeds to be killed and settled in the pond.

Smaller floating weeds, e.g. Spirodela, Lemna and Azolla can also be cleared with 0.1 kg/ha of paraquat.

Emergent weeds: Water lily, lotus, and floating heart can be cleared by spraying the herbicide 2–4-D at the rate of 8–10 kg/ha with detergent (0.25%). The chemical is diluted at the rate of 300 l/ha and sprayed through a footpump sprayer.

Submergedweeds: Ottelia, Vallisneria, Hydrilla, Najas, Potamogeton and Ceratophyllum can be controlled by paraquat at the rate of 3–4 ppm within two weeks. It can also be controlled by application of anhydrous ammonia at the rate of 15–20 ppm.

Marginal weeds: Ipomea, Jussiaea, etc., could be controlled by spraying the herbicide 2–4-D at the rate of 8 kg/ha.

Algal blooms and mats: Due to overdose of fertilizers or enrichment of the water through treated sewage or agricultural fertilizer, the minute algal cells multiply fast turning the pond water bright green or sometimes brickred. Some of the more harmful blooming algae are microcystis, anabaena and euglena. A number of chemicals have been employed to control these algal blooms. Copper sulphate is perhaps the oldest and a very widely used algicide. The recommended doses are 0.2 to 1.0 ppm, but it is not very effective in ponds having high pH (pH above 8.6), Microcystis bloom is cleared with 0.3 to 0.5 ppm of Diuron. Simazine also clears the bloom in 16–20 days and the rate of application is 0.3–0.5 ppm. Both the chemicals do not have harmful effect on fish. It has been observed that the sudden kill of blooms is likely to cause oxygen depletion which might cause mortality of fish. In order to avoid this a prophylactic dose of diuron (0.1 ppm) should be applied in the very early stage of bloom development. Usually the chemical is sprayed over the affected portions of the ponds. The common mat forming algae which occur in fish ponds are Spirogyra, Pithophora, Oedogonium and Cladophora. Although repeated netting can reduce the infestation to a considerable extent in nursery and rearing ponds, application of Diuron at the rate of 0.3–0.5 ppm is recommended. Various chemicals and the dose of application is summerised in the ready reckoner given below.

Biological control of aquatic weeds

Another important controlling method is by introduction of weed-eating fishes. Common carp, gourami, tilapia, pearl spot, the grass carp and a species of puntius are the fishes of known weed-eating habits (Table 22).

Grass carp is the most effective biological control agent against most of the submerged and floating weeds except the water ferns. Grass carp normally consumes choiced aquatic weeds, at least 50% of their body weight in a day. About 300–400 fish, each of about 0.5 kg weight, are enough to clear 1 ha of Hydrilla infested water body in about a month. Normally Hydrilla infestation density ranges from 5–25 kg/m^2 (Alikunhi and Sukumaran, 1964).

Eradication of unwanted fish

Predatory fish prey upon the spawn, fry and fingerlings of carps and the weed fish compete with carp for food, space and oxygen. Therefore predatory and weed fish should be completely eradicated from nursery, rearing and stocking ponds before these ponds are stocked. The commonly encountered predatory and weed fish in undrainable ponds are listed below.

Absolute removal of these unwanted fish by thorough and repeated netting is not possible and hence dewatering and poisoning the pond are the only alternative methods. If situation permits, dewatering should be the preference as it ensures complete eradication of unwanted fishes and disinfects the pond bottom. Dewatering also offers the opportunity to desilt the pond bottom. However, where it is not possible, which is true in most situations, the pond should be treated with fish poison. From an economic point of view the poisoning should be done during pre-monsoon season when the water level is usually low, requiring the minimum quantity of poison material. The date of poisoning, however, should be fixed about three weeks before the anticipated date of stocking. Seasonal ponds which dry up during summer months need not be treated with fish toxicants.

Ready reckoner for chemical control of aquatic weeds

	Weeds	Herbicide	Brand name	Dose	Additives
1.	Water hyacinth pistia and other floating weed	2–4–D (sodium salt/amine salt)	Taficide Hexamar Fernoxone	2–12 kg/ha	0.1–0.2% detergents
2.	Lotus, water lily trapa, etc.	-do-	-do-	8–10 kg/ha	0.25% detergent
3.	Marginal weeds	-do-	-do-	8 kg/ha	0.25% detergent
4.	Salvinia	Paraquat	Gramoxone	1.0 kg/ha	-

5.	Pistia,spirodela lemna, azolla, etc.	-do-	-do-	0.1–0.2 kg/ha	0.1% detergent
6.	Submerged weeds (Ottelia, vallisneria, hydrilla, najas, potamogeton, ceretophyllum, etc.)	-do-	-do-	4 ppm	-
7.	Pistia	Aquous ammonia	Dry ammonia gas	50–70 kg/ha	0.2% detergent
8.	Submerged weeds	Anhydrous ammonia	Dry amomia gas	15–20 ppm	-
9.	Rooted submerged weeds	Copper sulphate	-	35 kg/ha	-
10.	Algal blooms/mats	Copper sulphate	–	0.2–1.0 ppm (not very affective at high pH	-
		Simazine	-	0.3–0.5 ppm	-
		Diuron	Karmex	0.3–0.5 ppm	–

Common weed eating fish and the weeds of their preference		
Fishes	**Names**	**Feed upon**
Common carp	Cyprinus carpio	Tender shoots
Gaurami	Osphronemus goramy	Tender shoots of submerged weeds and filamentous algae
Pearl spot	Etroplus suratensis	Filamentous algae
Grass carp	Ctenopharyngodon idella	Submerged weeds e.g Hydrilla Najas, Ceratophyllum, Potamogeton, Ottelia and duck weeds
Silver carp	Hypophthalmichthys molitrix	Algal bloom

Common predatory and weed fish of undrainable ponds	
Predatory fish	**Weed fish**
Channa spp.	Puntius spp.
Clarias batrachus	Oxygaster spp.
Heteropneustes fossilis	Gudusia chapra
Pangasius pangasius	Amblypharyngodon mola
Mystus spp.	Laubuca spp.
Ompok spp.	Esomus danricus
Wallago attu	Osteobrama cotio
Glossogobius giuris	
Mastocembelus spp.	
Amphipnous cuchia	

Fish toxicants

Although a number of chemicals and plant derivatives are available in the market which are poisonous for fish, only a limited number of such toxicants are safe and suitable for fish culture purposes. Based upon the following criteria a suitable fish poison is selected.

- Poisoned fish should be safe for human consumption
- Least adverse effect on the pond biota
- Toxicity period should be of short duration
- Should not have residual effect
- Easy commercial availability
- Simplicity of application
- Cost considerations.

Mohua oil cake, bleachng powder and ammonia are considered suitable.

Application of toxicants in ponds

Mohua oilcake: Of all the fish poisons of plant origin, the most extensively used fish toxicant in undrainable ponds is oil cake of Mohua (Basia latifolia). It kills all the fish species within a few hours when applied at the rate of 250 ppm (CIFRI, 1968). It contains about 4–6% of active ingredient, the saponia, which on dissolving in water haemolyses the red blood cells and thus kills the fish (Bhatia, 1970). The required quantity of mohua oilcake should be soaked in water and uniformly broadcast over the entire pond surface. Following this operation, repeated netting should be done to ensure proper mixing of the poison and removing the affected fishes which are suitable for human consumption. The toxicity of doses up to 250 ppm lasts for about 96 hours (Jhingran and Pullin, 1985) and subsequently it serves as organic manure in the pond. It should be applied at least two weeks before stocking the ponds.

Bleaching powder: Bleaching powder or Calcium hypochlorite ($CaOCl^2$) is another practical and safe fish toxicant. It kills all the predatory and weed fish of the pond when applied at the rate of 25–30 ppm (Tripathy et al., 1980). However, during storage, significant chlorine content is lost and hence it is always safer to use the commercially available bleaching powder at the rate of 35–50 ppm or 350–500 kg/ha/m of water. Fish kill occurs within 1–3 hours and the toxicity lasts for 3–5 days. Plankton and benthic fauna start developing from the 7th or 8th day after treatment. Chlorine content of the bleaching powder thoroughly disinfects the pond which is essential in undrainable ponds where disinfection by sun drying is not at all possible. Disinfection of the pond is one of the essential measures for maintaining proper health condition of the fish. Besides, it also satisfies the lime requirement of the pond soil.

The method of application is also relatively simple. The powder is mixed with water and uniformly spread over the entire water surface. Distressed and dead fish are removed by netting. Chlorine killed fish are safe for human consumption.

Ammonia: Anhydrous ammonia when applied at the rate of 20–25 ppm kills the predatory and weed fishes. Besides, it also controls the aquatic weeds and later acts as nitrogenous fertilizer. Toxicity of ammonia lasts for 4–6 weeks.

Details of doses for commonly used fish toxicants are summerised in the following table.

Recommended doses of fish poison

Poison	Dose (kg/ha/m)
Bleaching powder	350 – 500
Mohua oil cake	2 500
Anhydrous ammonia	20 – 30
Powdered seed of Croton tiglium	30 – 50
Root powder of Milletia pachycarpa	40 – 50
Seed powder of Milletia piecidia	40 – 50
Seed powder of Barringtonia acutangula	150

Seed meal of tamarind (Tamarindus indica)	1 750 –2 000
Tea seed cake (Camellia sinensis)	750

The nursery ponds require subsequent poisoning for selective killing of the larger planktonic copepods. These copepods are predatory in nature and instead of serving as food for the delicate spawn and early fry, they attack and prey upon them resulting in poor survival. For this reason 4–5 days prior to stocking of spawn, the pond should be treated with malathion at the rate of 0.25 ppm (active ingredient) for selective killing of the planktonic copepods. This treatment significantly increases the survival in nursery ponds (Kumar et al., 1986). Such treatment is not required in rearing and stocking ponds.

Calculation of dose

The required quantity of poison can be calculated using the following formulae.

For rectangular ponds:

$$\frac{\text{Length (m)} \times \text{width (m)} \times \text{average depth (m)} \times \text{dose (ppm)}}{1\ 000}$$

= Required amount of poison in kg.

For circular ponds:

$$\frac{3.143 \times \text{square of pond radius (m)} \times \text{average depth (m)} \times \text{dose (ppm)}}{1\ 000}$$

= Required amount of poison in kg.

Eradication of predatory insects

Many aquatic insects in their larval and/or adult stages, prey upon fish hatchlings and fry and also compete with them for food. The common insect predators are beetles, bugs and dragonfly nymphs (Fig. 36). Among beetles, diving beetle (Cybister), water scavenger beetle (Sternolophus) and whirling beetle (Gyrinus) are more dangerous forms. Back swimmers (Anisops) appear in swarms in manured ponds during rainy season and cause heavy damage. Other predatory members of this group are water scorpion (Laccotrephes), giant water bug (Belostoma) and water stick insect (Ranatra). Dragonfly nymphs are highly predatory on carp spawn.

Proper prepration of nursery ponds for stocking with spawn thus also aims at total eradication of such predatory insects. The basic method is to apply a thin oily film over the pond surface which chokes the respiratory tubes of aquatic insects. The spawn and fish food organisms remain unaffected. Some of the common treatment methods are presented in the following table.

Pond treatment methods for eradication of predatory aquatic insects	
Treatment method	**Dose/ha**
Soap oil emulsion	56 kg vegetable oil + 18 kg soap
Diesel oil	50 – 60 1
Kerosene oil	80 – 100 1
Turpentine oil	75 1
Diesel emulsifier	Diesel 50 1 * emulsifier 37.5 ml + water 2 1.

Except for soap-oil emulsion other mixtures or emulsion are easily prepared by simple mixing. For making soap-oil emulsion, the soap is mixed with oil and gently heated for some time with vigorous stirring. These emulsions are applied by spraying over the pond surface about 12–24 hours prior to stocking of spawn. It is the film of the emulsion which is important and hence care is taken not to disturb the film for a few hours. Windy days should be avoided as it will break the film.

Malathion application in nursery ponds also controls the predatory insects population and hence subsequent treatment for control of insect is not required. However, if swarms of these predatory insects are seen in the nursery pond, treatment should be applied immediately.

Fertilization of ponds

Fertilization schedule involving both organic and inorganic fertilizers starts 10–15 days prior to stocking and is prepared on the basis of nutrient status and chemical environment of the pond soil and water.

Basis of fertilization

In undrainable ponds where the frequent change of water is a remote possibility, the physico-chemical properties of pond water governing the biological production cycle are more or less a reflection of the bottom soil. The organic and mineral constituents of the soil play their part in releasing the required nutrients into water for pond productivity through chemical/biological processes. Pond bottom soil also provides suitable substrates and necessary environment for the microbial decomposers - the living fertilizer factory of the pond. Thus it is the soil condition and its nutrient status that forms the basis of pond fertilization by using either organic manure or inorganic fertilizer or a combination of both. Important characteristics of pond soil which influence fertilizer use is briefly described here.

Texture of the soil: The texture of pond soil, i.e. mechanical composition of the soil comprising sand, silt and clay and organic matter content, basically influences the economy of both inherent and added nutrients. Sandy and very clayey soil are not desirable as in the former the nutrients are lost due to heavy leaching; while in the latter, due to high adsorption capacity, the nutrients from the water are trapped. Clay minerals and organic matter of the bottom mud are both colloidal in nature and thus exhibit colloidal properties like adsorption and cation exchange phenomenon. Sandy soils, on the other hand are low in colloidal substances and also deficient in organic humus. These are important considerations for deciding the application of fertilizers and manures.

Soil pH: As in water, pH of soil is also one of the critical factors affecting pond productivity. Under anaerobic condition the decomposition of organic matter is slow and the products of decompositions are mainly reduced compounds and short chain fatty acids thus making the soil strongly acidic. Soil pH also influences transformation of phosphorus into available forms and controls the adsorption and release of essential nutrients at the soil-water interface. Both for soil and water a slightly alkaline pH is considered favourable for fish ponds.

Availability of essential mineral nutrients such as phosphate, nitrogen, potassium, carbon and calcium is a consideration which determines the quality and quantity of fertilizers to be applied. Nitrogen is required in large quantities as it is the basic and primary constituent of protein and chlorophyll. Although, phosphorus is required in a small quantity compared to nitrogen, it is considered as the single critical element for maintaining aquatic productivity. Banerjee (1967) classified the undrainable ponds into low, medium and highly productive groups, on the basis of their nutrient status considering mainly nitrogen, phosphate and organic carbon.

Fertilization schedule

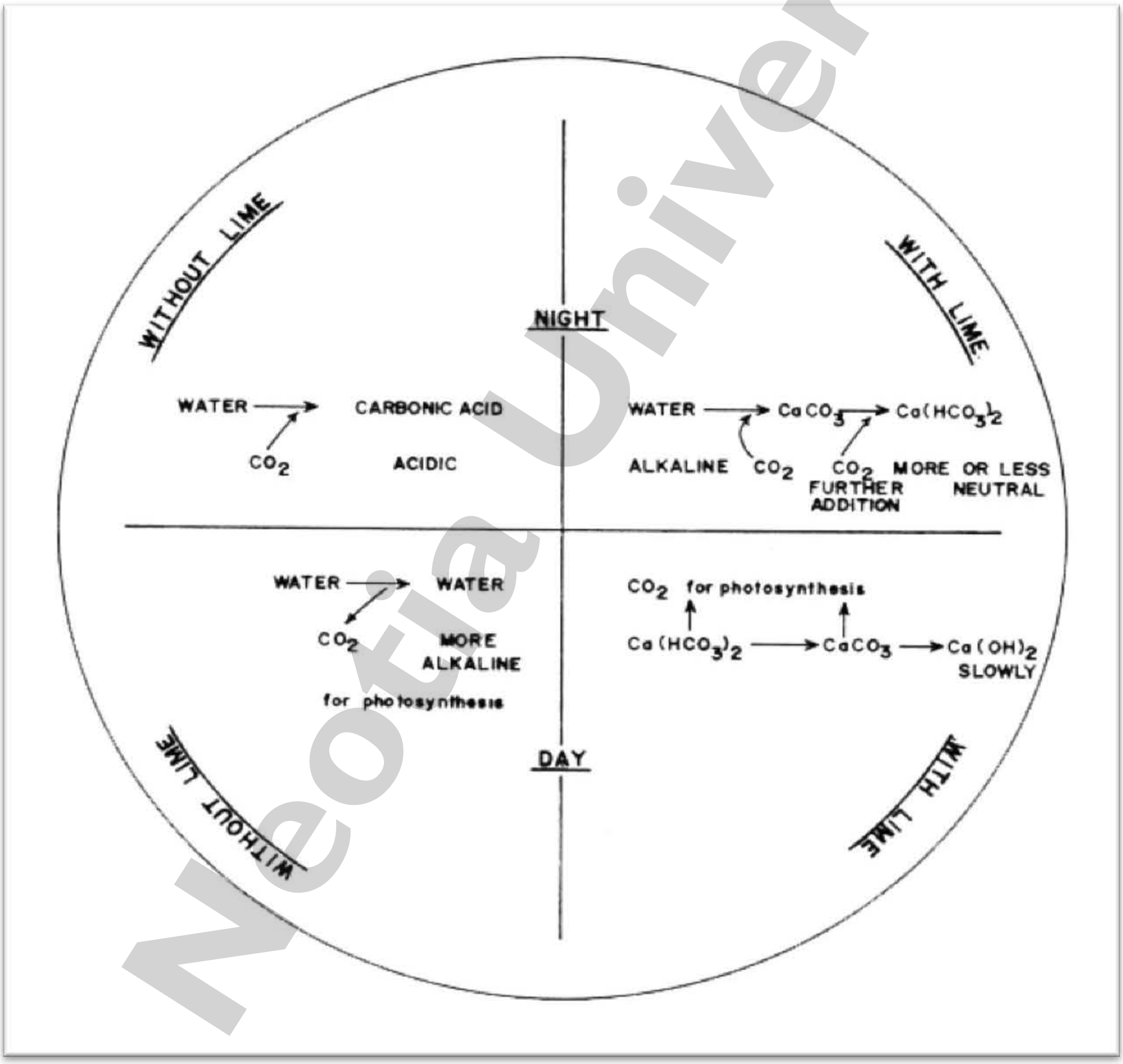
Proper analysis of soil and water is essential before deciding on the fertilization schedule.

Nutrient status of high, medium and low productive ponds

		Available nutrients		
Productivity level	**pH**	**N(mg/1000 g soil)**	**P_2O_5 (mg/1000 g soil**	**Organic carbon (%)**
High	6.6 – 7.5	50 or more	6 – 12	1.5 or more
Medium	5.5 – 6.5	25 – 49	3 – 5	0.5 – 1.4
Low	Below 5.5	Less than 25	Less than 3	Less than 0.5

Liming: Diurnal changes in pH values ranging from pH 5 during the night and pH 11 during the day due to community respiration and photo-synthesis is a common experience but such wide variations impose stressful conditions for the fish. An adequate level of calcium in the pond provides a buffering system as shown in Figure 37.

Liming helps to raise the total alkalinity level and consequently the reserve CO_2 will increase the availability of carbon for photosynthesis by raising the bicarbonate concentration in water. This raised level of reserve CO_2 will also prevent biological decalcification.



Mechanism of Buffering Action of Line

Depending on the pH of the soil, the dose of the liming should be Adjusted as per the following table (Table 27). Alkalinity can also be used as an indicator of the need for lime in fish ponds.

The total dose of lime calculated as per the table, need not be applied at one time. It may be divided into 3–4 doses and the first dose may be applied about a week prior to the manuring of the pond. It helps in faster mineralisation of organic matter in the pond sediment and acts as a prophylactic agent as well. The same dose is applicable for nursery, rearing and stocking ponds. However, as and when needed during the culture period, additional doses of lime can also be applied.

Requirement of lime for different types of pond soils		
Soil pH	**Soil type**	**Requirement of lime(kg/ha)**
4.0 – 4.9	Highly acidic	2 000
5.0 – 6.4	Moderately acidic	1 000
6.5 – 7.4	Near neutral	500
7.5 – 8.4	Mildly alkaline	200
8.5 – 9.5	Highly alkaline	Nil

Manuring: Organic manuring besides being important as means of adding the nutrients, is also equally important for improving the soil texture. A combination of organic manures and inorganic fertilizers is considered more effective than using either of these alone. However, in nursery ponds, use of mineral fertilizers is not recommended as the application may cause blooms of algae which may persist and may harm the young fry. Cow dung at an initial dose of 10 000 kg/ha may be applied in the nursery ponds about two weeks prior to anticipated stocking. If the pond is poisoned by mahua oil cake, then the dose should be restricted to 5 000 kg/ha. If two or more crops of fry are to be produced during the season from the same nursery ponds, then the pond should be fertilized with 2 000 kg/ha of cattle dung about a week before each subsequent stocking. In case of poultry manure the dose should be only 33% of the cattle dung. Rearing ponds are initially manured with the raw cattle dung about two weeks prior to stocking. The rate of application is between 5 000 – 7 000 kg/ha in 5 instalments. If the pond is treated with mohua oil cake then the dose of organic manuring is reduced to half. Dose of inorganic fertilizers may be regulated as per pond soil productivity determined by detailed analyses. In the absence of soil testing facilities a general recommendation should be followed. In such cases inorganic fertilizers are applied at the rate of urea 140 kg/ha and triple superphosphate 60 kg/ha in 4–5 instalments.

In stocking ponds a combination of organic and inorganic fertilizers is considered more effective. Initial manuring with organic manure at the rate of 20% of the total requirement is done 15 days prior to stocking and the remaining 80% of the organic manure is applied in 11 equál monthly instalments during the rearing period. However, if mohua oil cake is applied earlier, the initial manuring is not essential.

The total quantity of inorganic fertilizers to be applied is decided according to soil type and applied in equal monthly instalments. The monthly instalments of organic and inorganic fertilizers are applied alternately allowing a gap of a fortnight between the two applications. Nitrogenous fertilizers are selected on the basis of soil pH.

Amount of fertilizers required for ponds having high, medium and low levels of productivity			
Pond productivity levels			
	High	**Medium**	**Low**
Rate of application of fertilizer (kg/hg/y)			
Cattle dung	5 000–8 000	8 000–10 000	10 000–25 000
Urea (43–45%)	112–155	156–225	226–260
Ammonium sulphate (20.5%)	225–330	-	-
Calcium ammonium nitrate (20.5%)	-	350–500	501–650
Single super phosphate (16–20%)	156–219	220–315	316–405
Triple super phosphate (40–45%)	54–75	76–110	111–145

In the absence of proper soil testing facilities fertilization schedule in stocking ponds may be followed as per the following table.

Generalized fertilization schedule for stocking ponds (CIFRI, 1985)			
	Item	**Quantity (kg/ha)**	**Periodicity of application**
A.	Cattle dung	2 000	Initial dose
	Cattle dung	1 000	Monthly
B.	Urea (pH 6.5–7.5) or	25	Monthly
	Ammonium sulphate (pH above 7.5) or	30	Monthly
	Calcium ammonium nitrate (pH 5.5–6.5)	30	Monthly

C.	Single super phosphate or	20	Monthly
	Triple super phosphate	8	Monthly

Video Link:

https://www.youtube.com/watch?v=tQzBrTsUuEs&ab_channel=Biolearnia

7. Practices of Pond Management (Stocking Management).

Stocking

Complete detoxification of the piscicide applied earlier should be ensured before stocking the nursery, rearing and stocking ponds. One or two days prior to stocking, a hapa should be fixed in the pond and some stocking materials should be put inside the hapa. Absence of distress and mortality after 24 hours confirm complete detoxification and the pond should be regarded as ready for stocking.

Stocking of nursery ponds

Carp spawn requires natural feed immediately after stocking and hence it is essential to have a minimum plankton value of 30–40 ml/m^3 in case of stocking at a moderate rate (1.5–2.5 million/ha). When a higher stocking rate is to be adopted, plankton population is also required to be increased accordingly. In case the stocking density is over 5 million/ha, the plankton volume should be around 100 ml/m^3.

Self-produced or procured 3–4 days old spawn should be stocked in the morning at the rate of 4–6 million/ha. The stocking density must be according to the condition of the pond and the amount of fish food organisms available. The rate of stocking in a well prepared nursery pond with adequate fish food organisms can be as high as 10 million/ha. However, the survival level decreases with the increase in stocking density (Sen, 1976).

Survival of carp fry at various stocking densities

Survival level (%)	Stocking density (million/ha)
87.3	2.5
74.6	3.75
62.0	6.25
66.2	10.00

Combined rearing of two or more species of spawn should not be done in nursery ponds. The pond should be stocked after three days of hatching when their sizes range from 0.6–0.75 cm and counts on an average about 500 numbers/ml. The required number of spawn are measured with the help of metallic or plastic sieve cups of known volume. Spawn are reared in nursery ponds up to fry stage for about 2–3 weeks when they usually attain 2–3.5 cm in length and 0.15–0.75 g in weight. At higher stocking density the growth is relatively slow. It is possible to raise 3–4 crops of fry from the same pond during the same breeding season and in addition, the pond can also be utilized for rearing of common carp seed during January to March.

Stocking of rearing ponds

Rearing of fry to fingerling stage is done in rearing ponds where fry are stocked at the rate of 0.25–0.30 million/ha with a survival level of 60–80% under proper pond conditions. Either monoculture or polyculture methods can be adopted for this rearing.

In the case of polyculture the species combination and their ratio should be decided on the basis of their habit, feeding, availability of feed, etc. Some of the possible combinations are - catla, rohu, mrigal, common carp (3:4:1:3); silver carp, grass carp (1:1); silver carp, grass carp, common carp (4:3:3); catla, rohu, mrigal, grass carp (4:3:1.5); silver carp, grass carp, common carp, rohu (3:1.5:2.5:3), etc. Combination of too many species should be avoided as it invites excessive handling at the time of harvesting for species segregation. Fry are reared in ponds for about 3 months when they usually attain 100–150 mm in length and 15–40 g in weight. For healthy fry rearing it is recommended that the size of the fry at the time of stocking in the rearing pond should be as uniform as possible. This can be done by size grading at the time of fry harvesting from nursery ponds. Prior to stocking the rearing ponds the pond waters must have a plankton level of about 30–50 ml/m^3.

Stocking of grow-out/stocking ponds

After proper preparation, the pond should be stocked with 100–150 mm long fingerlings of desired carp species. In case the fingerlings are not available, the pond can also be stocked with advanced fry or early fingerlings in absolutely predator-free ponds. The stocking rate depends primarily upon the volume of water and on the oxygen balance of the pond. Quality of available natural fish food in the pond and the capacity of the farmer to provide supplementary feed, are also matters for consideration. Usually a pond having average water depth of 1.5–2.5 m should be stocked at the rate of 5 000 fingerlings/ha. The volume of water available for fish in an undrainable pond should not be less than 2 m^3/fish if there is no provision of artificial aeration. In composite fish culture, rearing of six species of carps, viz. catla (Catla catla), rohu (Labeo rohita), mrigal(Cirrhinus mrigala), silver carp (Hypophthalmichthys molitrix), grass carp (Ctenopharyngodon idella) and common carp (Cyprinus carpio) is considered to be the ideal combination. However, depending on the availability of quality fingerlings of these carp species, three or four species combinations can also be taken up. Ratio of different species in the combination is also equally important. However, there are certain general guidelines for selecting species combinations.

Different species combinations and their stocking ratios for composite fish culture

Species combination	Surface feeder		Column feeder	Bottom feeder		Macrophyte feeder
	Catla	Silver carp	Rohu	Mrigal	Common carp	Grass carp
3	40	-	30	30	-	-
4	30–40	-	20–30*	15–20	20–25	-
6	10–15	20–30	15–30*	15–20	20–25	5–15

* Lower units in shallow ponds

Availability of weed in the pond or in the vicinity decides the stocking density of grass carp. In older ponds where the soft sediment layer of the pond bottom is usually very thick and anaerobic in nature, the ratio of bottom feeder and especially the common carp should be kept at a higher level. Likewise, the relative density of column feeder-rohu should be kept on the high side in deeper ponds than in shallower ponds, whereas ponds showing consistently higher zooplankton population should have a higher ratio of surface feeders. Based on the performance of individual species in the combination and availability of seed, combinations can be modified in subsequent years. Silver carp, however, should be stocked 1 or 2 months later. Interspecies competition for food between catla and silver carp to some extent is the key point for such differential stocking. The stocking pond also should have a desired level of plankton population of about 30–50 ml/m^3.

Method of stocking

Stocking of spawn, fry and fingerlings should be done very carefully to avoid any post-stocking mortality due to shock or infections. To minimize post-stocking mortality the fry/fingerlings should be slowly and gradually acclimatized to the temperature and quality of the water in the stocking pond. To do so, open the mouth of the seed transport bag/container and gradually add the pond water in phases and after 15–20 minutes slowly dip and tilt the bag/container in the pond so that the spawn/fry/fingerlings are free to swim out. Stocking should preferably be done in the cool evening hours. Apply prophylactic treatment to seed prior to their release so as to avoid any post-stocking infections.

8. Practices of Pond Management (Post-Stocking Management).

Post-stocking management

Post-stocking management involves harnessing the pond productivity in the form of natural fish food, maintenance of pond environment congenial to the cultivated fish and fish husandry, mainly feeding and health care.

Feeding

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 broadcoast on the pond surface in the form of fine powder daily in the morning hours at prescribed rates.

Rates of daily supplementary feeding at various stages of culture

Stage	Daily feeding rate
Spawn to fry	4–8 times of the initial body weight
Fry to fingerlings	50–100% of the initial body weight
Growers	1 – 2%
Brood fish	1 – 3%

The following schedule of feeding should be followed for nursery ponds.

Feeding schedule for nursery ponds

Period (Day from the date of stocking)	Rate of feeding	Amount of feed for 0.1 million of spawn
1 – 5	4 times the total initial weight	560 g/day
6 – 12	8 times the total initial weight	1 120 g/day
13	No feed	-
14	Harvesting	

At the time of stocking, the spawn of 0.65–0.75 cm average length weigh about 0.0014 g each, and a mixed collection of 0.1 million weigh about 140 g.

Grass carp is fed its preferred aquatic vegetation or green animal fodder as per the following table.

Feed for grass carp during various stages of life cycle	
Stage	**Feed**
Fry (1.7 – 3.9 cm)	Soft macrophytes such as Azolla, Wolffia, Lemna and Spirodella, etc.
Fingerlings (4.0 – 15.0 cm)	Hydrilla, Ceratophyllum, Vallisneria, Najas, Chara, etc., in addition to those mentioned above.
Juveniles/Adults (above 15.0 cm)	In addition to above, green animal fodder such as barseem, napier, hybrid napier, elephant grass, tender leaves of vegetables and trees such as soobabul, drumstick, etc.

Feeding Enclosure for Grass Carp

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 (Fig. 33B). 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 (Fig. 39), 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.

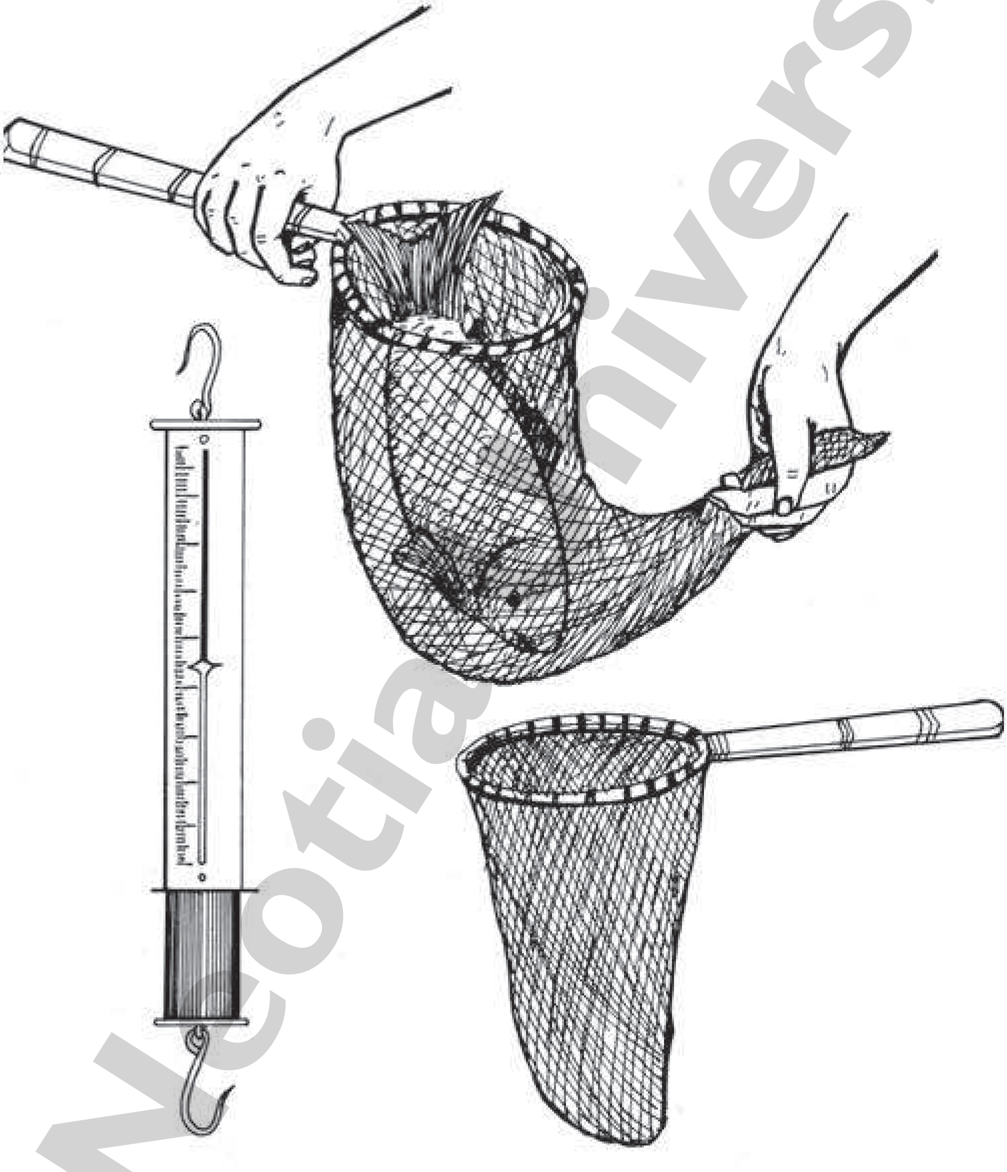
Data sheet for monthly netting

Species stocked	Av. wt. of 10 fish (g)					Av. wt. of this month(g)	Av. wt. of last month(g)	Monthly growth (g)	No. of fish stocked	Total estimated crop (kg)
	1	2	3	4	5					
	(Samples)									
Catla	11000	11000	11500	11250	11750	1 110	1 025	85	150	166.500
Rohu	6000	7000	7500	7000	7500	700	650	50	200	140.000
Mrigal	9000	9500	9000	9500	9100	922	850	72	200	184.400
Silver carp	22000	22750	22500	22500	22250	2 240	2 000	240	150	336.000
Grass carp	50000	50500	50000	45500	48000	4 880	4 300	580	100	458.000
Common carp	12000	12600	12000	12500	12500	1 232	1 150	82	200	246.400
	Estimated total standing crop									1531.300
Amount of feed to be applied daily at the rate of 2% body weight										30.6 kg

Av. wt. - Average weight

Periodic fertilization

The next step in post-stocking management is the periodic fertilization which ensures replenishment of nutrients and consolidation of the energy base for microbial decomposition activities. The desired total quantity of fertilizers are best applied in small equal doses at periodical instalments throughout the rearing period so as to ensure maximum utilization of these fertilizers. The mode, sequence and timing of application of fertilizers are important or achieving best results. Lime should be applied first followed by the organic manure and finally the inorganic fertilizers an the same order is followed subsequently. These fertilizers should be applied only when the physical conditions of the water are most suitable such as plenty of sunlight, adequate oxygen, optimum temperature, adequate water level and low wind velocity. Turbid water with a high content of suspended solids are not preferred. Fertilizer should be sprayed or distributed properly over the water surface during the day time when the top layer of water is warmer and lighter. Inorganic fertilizer application must be stopped temporarily when the nitrate and phosphate content of water show a level of 0.5 ppm or above at any stage during the periodic pond environment monitoring. Similarly, organic manuring may also be stopped if the soil organic carbon level goes beyond 2%. However, normal application may be resumed after the specific nutrient level goes down. Care should be taken to see that the phosphatic fertilizers dissolve properly in the water since powdered orgranular fertilizer may often solidify after coming in contact with water. It is more effective if doses are divided further so that application is more frequent. The results are encouraging when organic manures are applied in daily doses in pons. The desired amount of cattle dung is mixed with water and uniformly spread over the entire pond surface. In nursery ponds the first manuring is done two weeks prior to stocking and if more than one crop is nursed, fresh manuring should be done a week prior to every subsequent stocking.



Hand Net and Spring Balance

A periodical fertilization schedule is summarized in Table below.

Periodicity of fertilization in nursery, rearing and stocking ponds

Ponds	Manure	Periodicity
Nursery ponds	Organic manure	3 weeks
Rearing ponds	Organic manure and Inorganic fertilizer	3 weeks - daily

Stocking ponds	Organic manure and Inorganic fertilizer	Monthly

Pond environmental monitoring

Parameters to be monitored

It is essential for extension workers to name and code-number the ponds in their area. Such coding may be based either on postal district/unit/village farmer's name, etc. The fish farmer should record the following information on his fish farm:

Nature of pond: Perennial or seasonal; nursery pond, rearing pond or stocking pond.

Water area: Measurement of the water area is essential in order to know the size of the pond for proper fish stocking and quantifying the production processes. This can be done easily with the help of a bamboo pole of known length.

Age: Age is one of the most important parameters, since it has direct relevance with the productivity of the pond which usually varies from one year to several hundred years.

Management: Management status should record the existing management techniques and its level (intensive or extensive). The species of fish present, details of culture activities, stocking structure and density, fertilization, feeding, harvesting, marketing, etc, need to be recorded. To obtain qualified data on the organic carbon and biogenic nutrient load it is necessary to know the number of livestock and human population associated with the particular pond.

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 trophic 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 can be measured with a 4–5 m long bamboo pole fitted at its base with a wooden disc of 25 cm dia.

Soft sediment depth: A soft sediment layer is usually present in the pond bottom. The depth of this layer can be measured with a 6–8 m long bamboo pole having a wooden disc of 10 cm dia at its base.

Solid sediment depth: In older ponds, in addition to the soft sediment layer, a solid sediment layer with a low water content is also present. The thickness of the layer can be measured with a 6–8 m long bamboo pole with a sharp end. The total thickness of the soft plus solid sediment layers has a direct relation to the age of the fish pond, at times the sediment layer measures more than 2 m. Such thick sediment, having a rich nutrient content, is anaerobic in nature with slow bacterial decomposition and mineral cycling rates. This should be properly utilized for fish culture.

Chemical environment in the water column: The water is chemically characterized by pH, alkalinity, NH_4-N, NO_3N and PO_4-P measurements following standard methods. Normally the pH and alkalinity do not change from pond to pond on the same types of maternal soil. The measurements of NH_4-N, NCO_3-N and PO_4-P indicate the basic inorganic nutrient status of the pond.' Simple chemical parameters such as dissolved oxygen and pH may be measured using field kits. Slightly alkaline water (pH 7.0–8.5) and oxygen levels of 6–9 ppm indicate optimum condition.

Dawn 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. Desirable ranges of various pond environment parameters are presented in.

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

A simple schedule for monitoring the important parameters is presented.

Environmental monitoring schedule

		Periodicity				
	Parameters	**Daily**	**Weekly**	**Fortnightly**	**Monthly**	**Quarterly**
A.	**Water**					
	Water colour	x	-	-	-	-
	Transparency	-	x	-	-	-
	Temperature	x	-	-	-	-
	Depth	-	-	-	x	-
	pH	-	x	-	-	-
	Free CO_2	-	x	-	-	-
	Alkalinity: Total	-	-	x	-	-

	Bicarbonate	-	-	x	-	-
	Dawn Dissolved O_2	x	-	-		-
	NH_4-N	-	-	-	x	-
	NO_3-N	-	-	-	x	-
	PO_4-P	-	-	-	x	-
B.	**Soil**					
	Sediment depth	-	-	-	-	x
	pH	-	-	-	x	-
	Organic carbon	-	-	-	-	x
	Total nitrogen	-	-	-	-	x
	Total PO_4-P	-	-	-	-	x

Video Link:

https://www.youtube.com/watch?v=tQzBrTsUuEs&ab_channel=Biolearnia

9. Practices of Pond Management (Fish Health Management).

Fish health monitoring

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. The approach to health care in composite fish culture in undrainable ponds is essentially one of management of ecosystem and fish husbandry.

Host-pathogen-environment linkage

Susceptible fish, the virulent pathogen and the aquatic environment in which they encounter each other are the three contributing factors in fish disease outbreaks (Snieszko, 1974). The fish itself possess a varied and complex defense system, the immune system, the potency of which determines the susceptibility or resistance to the particular pathogen under a particular circumstance. Several environmental components effectively influence the normal immune mechansim of the fish when their value exceeds the normal tolerance limits. A virulent pathogen, when present in the surrounding, is usually capable of causing an infectious disease to fish under stress. The causative agents of the disease and their fish hosts carry on their struggle in the aquatic environment and the environmental parameters which influence this encounter may shift the balance from one side to the other and often determine whether the host will overcome the infection or the pathogen will flourish (Fig. 40).

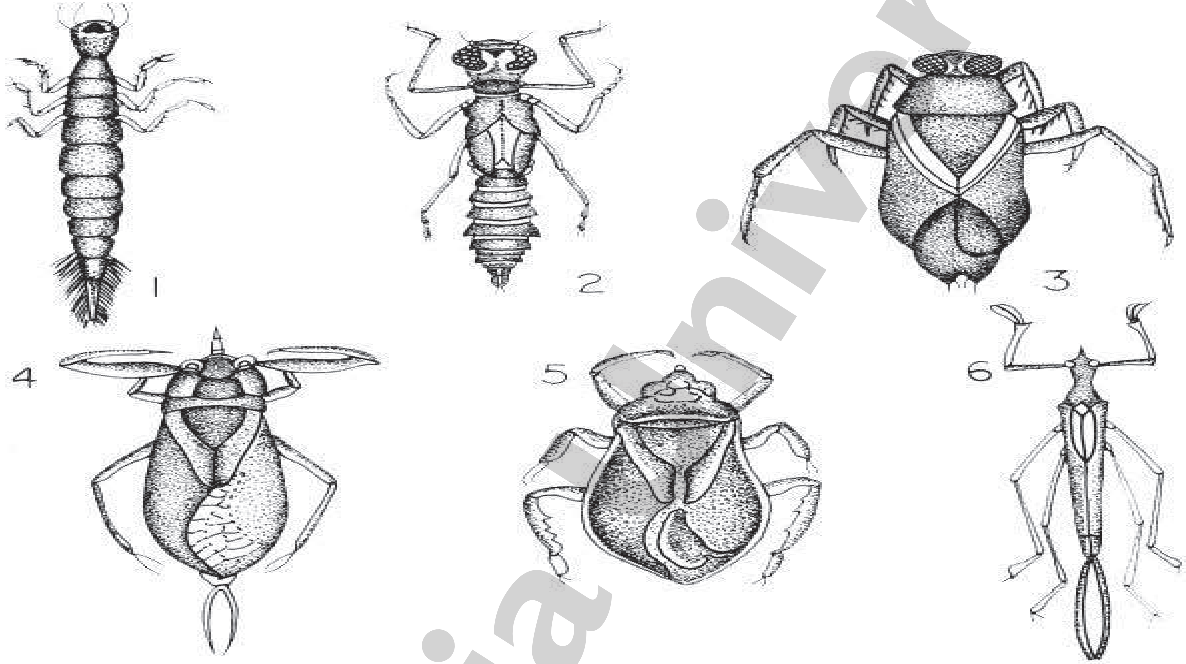
Some of the infectious and parasitic agents can survive only in live fish, and in such cases the disease transmission is from fish to fish. Such disease-producing agents are true pathogens. Others are extremely adaptable organisms which can survive outside the fish and cause infections whenever fish are weakened or otherwise predisposed to disease due to environmental stress. Most of the fish disease agents belong to this category.

Health monitoring programme

Health protection of cultured fish is considered to be one of the most important aspects of modern aquaculture systems including the composite fish culture which requires a programme basically to check the health status of the fish quite frequently and employment of fish health management measures. This enables timely detection of any disease outbreak and taking up proper treatment measures at the initial stage. Otherwise, in advanced stages of the disease, control and treatment measures do not provide economical and effective.

A fish health monitoring programme should consist of the following components:

i. Daily observation of fish in each pond.
ii. Sampling and examination of fish at regular intervals for health check and diagnosis of the disease if any.
iii. Monitoring of pond quality and sanitation.
iv. Sampling and examination of fish at the onset of distress, disease outbreak or mortality.



1. Cybister Larva 2. Anisoptera nymph 3. Nototecta 4. Nepa 5. Belostoma 6. Water stick-insect.

Effects of Environmental Changes on Fish-Pathogen Relationship

The sampling for health check of fry and fingerlings should be done at weekly and fortnightly intervals respectively, while in composite fish culture ponds it should be at least once a month. A thorough health check of fry/fingerlings is required 1 or 2 weeks before netting out for stocking in grow-out ponds or before transfer to another pond. Such an examination will provide sufficient information for planning.

Diseased fish may exhibit either or both physical and behavioural signs, the most common of those are listed below:

Behavioural signs:

- slowing down or a complete stoppage of feeding;
- loss of equilibrium, swimming erratically or in spirals;
- surfacing for gulping air and scraping against the floor and sides of the pond.

Clinical symptoms:

- excess mucous secretion;

- change in normal colouration;
- erosion of scales, part of fins, skin, etc.;
- decolouration or paling of gills;
- abdominal swelling;
- bulging of eyes;
- presence of cysts, spots or patches over the body and gills, etc.;
- appearance of lesions, haemorrhagic spots and greyish or brownish areas over the body.

Laboratory examinations:

Methods for diagnosis of commonly occurring diseases of Asiatic carps in undrainable ponds

	Disease agent	Method of examination	Positive indications
A.	**Parasites**		
1.	Protozoa		
	Ichthyophthirius	Microscopy	Pin-head size white spots on the skin, fins and gills. Presence of ciliated trophozoites with relatively large horseshoe shaped nucleus.
	Trichodina	Microscopy	Presence of saucer-shaped actively moving ciliate parasites on body surface and gills.
	Myxozoans	Microscopy	Presence of cysts, spores on gills, body surface and/or in the squash preparations of kidney. spleen, air-bladder, etc.
2.	Crustaceans		
	Argulus	Visual examinations/ microscopy	Haemorrhagic spots, lesions over the body and presence of parasites attached to fish body by means of suckers and hooks.
3.	Flukes		
	Gyrodactylus/ Dactylogyrus	Microscopy	Presence of parasites in gills and skin.
	Diplostomum	Visual examination/ microscopy	Small pigmented black nodules over the body surface
B.	**Fungi**		
1.	Saprolegnia	Microscopy /visual examination	Body lesions associated with small white tufts of hyphae on fins and skin. Infected fish eggs fail to hatch and show presence of fungus mycelium protruding from the egg surface.
2.	Branchiomyces	Microscopy	Decolouration of gills, erosion of lamellae and presence of fungal hyphae in blood vessels.
3.	Achlya	Microscopy	Cottony outgrowths of fungal mycelium over the infected area.
C.	**Bacteria**		
1.	Aeromonas hydro- phila	Culture/microscopy	Dropsy condition and haemorrhages over the body.
2.	Pseudomonas fluodrescens	Culture/microscopy	Clinical condition is usually indistinguishable from that of aeromonas. Haemorrhages over the body.
3.	Flexibacter columnaris	Culture/microscopy	Appearance of external lesions on the body, head region and gill. Lesions initially begin as whitish or brownish patches with reddish zone

			around the periphery.
D.	**Virus**		
1.	Rhabdovirus of common carp	Cell culture/serum neutralization test	Common carp is prone to this disease showing dropsy condition.
2.	Rhabdovirus of grass carp	Cell culture/serum neutralization test	Only grass carp is prone to this disease exhibiting similar dropsy symptoms.

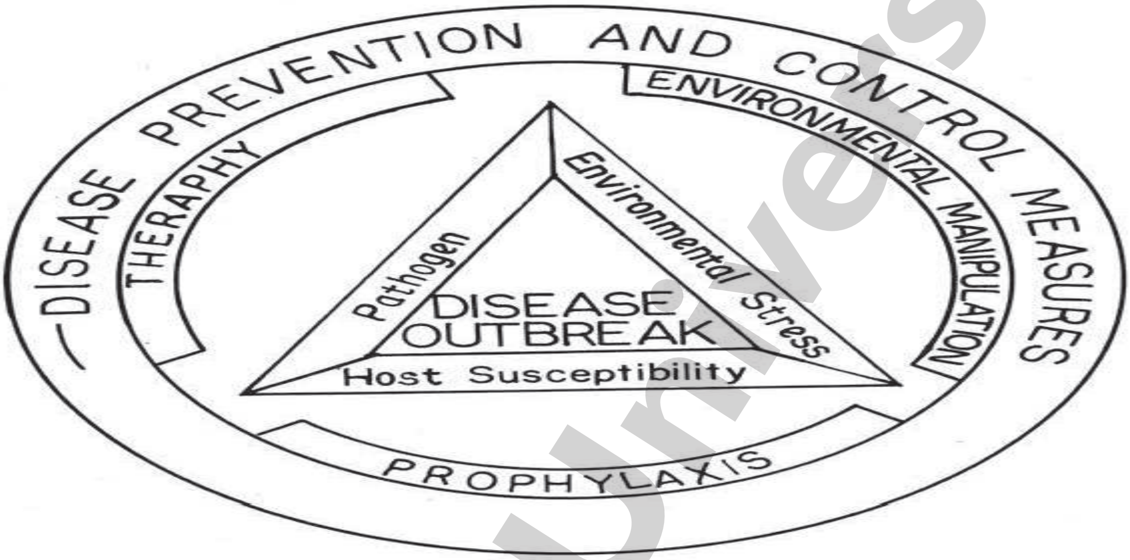
Health management measures

Understanding and managing the undrainable pond environment is the key to successful fish health management and profitable fish culture, and to ensure this the knowledge of the role of various environmental components in the occurrence of disease outbreak is essential. The main thrust of such measures is directed toward:

- minimizing the stress on cultured fish;
- prevention of the introduction of serious disease agents;
- confinement of disease outbreaks to affected areas;
- minimizing losses from disease outbreaks.

The following important measures are the key components of successful fish health managements.

Surveillance and maintenance of water quality: Abrupt and wider fluctuations in some of the environmental parameters such as dissolved oxygen content, pH, turbidity, temperature, additions of some chemicals, detergents, pesticides and naturlaly produced toxic substances such as hydrogen sulfide, ammonia, dinoflagellate toxins, etc., often cause stress in fish and predispose them to infectious diseases. Anything that alters the environment of the fish is a potential stressor and efforts should be made to identify and avoid them. Undrainable ponds



offer great protection against spreading of disease outbreaks by confining the outbreaks only to the affected ponds. However, the recent trends of intensification in aquaculture involve high stocking rates, increased feeding and fertilization programmes resulting in nutrient accumulation leading to appearance of algal blooms that lead to dissolved oxygen and other water quality problems. In older ponds, cases of excessive accumulation of organic matter have been observed, resulting in the appearance of bacterial bloom and related oxygen depletion (Radheyshyam et al.,). For health and optimum growth, the dissolved oxygen level should not drop below 5 mg/1. Carbon dioxide concentration up to 20–30 mg/l may be tolerated by fish provided oxygen is near saturation. At lower levels of dissolved oxygen, toxicity of carbon dioxide increases. When pH values remain above 9.5 or below 6.0 for extended periods, fish will be under stress and may not grow well. Liming agents may be used for low pH corrections. Ammonia concentration above 1.0 mg/1 indicates organic pollution. Hydrogen sulfide toxicity increases with decreasing pH and it is harmful even at 1.0 mg/l concentration level. Making the pond environment more congenial and hygienic, eliminates the risk of stress and provides safety to fish. Proper and timely management of soil and water qualities by manipulating feeding, fertilization, liming, addition of clean water, bottom raking, aeration of water by recirculation or splahsing, etc., reduces most of the environmental problems and provides congenial conditions for the health growth of fish. An interval of about 15 days between the pond poisoning and the stocking eliminates most of the pathogens from the environment.

Model for Integrated Fish Health Management System

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. This avoids any risk of introducing infected stock in the pond. However, the stocking materials should also be prophylactically treated before releasing into the pond (detailed under Chemoprophylaxis).

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.

Minimizing handling stress: The rougher the handling, the greater is the stress and the risk of disease (Kumar et al., 1986). Care should be taken not to break the protective mucous coating of the skin. During summer months netting should always be done early in the morning and it is better to have minimum possible handling during hauling. High temperature during hot water causes increased metabolic activity and induces more stress upon them.

Measures in pond management:

Poisoning of pond - Wild fish population is one of the most potential sources of disease-producing organisms. Use of chlorinated lime (bleaching powder) is the most suitable material for this purpose, since it kills all the wild fish species, molluscs, tadpoles, frogs, crabs, etc., and also disinfects the pond water and soil. It is applied at the rate of 40–50 ppm (Tripathy et al., 1978). Mahua oilcake is also a widely used piscicide, but it fails to disinfect the pond. In nursery and rearing ponds it is desirable to have second poisoning with malathion at the rate of 0.25 ppm 4 or 5 days prior to stocking. It eliminates the larger copepods which do appear in large numbers after organic fertilization. These copepods prey upon young fish larvae and also serve as vectors or carriers of many infectious pathogenic organisms. Some of the common crustacean fish parasites also get killed. Malathion application has significantly increased the survival level in nursery ponds (Kumar et al., 1986).

Disinfection of appliances - All required appliances such as fry carriers, hapas, utensils, buckets, nets and gears, etc., require thorough cleaning and disinfection before being put to use. Some of the pathogenic organisms are found adhering to them and may cause disease if they are allowed to come in contact with the host fish species. Disinfection can be done by washing or immersing in a concentrated solution of disinfectant. Some of the most effective and easily available disinfectants for such use are chlorine, sodium hydroxide, sodium chloride potassium permanganate, etc. Chlorine is probably the most widely used disinfectant in fishery management and is easily available as a solution of sodium hypochlorite and powder of calcium hypochlorite (bleaching powder). Solution of 1–2% chlorine is active against bacteria, viruses and fungi but is extremely toxic to fish and hence their residues must be thoroughly rinsed from the disinfected items before being brought into contact with fish. Sun drying of nets, hapas, etc., is also a practical method of disinfection.

Proper feeding - In addition to the natural fish food which is made available by fertilization, an adequate amount of good quality supplementary feed is essential for maintaining healthy growth of fish. Any deficiency in quantity and quality of feed may cause various diseases by increasing susceptibility to many infections.

Prevention of entry of unwanted fish: Most undrainable ponds lack proper embankments. Most of these ponds have channels in the embankments connecting them with outside waters during the rainy season. Most of the ponds lack even proper embankments. These channels are the vulnerable sites through which some of the wild unwanted fish species or other animals get entry to the pond. Fixing fine meshed screen into these channels may eliminate the risk of entry of unwanted fish species into the pond. Pond embankments may also be raised to prevent risk of inundation and entry of undesirable animals and fish species. Some fish eating birds, molluscs, etc., serve as intermediate hosts for many parasites that infect fish. Tadpoles and frogs may also act as carriers of certain parasites and bacteria which ultimately may infect carp species and hence such animals should not be allowed in the pond.

Separation of young and brood fish: Brood fish may serve as carriers of disease causing organisms without exhibiting any clinical symptoms. They sometimes become survivors of previous epizootics due to built up immunity but retain some of the pathogens. To avoid such risk, the best course is to separate the young ones from the adults.

Removal of dead fish from the pond: Dead and apparently sick fish should be removed. A daily log of losses must be kept. Such records will provide valuable insight into the problems and may lead to their solution.

Holding the fish in a hand net and dipping it into a concentrated solution of the drug for one minute or less is used as prophylactic treatment in case of mild diseases. A short bath is useful when facilities for a rapid flow of water are available. Water flow is stopped and relatively high concentration of the drug is added. Exposure time should not be longer than one hour. A long bath is a very effective method for prophylactic treatment of pond fish for external parasites. The oral route is used in prophylactic treatment to prevent certain infections. It is generally conceded that feeding medicated feed to fish is a prophylactic rather than a curative measure.

Prophylactic use of streptomycin and penicillin at the rate of 25 mg of streptomycin sulphate and 20 000 I.U. of penicillin has been found to be very effective in preventing outbreak of columnaris disease in rohu in a field-oriented experiment (Kumar et al., 1986). Feeding antibiotics with feed has successfully prevented the occurrece of CE (Carp Erythrodermatics) in European carp culture. Prophylactic treatment of pond with locally available organophosphorous insecticide (malathion) at the rate of 0.25 ppm of active ingredient successfully prevents occurrence of trematode and copepod infections.

Occasional application of potassium permanganate at the rate of 2 or 3 ppm is recommended for increasing dissolved oxygen concentration and hauling prophylaxis. Dip treatment in 500–1 000 ppm solution of potassium permanganate for a few seconds before releasing adult fishin ponds is also a very effective and practical prophylactic measure. Short bath for a few minutes in 2 or 3% common salt solution is also a safe and inexpensive prophylactic measure against a wide range of parasitic an microbial pathogens.

Immunoprophylaxis

Immunization is becoming one of the most important ways of preventing communicable diseases in animals, including fish. Several commercial vaccines are now available and being used in many developed countries. Vaccines for some of the bacterial diseases of carps which do occur in undrainable pond culture systems are also available. These vaccines are against Aeromonas hydrophila and Flexibacter columnaris. Viral vaccine against Spring Viremia of Carp (SVC) is also being used on a commercial scale very successfully.

10. Growth studies in aquaculture system (Otolith Microstructure).

The determination of fish age and growth is fundamental in fisheries biology and management. Such age-determined parameters as mortality and growth underlie the population dynamics models used in fishery analyses. Age studies can furnish other basic data such as stock age structure, age at first maturity, spawning frequency, individual and stock responses to changes in the habitat, recruitment success, etc. Age and growth data also permit the determination of population changes due to fishing rates.

Age can be determined by one or more of the following methods.

- Anatomical method: counting the regular growth marks formed in hard tissues such as scales, otoliths, vertebrae, spines and tail bones.
- Length-frequency analysis: monitoring the progression through time of the identifiable modes in size classes.
- Direct estimate: through direct measurements of growth rate of specific specimens extrapolated to the stock as a whole. Marking and subsequent recapture of fish, or monitoring the growth of captive fish of known age are two direct estimation methods.

The deposition of annual growth rings (annulae) in the calcified tissues of bony fishes is at least partly caused by seasonal changes in the environment. These periodic changes (temperature cycles, available food) are less regular and less severe in tropical than in temperate zones. Several authors do, however, mention the presence of annual growth rings in tropical fish otoliths (Poinsard and Troadec, 1966; Quasim, 1973; Manooch III, 1987). The causes of this cyclical annual growth are unclear: some authors link them to spawning periods and others to water temperature changes. As annual growth rings are present in immature fish, ring formation probably follows an internal rate of growth synchronized to seasonal environmental variations.

These anatomical methods make it relatively easy to determine age and growth (Bagenal and Tesch, 1978; Casselman, 1983; Beamish and McFarlane, 1987). Nonetheless, annulae and growth studies cannot assume specific periodicity in growth marks, and so this must be determined for each age class of the stock studied (Beamish and McFarlane, 1983).

The right method to apply in each case will depend on the available data and the characteristics of the population under study, plus technical and cost factors (Mathews, 1987; Gulland, 1987). Additional time and experienced, expert staff will be needed for the interpretation of the otoliths (Williams and Bedford, 1974), whereas length analyses are based on rather easily obtained data which can be quickly processed. The evaluation of the relative cost of each method should, however, bear in mind the degree of precision of the findings (Gulland, 1987).

The relative uncertainty inherent in all growth determination methods suggests the use of two independent techniques to confirm the findings. The use of length-frequency analyses and the simultaneous interpretation of growth marks probably offers the best results. The international ICLARM/KSIR meeting on the theory and application of stock assessment methods based on length-frequency analyses, which was held in 1985 (Pauly, 1987), concluded that length-frequency analyses methods are made much more precise by the inclusion of information on growth obtained through the use of an independent method, usually based on otolith reading (Morgan, 1987).

OTOLITH MICROSTRUCTURE

Bony fish otoliths are complex polycrystalline bodies which act as organs of balance in the inner ear (Carlstrom, 1963; Gauldie, 1988). The otoliths are primarily composed of crystallized calcium carbonate in the form of aragonite and of a fibrous, collagen-like protein: otoline (Degens et al., 1969; Morales-Nin, 1986 a; 1986 b). Partly or wholly abnormal otoliths made up of calcite are relatively common (Morales-Nin, 1985 a). These crystalline otoliths are transparent and lack clearly defined growth marks.

The otolith grows by the surface deposition of materials, a cyclical process dependent on internal calcium metabolism rates (Simkiss, 1974) and on amino-acid synthesis. The result is the formation of daily growth increments in the otolith, made up of a continuous or incremental unit, and a check unit (Pannella, 1971; 1974; Dunkelberguer et al., 1980). The incremental zone is made up of needle-like aragonite microcrystals surrounded by the organic matrix and laid down across the surface of the otolith. The check zone or unit is mainly made up of concentric shells of organic matter (Mugiya et al., 1981; Watabe et al., 1982; Morales-Nin, 1986 b).

The thickness of the increments and density of the microcrystals depends on the stage of growth (Irie, 1960). In active periods of growth, for example, the increments are thick with well-developed check units and in slow periods the increments are finer and the microcrystals more compact and continuous. Often, there are two or more sub-increments, probably caused by migrations, feeding rates (Pannella, 1974; 1980) and temperature changes (Brothers, 1978; Pannella, 1980; Campana, 1983; Campana and Neilson, 1982; Geffen, 1982, 1983), etc.

As bodily growth and otolith growth are closely linked, the increment thickness will reflect the rate of growth, recording periods of environmental and physiological stress and growth fluctuations caused by age-linked metabolic slowdown (Gutiérrez and Morales-Nin, 1986). Bodily growth and otolith growth do in some cases, however, appear to occur independently (Wright et al., 1990).

The daily deposition of increments depends on circadian endocrine rhythms which are synchronized at an early age with photo-periodicity or other external daily factors (Tanaka et al., 1981; Radtke and Dean, 1982; Campana and Nielson, 1985).

In addition to age determination, increments have been used to validate annulae periodicity (Pannella, 1980; Victor and Brothers, 1982), to determine changes in growth (Gutiérrez and Morales-Nin, 1986), to detect life transitions (Radtke, 1984), to estimate recruitment and mortality (Methot, 1981, 1983; Robertson et al., 1988; Thomas, 1983) and in taxonomic studies.

OTOLITH REMOVAL AND STORAGE

Otolith selection and removal

The otoliths must be removed as soon as the fish dies, barring which the fish must be frozen or duly fixed to avoid the loss of the growth structures present in the otoliths. Larvae and juveniles must be handled with great care, because the area to otolith volume ratio makes them much more susceptible to deterioration.

Being calcified, otoliths are broken down by acid fixatives such as formalin. The pH of buffered formalin can vary over time and it should therefore be used only for short periods. The fixative which produces the best results is ethanol, which should be used in a concentrated, 85 percent solution to compensate for dilution by the passage of bodily fluids into the storage medium. The alcohol should be changed from time to time for better storage. The addition of marble chips to the fixative will stabilize pH and improve otolith storage (Brothers, 1987).

Freezing is a good storage method where there is no risk of partial thawing due to temperature changes, which would degrade otolith quality.

The sagittal otolith is the one most commonly used, although some studies have employed the lapilli, which is smaller and requires less preparation (Brothers, 1987). In ageing, the same type of otolith must always be used as increment growth is not simultaneous in the three pairs of otoliths.

Both left and right otoliths of each fish should be collected and kept separate until their morphology can be differentiated (Hecht, 1978). The growth rings are usually identical in both otoliths: if one has been damaged during handling, or is crystalline, the other can be used.

To remove otoliths

The cranium must be sectioned to reach the chambers of the inner ear.

Cranial shape is filogenetic and therefore the removal technique must be modified to suit the species studied (Holden and Raitt, 1975).

In round fish a transversal cut is usually made in the head a little behind the eyes.

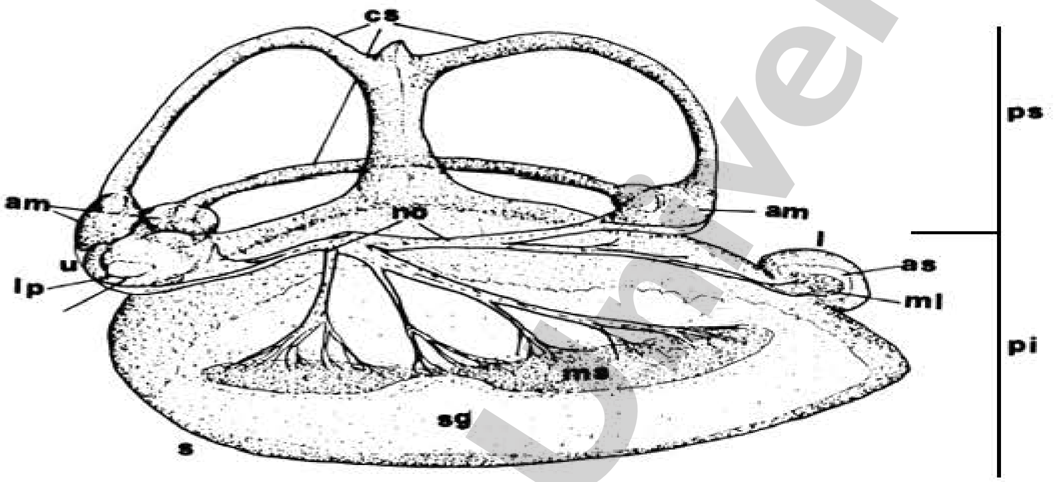
The cut must be deep enough to open the skull without damaging the otoliths.

When the saccule is exposed the otoliths are withdrawn carefully with forceps so as not to break them.

With small otoliths, it is better to remove the semicircular canals and separate the otoliths under a binocular microscope.

Any adhering tissue can be removed from the otoliths by rubbing them gently between the fingers or with tweezers under a magnifying glass.

Immersion in a five percent sodium hypochlorite solution facilitates the cleaning operation.



Transverse section of right inner ear. am: ampulla, as: asterion, cs: semicircular canals, l: lagena, lp: lapillus, ml: macula lagenae, ms: macula sacculi, mu: macula utriculi, no: auditory nerve, pi: pars inferior, ps: pars superior, s: saccula, sg: sagitta, u: utricle.

Otolith storage and preservation

The otoliths must be stored in such a way as to ensure they occupy the minimum space, save money, and are well-preserved and easy to identify. As otoliths are acellular bodies with a small proportion of organic matter, the risk of decomposition is minimal. Growth structures are nonetheless more easily visible in newly collected otoliths. They should therefore be read as quickly as possible.

Otoliths can be stored in test-tubes or vials, dry or with a clarifying liquid when they are to be read immediately. Another method in use is to stick them with transparent nail varnish to a slide or with two-sided sticky tape to a sheet of acetate. The more sturdy otoliths are usually stored dry in properly labelled envelopes.

Morphometric measurements

The otoliths must be weighed and measured before preparation, in order to determine the fish size/otolith measurement ratio. First determine otolith orientation using the standard terminology to describe the exact location of the measurements.

The most frequent measurements are length (from rostrum to postrostrum) and maximum width, perpendicular to otolith length. When the central focus of the otolith is visible, other measurements are possible, such as radius (from the focus to the postrostrum) distance to the antirostrum, etc. Do not use broken or altered otoliths for morphometry.

Very small otoliths must be measured under the microscope using millimetre grids. Larger ones (> 1 cm) can be measured with calipers. All otoliths must be measured without changing their axial inclination: the small, fragile, edge markings which may be broken should not be counted.

Image analysis is a technique which provides objective data on otolith dimensions, allowing length, width and area to be calculated (Lombarte, 1990). The image is acquired through a high resolution television camera coupled to a computer, and transformed and analysed through image analysis. The stages of the process are:

The real image, caught by the camera, is transformed into an analog image which is digitalized by an analog transformer and real-time image processor. The digital image is composed of pixels: pixel size and light level determine image quality.

The real size of the digitalized sagitta is determined by calibration and calculation of the pixel equivalent in mm. Lastly, image analysis produces the biometric measurements of area, perimeter, length and height. Using these data as a basis, biodimensional morphometric measurements or the implied functions can be plotted to determine growth (Berman et al., 1984), differentiate populations or determine otolith biometry (Lombarte, 1990).

To avoid possible errors in weight caused by changes in moisture content (Pawson, 1990), the otoliths should be dried in a moderate oven (80°) until the weight remains constant. The otoliths are then kept in a dryer until it is time to weigh them.

Sectioning

Cross-sections are necessary to study increment sequence in the otolith. Sections across the various planes of the otolith can be cut or polished. All sections must be taken across the nucleus to avoid missing part of the increment sequence.

The orientation of the section is important as many otoliths grow asymmetrically. In sagitta with preferential growth in the internal or sulcal phase, transverse and diagonal cross-sections are recommended. In otoliths with preferential longitudinal growth, the transverse sections may contain many growth checks, and therefore the frontal sections are to be used. In beginning the study of a species, otolith sections representative of the size range must be prepared, and the most suitable section plane determined.

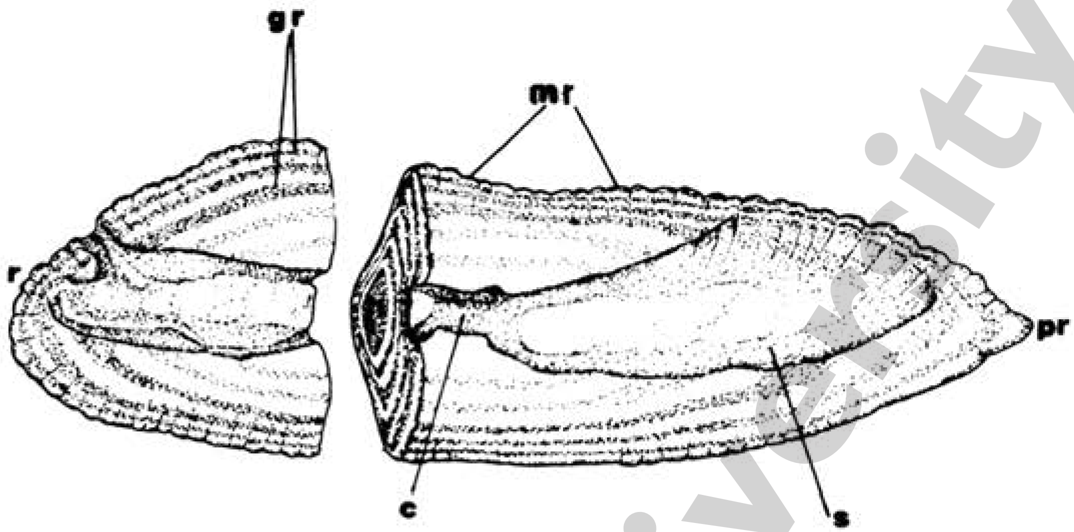


Diagram showing the transverse section of the sagitta and its principal parts. r: rostrum, s: sulcus, c: collum, n: nucleus, pr: postrostrum, mr: dorsal crests, gr: annulae.

Ageing by reading annulae

Many authors have reported the presence of seasonal growth rings (annulae) in tropical fish otoliths (Brothers, 1979; 1982; Sainbury and Whitelaw, 1984; Samuel et al., 1985) although ring deposition in some species is irregular (Mathews, 1974). Once the annual ring periodicity has been determined, age reading is rather simple.

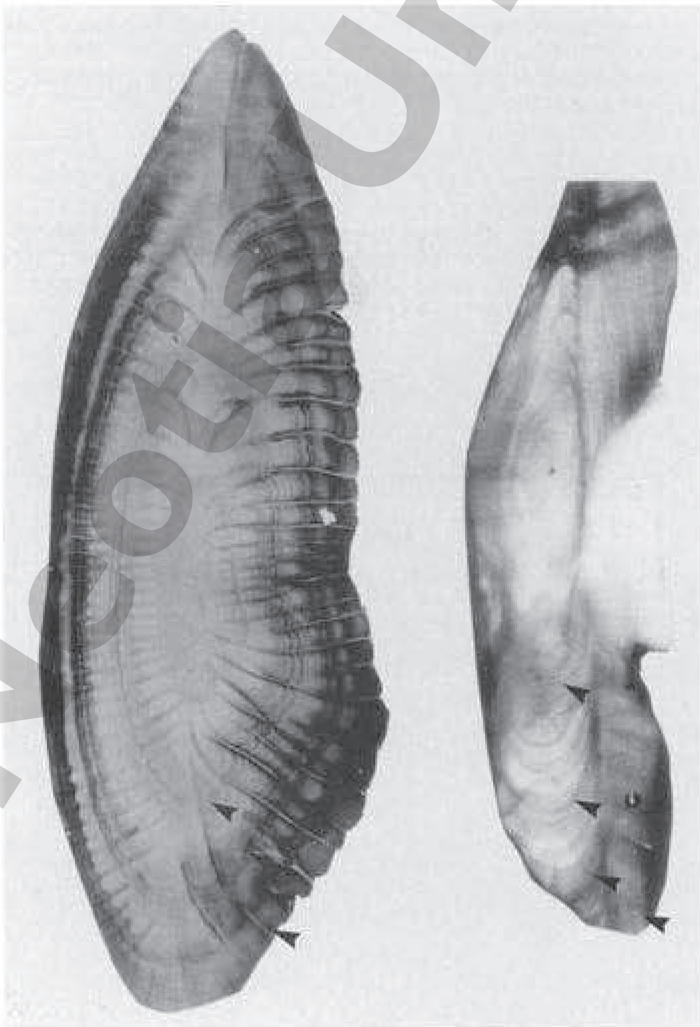
Otolith rings in tropical species are rather less clearly defined than in cold-water fish: the predominance of transparent zones requires methods which can bring out the contrast between the opaque and the hyaline rings. For interpretation, the otoliths can be immersed in a dense clarifying liquid (clove oil, liquid paraffin, glycerine) in a dark container. Reflected light and a binocular microscope are used for the reading. Slow growth rings will appear dark through the dark transparent background of the container, whereas fast or opaque growth rings will appear light under reflected light. Move the light focus and alter the positioning of the otoliths to help differentiate the growth rings: avoid fixed mounting media which will not let you touch the otoliths.

Thick, opaque otoliths can be interpreted after they have been left for some time in a clarifying liquid such as water or glycerine. The otoliths can be positioned in numbered ice-cube trays containing the liquid selected and left to clarify. The time depends on the species but 12–24 hours is enough for most. Another technique is to heighten the contrast between the growth rings by burning the otoliths (Christensen, 1964). The slow, hyaline growth rings which contain more protein (Casselman, 1974) acquire a darker, caramelized tone when burned. The otolith is burned on a metal sheet under a low flame (Bunsen burner) or in an oven at 100°C. Burning time depends on otolith size and flame heat. The process must be carefully monitored to avoid burning the otolith and thereby losing it. The otoliths may be stained with a protein-affinity dye.

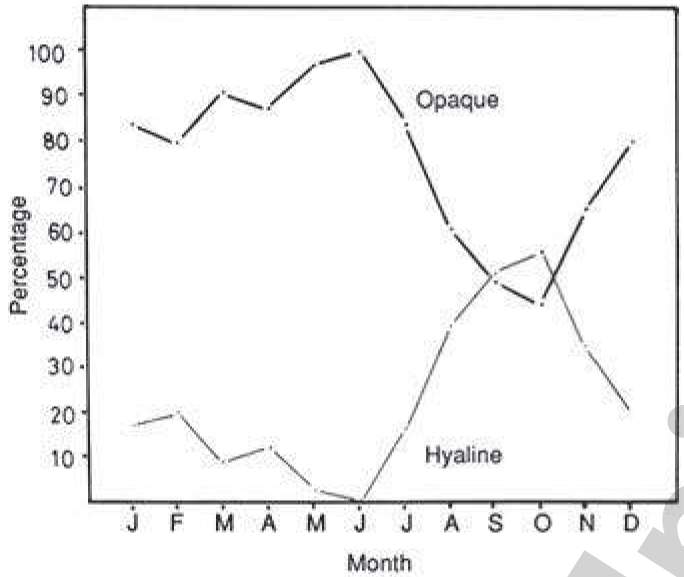
If necessary, otoliths can be polished or sliced to read the macrostructural growth pattern. Generally speaking, fish which reach a great age and grow slowly can be aged more precisely in sections than by reading the whole otolith. Reading whole otoliths for young specimens and sections for larger fish can facilitate the study and produce good results.

Ring periodicity can be read by following the progression of the rings formed on the edge of the otolith throughout the year. A graph of the monthly percentage of otoliths with opaque and hyaline borders will show the ring deposition period. In the case of annual formation, one maximum per year will be found for each type of ring (Fig. 9).

Once the daily periodicity of the increments has been determined for a species, the number of annulae increment components can be used to determine how frequently these growth structures form. When the number of increments in one opaque ring and one hyaline ring does not differ significantly from 365, annulae formation can be considered to be annual. This method is applicable even when daily increment periodicity has not been determined to obtain an approximation of annulae periodicity. In this case, however, the results obtained must be validated by other methods.



Sagitta of Merluccius capensis showing seasonal growth rings. The slow (hyaline) growth rings appear darker (arrows) under incidental lighting. In the upper part of the figure there is a cross-section of the otolith. Note the numerous false (non-seasonal) rings which form in this species.



Yearly variation of the percentage of otoliths with a rapid (opaque) growth ring on the edge.

After measuring the distance from the nucleus to each ring, ring distances can be plotted for each age group. This will give a unimodal distribution in approximately the same places for each of the growth rings when ring formation is regular and corresponds to a seasonal growth pattern common to the stock (Manooch III, 1987; Taubert and Coble, 1977).

After counting the rings and determining their annual periodicity, the age has been established. A fish's age is the interval between birth up to a given point in time, usually capture. The age class or annual group is determined from the birthday. The birthday of a given fish is unknown and therefore arbitrary birthdays are used for an entire stock based on maximum spawning or other decisive factors in recruitment. The standard birthday in the northern hemisphere is 1 January and in the southern 1 July. Other dates can be used as convenient, however.

Video Link:

https://www.youtube.com/watch?v=oLAtJXa6sKc&ab_channel=FishingintotheFuture

11. Growth studies in aquaculture system (Length- Frequency Analysis)

ESTIMATING GROWTH BY LENGTH-FREQUENCY ANALYSIS

The length distribution in a sample from a specific population is the product of recruitment, growth, mortality and sampling errors. Annual variations in recruitment and individual variability in growth frequently mask the interpretation of modal classes in length frequency.

These methods are based on the assumption that each modal class in a frequency distribution will correspond to a cohort and represent different age classes determined at regular intervals. The presence of modes in the length distribution depends on the distance between the medians, the extent of the variance, the proportion of each age class in the population and the size of the sample studied (MacDonald and Pitcher, 1979; Fournier, 1983).

Methods of growth determination based on length-frequency analysis can be applied to populations with a markedly seasonal recruitment, where the identity of the year classes is maintained, and when growth is sufficiently swift to avoid excessive superimposition of the lengths of successive age classes.

Gear selectivity can influence the type of length frequency. The smaller lengths, for instance, not fully recruited to the gear, will be under-represented. Selectivity can be corrected by calculating the capture probability (Brey and Pauly, 1986). When the gear is also selective with respect to larger-sized fish, as with trammels and long-lines (Ralston, 1990), it is much harder and sometimes impossible to use methods based on length frequency analysis.

Hosmer (1973) showed that the estimation of the parameters of each age class, such as average length and relative abundance, are enormously facilitated by having separate samples from one or more age class. This author formulated the calculations needed to identify two normal components in the frequency distribution. Based on these original calculations, more general systems were developed for a larger number of components.

A time sequence of length frequency distributions makes it possible to separate age classes which might otherwise be obscured by the super-imposition of frequencies. Changes over time in each cohort can be analysed visually (Petersen, 1891), or by computerized methods developed from Hasselblad (1966), which separate the modal classes of the length-frequency (MacDonald and Pitcher, 1979; Schnute and Fournier, 1980). Pauly and David (1981) analysed the time series, assuming that the mode of each class followed a von Bertalanffy curve (1938; 1957; 1964).

Various approaches have been utilized in the process of selecting modes in a single frequency; graphic methods which determine the area of the cumulative frequency (Cassie

1954; Bhattacharya, 1967) and statistical methods based on maximum likelihood. Growth parameters in the second group can be determined by adapting complex models to length-frequency (Schnute and Fournier, 1980). These hypotheses can be determined and verified when specific characteristics are attributed to the processes (e.g. normal length distribution in each age class) and likelihood functions are maximized.

Assumed growth models can be adjusted by a minimum chi-squared method or other technique to the modal classes observed in the frequency (Pauly, 1984; Pauly and Gaschutz, 1979; Pauly and Morgan, 1985). Recently, Wetherall et al., (1987) developed an ingenious method for calculating Loo and Z/K based on scant length-frequency data.

Joint application of age data and length-frequency

The determination of median lengths and relative abundance in each cohort is more precise when a subsample of age data is available for one or more of the age classes present in the length-frequency (Hosmer, 1973). Given the close correlation of the von Bertalanffy parameters, Loo and K, errors in plotting from the same set of length-frequency data will be avoided by including in the calculation data which is not dependent on growth. Age determination of a length-frequency subsample makes it possible to know the number of age classes in the population and make the calculations more accurate.

MacDonald and Pitcher (1979) stated that the use of age data limits the number of possible components in length distribution and implies adjustments of greater biological significance. Comparably, Morgan (1987) applied age data to improve growth parameters calculated from length-frequency. A modification of Morgan's method was developed by Gayanilo et al (1988).

The necessary age subsample for the application of the above methods can be selected at random from the length-distribution, or by stratified sampling. The catch of most species is made up of various age classes of different abundances, and therefore the size-stratified sample will eliminate the errors introduced by the relative abundance of lengths and will allow more of the bigger fish to be sampled where the superimposition of lengths is greater.

12. Growth studies in aquaculture system (Other Methods)

OTHER GROWTH DETERMINATION METHODS

In vitro growth

Ottaway and Simkiss (1979) and Ottaway (1978) developed a method of incubating scales in vitro with C^{14} marked glycine. The scales must be extracted from live fish and incubated immediately with the glycine at temperatures like those in their habitat. The amount of radioactive glycine fixed by the osteoblasts which remain stuck to the scales by the end of a given period provides a basis for determining the rate of growth.

In normal cells, each cell has a fixed quantity of DNA, regardless of individual physiological condition. NRA present in the cell, on the other hand, is a direct anabolic function. The proportion of DNA and RNA is therefore an indicator of protein synthesis and growth (Bulow, 1987).

Radiometry

This method is based on the radioactive imbalance of the Ra^{226} fixed during otolith formation. The radioactive decay of this element produces Pb^{210}. The proportion of the two isotopes indicates how much time has gone by since the incorporation of the Ra^{226}. The Pb^{210} isotope is appropriate for age determination as its half-life of 22.3 years is comparable to fish longevity (Bennet et al., 1982; Campana et al., 1990).

The method requires species with a long life-span like Sebastes which can reach the age of 80, in which the changes can be evaluated (Bennett et al., 1982).

Lipofucsin analysis

Lipofucsin is a lipopigment which forms increasingly with age in the cytoplasm, and is considered one of the clearest indicators of ageing in post-mytotic cells (Nandy, 1985).

The lipofucsin build-up in krill (Euphasia superba) has been used to determine the age composition of the population (Ettershank, 1985). Its presence in cerebral tissues is a function of age and can be used to determine fish age (Hill and Radtke, 1988; Hill and Womersley, 1991).

Marking and recapture

Growth can be measured directly by capture, marking and subsequent release into the environment (Ikenouye and Masuzawa, 1968). Where a set of initial length values and length at recapture are available, and the time between tagging and recapture is known, then growth can be determined by the method of Gulland and Holt (1959), Ford-Waldford (Ford, 1933) and Munro (1982).

Direct observation of growth

Growth can be observed directly in fish raised in captivity, where length progression can be followed throughout the rearing period. Growth in captivity is not, however, comparable to growth under natural circumstances.

Growth can be established in sedentary populations which can be observed in the same place over long periods of time. This information is obtained by photographs or by drugging the fish and measuring them directly.

The sets of data obtained should make it possible to use the Gulland and Holt method (1959), or other methods.

13. Study on waste accumulation in Aquaculture System (CO_2 and its management).

To keep the water properties within safe levels, one must understand those processes so that the elements inhibiting growth and survival can be detected and their impact can be minimised

As organic materials and their derivatives accumulate and exceed safe levels, they become a liability to water quality maintenance. Therefore, water quality management is one of the most important culture practices, especially in semi-intensive and intensive culture systems.

Feed is an important input for the growth and development of fish. At the same time water quality parameters are also important for the growth and development of fish. When there is abundance of feed, whatever might be the source either natural or artificial, unfed material tends to pollute the aquatic system. Feeds are organic in nature and contain carbon, nitrogen, sulpher in organic form. Excess feed gradually decompose in the water medium, consume oxygen and settle down on the bottom sediment. This disturbs the physico-chemical parameters of water and soil in aquatic system. Excess feed decreases the concentration of dissolved oxygen, nitrate, phosphate, sulphate etc. and increases the load of harmful metabolites like urea, uric acid, amides, mercaptan and gases like carbon dioxide, ammonia, methane, hydrogen sulphide etc. This causes algal bloom, putrefaction of pond bottom and eutrophication. Conventional aquaculture is free from this risk, however, intensive aquaculture in which high density stocking and feeding are resorted, have these risks and requires regular monitoring of physico-chemical parameters of water and soil. Slow-sinking or slow released feed formulations, use of aerators, and fish culture in recirculatory systems are recent developments which take cares these problems of intensive aquaculture. Even in conventional aquaculture when the water quality is poor e.g. low level of oxygen, high temperature, high ammonia, nitrite and hydrogen sulphide decreases the feed intake.

Carbon dioxide and its management:

In semi-intensive and intensive culture systems, sincere efforts should be made to keep dissolved oxygen at optimum level (5-10 mg/L). Degradation of unfed feeds and waste products proceeds with consumption of oxygen and thereby tends to reduce its level. Most of the problems in enclosed culture condition are augmented in low level of dissolved oxygen. During day time carbon dioxide, the end product of respiration is utilised by photosynthesis and oxygen (and carbohydrate) is produced in aquatic system. However, in night, production of oxygen stops (as photosynthesis couldn't proceed in absence of sunlight) and O_2 level decreases gradually as the night advances. However, due to respiration, CO_2 is continued to produce and there is no process like photosynthesis to utilise it. So level increases as the night progresses. Oxygen level is lowest and Carbon dioxide concentration is highest at dawn.

Photosynthesis:

$$\text{Sunlight } 6CO_2 + 6H_2O\ C_6H_{12}O_6 + 6O_2$$

Respiration:

$$C_6H_{12}O_6 + 6O_2\ 6CO_2 + 6H_2O$$

The High level carbon dioxide on hydrolysis (in absence of sunlight) produce carbonic acid thus makes the water acidic by the reaction $CO_2 + H_2O = H_2CO_3$. [N.B. The same carbon dioxide and water reacts differently in presence of sunlight during daytime to produce food and oxygen (as described above in the photosynthesis) the two most important requirements for sustaining the life on this planet]. This decreases the pH level and alkalinity of water. Carbon dioxide is lowest and oxygen level is highest due to higher rate of photosynthesis at noon (12 – 2 PM) owing to stronger intensity of incident sunlight. Therefore, for the analysis of pH, dissolved oxygen, free carbon dioxide, acidity and alkalinity water sampling should be done both at dawn and noon time to have a clear idea of lowest and highest range of these parameters in the culture ponds.

All these happen in normal condition in ponds where conventional extensive aquaculture is practiced. In semi-intensive and intensive aquaculture system, decomposition of unfed feeds and waste products utilises most of the oxygen for oxidation, produce CO_2 and will make the situation worse. Concentration of CO_2 is dependent on pH. CO2 exists in unionised (CO_2) and ionised forms e.g. bicarbonate (HCO_3) and carbonate (CO_3). Unionised form (CO_2) is more harmful than ionised form (CO_3). Bicarbonate form is not harmful rather it buffers the water from sudden fluctuation of pH; carbonate is harmful when pH crosses 9.0.

Dominated by pH Range

H+ (Strong acid) >4.0 Free CO_2 5 – 7 HCO_3 7 – 9 CO_3 > 8.5- 11

2 to 10 ppm of free CO_2 is ideal for good productivity of pond. 20-30 ppm of CO_2 can be tolerated provided O_2 is near to saturation. Above 30 ppm CO_2 concentration cause depletion of O_2 but air-breathing fish may survive at 100 ppm concentration.

Below pH 5, water acidity: Reduce the appetite of the fish, their growth and tolerance to toxic substances; Increase toxicity of H_2S, copper and other heavy metal to fish; Impeding the circulation of nutrients by reducing the rate of decomposition; Inhibit the nitrogen fixation; Fish gets prone to attacks of parasites and diseases. Water more acidic than pH 5.5 is not fertilized until they are corrected by liming. Liming should be done before 10 am in the morning. Raw cow dung can be applied to restrict the increase of pH beyond 8.5 and it should be applied at noon (11 am to 2 pm) to make use of pH, CO_2, acidity and alkalinity fluctuations in pond water.

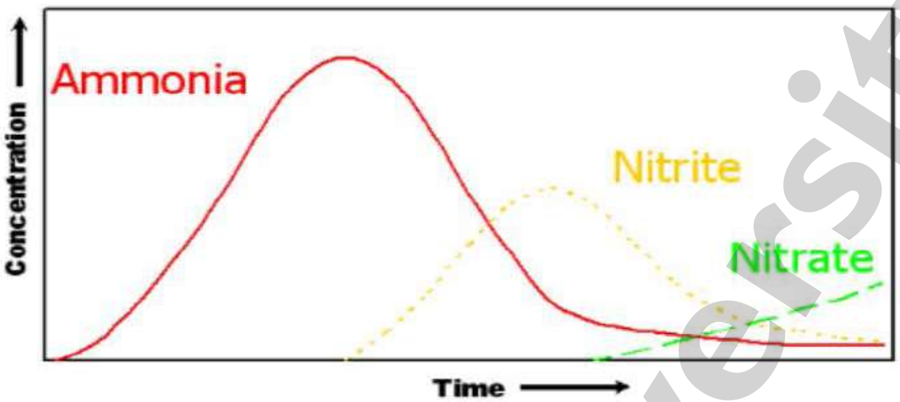
14. Study on waste accumulation in Aquaculture System (NH_3 and its management).

Ammonia and its management:

Ammonia is the second gas of importance in fish culture; its significance to good fish production is overwhelming. High ammonia levels can arise from overfeeding, protein rich, excess feed decays to liberate toxic ammonia gas, which in conjunction with the fishes, excreted ammonia may accumulate to dangerously high levels under certain conditions. Fortunately, ammonia concentrations are partially 'curbed' or 'buffered' by conversion to nontoxic nitrate (NO_3 +) ion by nitrifying bacteria. Additionally, ammonia is converted from toxic ammonia (NH_3) to nontoxic ammonium ion (NH_4 +) at pH below 8.0. Ammonia is the main end-product of protein catabolism and can account for 40-90% of nitrogen excretion for crustaceans (Parry, 1960). As ammonia concentrations in water increase, ammonia excretion by aquatic organisms diminishes, and levels of ammonia in blood and other tissue increases. The result is an elevation of blood pH and adverse effects on enzyme-catalysed reactions and membrane stability. Ammonia increases oxygen consumption by tissues, damages gills and reduces the ability of blood to transport oxygen. In water, ammonia can also be derived from microbial metabolism of the nitrogenous compounds under low oxygen condition. Ammonia exists in water in both ionised (NH_4 +) and unioniosed (NH_3) forms. Unionised ammonia is considered more toxic than unionised form due to its ability to diffuse readily across cell membrane (Fromm and Gillette, 1968; Emerson et al., 1975). The fraction of ammonia depends on pH, temperature, and to a lesser extent on salinity (Bower and Bidwell, 1978). As the pH or temperature rises, NH3 increases relative to the NH_4 + , and the toxicity of ammonia to animals increases. Chen and Sheu (1990) reported that as the pH level gets higher than 8.2, increasing pH levels in given ammonia solution could increase the ammonia toxicity to P. japonicus postlarvae. Free ammonia NH_3 may be harmful to fishes if it is above 0.05 mg/L of water. It denotes that pond bottom has become foul due to excessive decomposition of anaerobic nature. The unionised (NH_3) form of ammonia exists in equilibrium with the ammonium ion in water as per the following reaction:

$$NH_3 + H_2O = NH_3.nH_2O = NH_4OH + (n-1)H_2O$$

NH_3 is also excreted through gills epithelium by fishes and crustaceans. Fish excrete ammonia and lesser amounts of urea into the water as wastes. Two forms of ammonia occur in aquaculture systems, ionized and un-ionized. The un-ionized form of ammonia (NH3) is extremely toxic while the ionized form (NH4 +) is not. Both forms are grouped together as "total ammonia." Through biological processes, toxic ammonia can be degraded to harmless nitrates.



In aeobic situation, ammonia and ammonium nitrogen gradually converts to nitrite and nitrate by two aerobic bacteria i.e. nitrosomonas and nitrobactor respectively. Nitrite is toxic but nitrate is not. But when O2 level is low, concentration of gaseous ammonia gradually builds up in the aquatic system.

Pond seldom contains more than 2 to 3 mg/L of total ammonia nitrogen (Boyd, 1982). However, in superintensive ponds and at later stages of rearing, total ammonia-N concentration can reach as high as 6.5 mg/L (0.15 mg/L NH3-N) (Chen et al., 1989) and even 46.1 mg/L (0.87 mg/L NH3-N) (Chen et al., 1988). In the latter instance, NH3-N concentration higher than 0.1 mg/L were recorded in three samplings in one month, 12.3 ton per ha of P. penicillatus was harvested at a survival of 44.3%. It is difficult to evaluate ammonia toxicity on fish or prawns in a pond environment since daily cycle in pH and unionised ammonia concentration changes continuously.

In natural waters, such as lakes, ammonia may never reach dangerous high levels because of the low densities of fish, but the fish farmer who maintains high densities of fish, runs the risk of ammonia toxicity. Un-ionized ammonia levels rise as temperature and pH increase (Please see the Table given at page 15 for analysis of unionized ammonia).

Toxicity levels for un-ionized ammonia depend on the individual species; however, levels below 0.02 ppm are considered safe. Dangerously high ammonia concentrations are usually limited to water recirculation system or hauling tanks where water is continually recycled and in pond culture after phytoplankton die-offs. However, the intermediate form of ammonia--nitrite-- has been known to occur at toxic levels (brown-blood disease) in fish ponds.

Methods which improve the dissolve oxygen levels in ponds, reduce the ammonia level.

15. Study on waste accumulation in Aquaculture System (Dissolved Organics and its management).

Dissolved organics:

One of the important stress factors is the increase of dissolved metabolic organics in culture water. It can increase ammonia and microorganisms.

Dissolved metabolic organics	Causes	Stress
Decaying Excess high protein feed	Toxic Ammonia nitrate	Animal stops eating, weakness and become susceptible to diseases.
Dead Larvae, Organisms, algae	Microorganisms- bacteria, fungi and protozoans	Lower water quality
Animals excreta, urine	BOD (Biological Oxygen Demand)	

This explains why water quality deterioration could quickly cause a high mortality rate. To prevent the buildup of dissolved organics, frequent partial to total water change is necessary; or the pollution could be reduced by the chemically removing the pollutants by adsorption using activated carbon. The best way to facilitate the removal of metabolic wastes in a pond is by flushing out water from the bottom. Constantly maintaining high DO in the pond through supplemental aeration and water exchange, enhances nitrification. Nitrification is a major mechanism for ammonia removal in well-aerated ponds. Paddlewheel aerators are usually operated during dark (7 pm to 7 am) when oxygen depletion is likely to occur and at noon (12 noon to 2 pm) when temperature and oxygen stratification can become significant.

Phytoplankton management:

Phytoplankton play a significant role in stabilizing the whole pond ecosystem and in minimizing the fluctuations of water quality. A suitable phytoplankton population enriches the system with oxygen through photosynthesis during day light hours and lowers the levels of CO_2, NH_3, NO_2 and H_2S. A healthy phytoplankton bloom can reduce toxic substances since phytoplankton can consume NH_4 and tie-up heavy metals. It can prevent the development of filamentous algae since phytoplankton can block light from reaching the bottom. A healthy bloom also provides proper turbidity and subsequently stabilizes shrimp and reduces cannibalism. It decreases temperature loss in winter and stabilizes water temperature.

Pond bottom treatment:

For farms adopting advanced technology, it is necessary that pond bottom should be completely dried and aerated to get rid of toxic gases. Many ponds in low-lying areas cannot be completely drained and dried. To overcome this, Aquafarmers apply waste digesters to the ponds. The digesters are harmless bacteria (probiotics) and enzymes that consume organic matter on the pond bottom. After the application of digesters farmers apply a disinfectant, either organic silver or organic iodine. Copper sulphate is not used as a disinfectant now a days as it is not biodegradable and accumulates in the pond upto levels that are toxic to aquatic life. Organic silver is highly effective against bacteria and viruses and its toxicity to aquatic life is very low. Organic silver is applied at the rate of 18 litres (4 gallon) per hectare after lowering the water depth to 12 inches. Seven days after the application, this disinfectant disintegrates, so there is no need to flush the pond. Organic silver also prevents the development of algae that grows on shells. Organic iodine, can cure gill or shell diseases, kills bacteria on contact and has low toxicity. Its effect can be noticed within 24 hours and the pond bottom can be disinfected without emptying the pond. The suggested dosage is 5 ppm to 10 ppm. Its affectivity lasts for two to three days compared to about seven days in the case of organic silver.

Nitrogen Metabolites:

Large quantities of organic matter originating from the heavy feed load and feacal matter accumulate in aquaculture ponds. These undergo oxidation-reduction reactions leading to decomposition, mainly through the action of bacteria. Different forms of inorganic nitrogen like ammonia, nitrite and nitrate are produced during decomposition.

Maintaining water quality and preventing diseases:

Environmental conditions vary considerably at different times of the year and the bacterial and fungal, load of seawater also varies. During the dry moths; there is less dilution of organic and toxic pollutants from human and industrial wastes. During this time the absence of rains also reduces water exchange between clean seawater and polluted coastal water. The result is a rise of viral, bacteria, protozoa, fungi and toxic pollutants in the water. This is partially upset during the hot summer months by phytoplankton and zooplankton blooms, which assimilate some of the bacteria and toxic substances. Under such conditions, cultured animals become vulnerable to infection.

They are stressed by the following:

• Overcrowding in captivity.

• Temperature fluctuation of water, especially during water change (A one degree Celsius difference can cause stress).

• A temporary decline in dissolved oxygen level due to power failure.

• Increase of free-carbon dioxide, un-ionized ammonia and organics due to decaying excess feed and dead animals.

• Physical manhandling during water change.

• Poor nutrition – improperly fed fish and prawn.

• The high level of toxic pollutant in seawater that may contain heavy metals such as copper, zinc, lead, nickel, mercury and chemicals like poly-chlorinated biphenyl compounds, chlorinated hydrocarbons such as DDT and other pesticides.

While there is no known practical way to remove these pollutants. Efforts should be made to limit these stress-inducing factors to keep the animals strong enough to fight infection. Healthy animals, do not easily succumb to diseases. Where adequate filtration is not possible, treatment of water is suggested to lower the bacteria and fungal load of the water.

16. Analysis of Manure

China has a long history of pond fertilization for fish culture. Farmers adopted the method of manuring to rear fry ages ago. For example, "dacao" (green manure) is used in Guangdong and Guangxi provinces and human excrement (night soil) is used in Jiangxi and Hunan provinces to nurture fry into summer fingerlings. In fingerling-rearing ponds, fertilization is aimed at developing natural food organisms and saving artificial feeds.

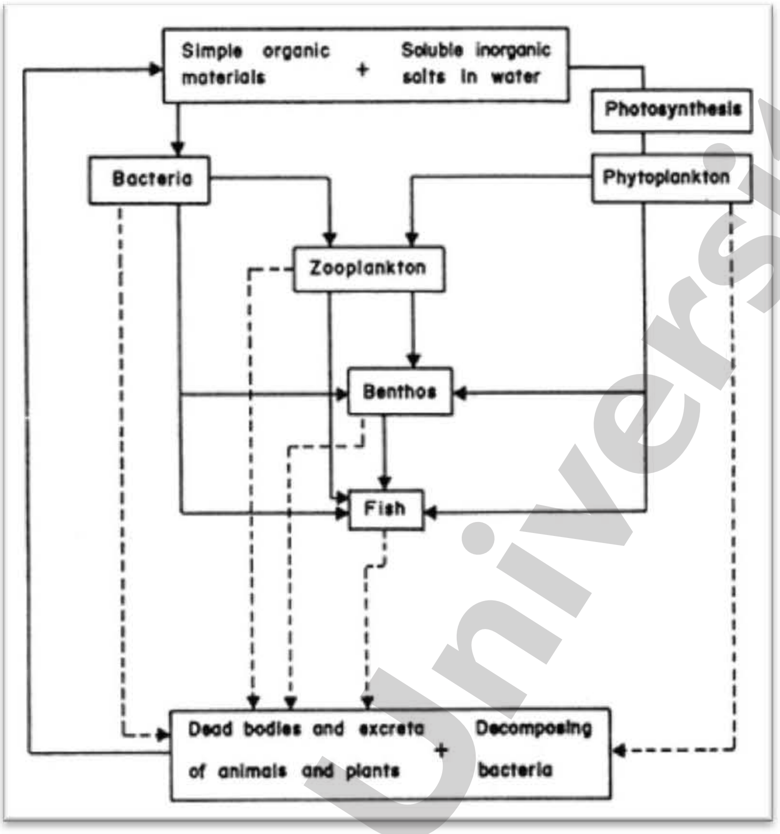
Phytoplankton, the elementary producers of the pond, carry out photosynthesis, converting the inorganic materials in the water into the organic nourishment needed for their growth and reproduction. Fertilization supplies the phytoplankton with the materials essential for photosynthesis. As the phytoplankton photosynthesize and reproduce, zooplankton, which feed on phytoplankton, flourish. In turn, the fish, which feed on zooplankton, phytoplankton, and benthos, also flourish. Therefore, the importance of pond fertilization lies in the cultivation and propagation of various food organisms for the cultured fish.

The series of interrelations between predators and prey is called a "food chain." In culturing ponds, fish are the final link: e.g., phytoplankton→silver carp; phytoplankton→zooplankton→bighead; aquatic plants→grass carp; plankton →benthos→black carp. Usually animals use only 5–20 per cent of the energy in both animal and plant feeds. Utilization of energy is related to the length of the food chain: the shorter the food chain, the higher the rate of energy transfer. In other words, the higher the utilization rate of energy, the higher the fish production.

The biota of the ponds is in a constant process of growth and decay. Dead organisms are decomposed from complex organic materials into simple inorganic materials by bacteria. These inorganic materials dissolve in water and are utilized by phytoplankton in photosynthesis. Hence, the materials in the pond are in a constant state of circulation mainly through the food chain (Fig. 3.1). This is called "pond material circulation."

Varieties of Organic Manure

Organic manures are mainly farm animal excrement. Generally, the term refers to manures containing organic matter. Today, mainly organic manures are applied to fish ponds in China. The following manures are often used: feces and urine of livestock and poultry, night soil, green manure, compost, arnd silkworm dregs. Only through decomposition by microorganisms is the organic manure converted to nutrients that the plants can absorb.



Pond material circulation.

Faeces and urine of livestock and poultry

Pig manure — Pig manure includes much organic matter and other nutritional elements such as nitrogen, phosphorus, and potassium and is a fine, complete manure (Table 3.1). Pig feces are delicate, containing more nitrogen than other livestock feces (C:N = 14:1), making them more susceptible to rotting. The major portion of pig urine is nitrogen in the form of urea. It decomposes easily.

Nutritional elements in pig manure.

Item	*Organic matter (%)*	*Inorganic matter (%)*		
		N	P_2O_5	K_2O
Feces	15	0.6	0.5	0.4
Urine	2.5	0.4	0.1	0.7

The excretory amount of a pig is greatly associated with its body weight and food intake. A 50-kg pig discharges around 10 kg/day or 20 per cent of its body weight. A pig excretes 1000 kg of feces and 1200 kg of urine in the growing period of 8 months from pigling to adult. A pig's daily excretory amount is less than a cow's or a horse's; however, pigs are advantageous because of their faster growth, shorter fattening period, and suitability for pen culture. Also, pigs are raised on much larger scale, so it is beneficial to collect their manure.

Cattle manure — The elements of cattle manure are similar to those of pig manure (Table 3.2), but cattle are ruminants and the food stuffs are repeatedly masticated, making the excrement quite delicate. Cattle manure contains less nitrogen than pig manure (C:N = 25:1). Cattle urine contains more nitrogen than pig urine (in the form of hippuric acid, $C_6H_5\,CONHCH_2\,COOH$); therefore, cattle excreta decompose slowly. The average daily excreta is 25 kg/cow, in which the ratio of feces to urine is about 3:2. The total annual amount of excrement for each animal is 9000 kg.

Nutritional elements in cattle manure.

Item	*Organic matter (%)*	*Inorganic matter (%)*		
		N	*P_2O_5*	*K_2O*
Feces	14.0	0.3	0.2	0.1
Urine	2.3	1.0	0.1	1.4

Poultry manure — Poultry manures include the feces of chickens, ducks, and geese, and are rich in both organic and inorganic matter.

Nutritional elements in poultry manure.

Item	*Organic matter (%)*	*Inorganic matter (%)*		
		N	*P_2O_5*	*K_2O*
Chicken feces	25.5	1.63	1.54	0.83
Duck feces	26.2	1.14	1.44	0.62
Goose feces	23.4	0.55	0.50	0.95

Poultry manures rot quickly and their nitrogen is mostly in the form of uric acid, which cannot be absorbed directly by plants. Accordingly, poultry manures are more effective after fermentation. The annual amount of excrement per fowl is as follows: chicken, 5.0–5.7 kg; duck, 7.5–10.0 kg; goose, 12.5–15.0 kg. Although the annual excretory amount of each is comparatively small, the quantity of poultry culture is often great; therefore, the total amount of feces is significant.

Night soil

The composition of night soil (human excrement) (Table 3.4) is greatly dependent on the food consumed. Nitrogen is abundant (C:N = 3:1) and 70–80 per cent of it is in the form of urea. This facilitates easy decomposition.

Nutritional elements in human excreta.

Item	*Organic matter (%)*	*Inorganic matter (%)*		
		N	*P_2O_5*	*K_2O*
Feces	20	1.0	0.5	0.4
Urine	3	0.5	0.1	0.2

On average, an adult excretes 790 kg/year of waste material. This is equivalent to 22 kg/year of $(NH_4)_2SO_4$.

Yearly excretion of waste by an adult human.

Item	*Annual amount (kg)*	*Equivalent (kg/year)*		
		$(NH_4)_2SO_4$	*Calcium superphosphate*	*Potassium sulphate*
Feces	90	4.5	2.25	0.7
Urine	700	17.5	4.55	2.8
Total	790	22.0	6.80	3.5

Night soil to be used as manure must be fermented before application. This is easily done by storing the manure in anaerobic conditions for 2–4 weeks. The decomposition of human waste produces ammonia. Under airtight conditions, the accumulation of ammonia can sterilize human waste. Quicklime (1–2 per cent) and formalin (0.1–0.2 per cent) are effective in killing the harmful pathogens in night soil.

Silkworm dregs

Silkworm dregs are composed of silkworm feces and slough and mulberry residues. They are rich in organic matter: dried dregs are 87 per cent organic matter and 13 per cent nitrogen. They also make good fish feed: 8 kg silkworm dregs can produce 1 kg fish.

Green manure

All wild grasses and cultivated plants, if used as manure, are called green manures. These manure rot and decompose easily, providing ideal environments for bacteria propagation. Therefore, they are good for application in fish ponds.

Nutritional elements in green manures (% wet weight).

Item	*N*	*P_2O_5*	*K_2O*
Stems and leaves of broad bean (*Vicia faba*)	0.55	0.12	0.45
Rape (*Brassica napus*)	0.43	0.26	0.44
Alfalfa (*Medicago falcata*)	0.54	0.14	0.40
Wild grass	0.54	0.15	0.46
Branyard grass (*Echlnochloa crusgalli*)	0.35	0.05	0.28
Alligator weed (*Alternanthera philoxeroides*)	0.20	0.09	0.57
Water hyacinth (*Eichhornia crassipes*)	0.24	0.07	0.11
Water lettuce (*Pistia stratiotes*)	0.22	0.06	0.10

Compost

Mixed compost consists of green manure and animal waste. Mixing several manures together may produce a fertilizer that is more suitable to plankton reproduction. The ratio of the constituents depends upon the local sources of manure. Experimental data show the following two mixtures to be suitable for plankton reproduction: (1) green grass — cattle feces — human excreta — lime, 8:8:1:0.17; (2) green grass — cattle feces — lime, 1:1:0.02.

Lime is included in the compost mixture to neutralize the organic acids produced during rotting and decomposition. If these acids were allowed to accumulate, they would inhibit the microorganisms responsible for decomposing the organic matter. There are two methods of making compost; heaping and soaking.

Heaping method — The manure heap must be made in aerobic conditions. Spread out a layer of green grass, sprinkle some lime on it, add layer of fecal manure, and repeat the procedure. When the compost reaches 1.5–2 m, cover it with 5–6 cm of mud. The ingredients of the compost will rot and decompose. After 3–4 weeks the compost can be used.

Soaking — Dig a pit near the fish ponds and layer in green grass, lime and fecal manure, respectively and then add enough water to soak the compost ensuring there is no leakage. The compost can be removed for use after 10–20 days of fermentation at a temperature of 20–30°C.

Methods of Organic Manure Application

Application of Dacao

In Guangdong and Guangxi provinces, Dacao is commonly used to fertilize pond water. Dacao consists mostly of composite plants, with some gramineous plants and leguminous plants included. Dacao is applied by heaping it at a corner of the pond and turning the pile once every 2 days. The rotten parts will spread into the water. The roots and stems, which rot slowly, are dredged out of the ponds when the Dacao pile is depleted. The decomposition of green manure in water consumes a great amount of oxygen. Experimental data show that if 1000 kg of grass is applied to a 1-mu pond with a water depth of 1 m, there will be no available oxygen from the 2nd to the 6th day and all the fish will die. The peak of oxygen consumption because of decomposition is on the 2nd and 3rd days. For this reason, it is appropriate to apply green manures frequently and in small amounts, to frequently add fresh water to the pond, or to use aerators in the pond to guarantee sufficient oxygen for the fish.

Application of night soil

In Jiangxi and Hunan provinces, night soil is commonly applied to the fish ponds. Before application, one part night soil is diluted with two parts water. This dilution is then sprayed along the pond dikes once a day. The quantity depends on the fertility of the water and the size of the fish.

Application of livestock manure

The application of livestock manure as a base manure is similar to the method for green manure: heap the manures at a corner of the pond or in small piles in shallow water and with a sunny exposure, allow them to decompose and spread gradually into the water. If the manure is used as an additive, it is added in small quantities every 7–10 days.

Application of mixed compost

After fermentation, the compost is flushed. The liquid is collected and the residue is removed. This liquid is sprayed into the pond around the dikes. In the case of a large pond, the manure may be loaded on a boat, flushed in batches with pond water, and sprayed evenly over the pond. The manure dregs can be used to fertilize crops. Alternative method is to flip the compost and expose the liquid. The appropriate amount of manure liquid can then be ladled out and spread into the ponds.

The nutrients of the compost are quickly absorbed by phytoplankton. They consume less dissolved oxygen because the organic materials are already decomposed.

Effects of Manure Application on Natural Food Organisms

The application of organic manure results in the rapid multiplication of bacteria. Bacteria are added with the fertilizer and use the nutrients to reproduce. Also, organic detritus is rich with bacteria, which are an important food source for the lower aquatic animals and filtering fish.

The initial, predominant species of plankton depends closely on the properties of the manure applied. If organic manure is applied, phytoplankton, (*Ochromonas* spp, *Cryptomonas*) and zooplankton (*Urotrichia* spp.), which are fond of organic materials, will appear first. For inorganic manure, the initial, predominant species will be centric diatoms (*Centomonas* spp. and *Scenedesmus acuminatus*). There is a close relationship between the amount of manure applied and the make-up of the plankton community. Large amounts of manure will lead to the presence of some species of green algae (*Chlorophyta*) and blue algae (*Cyanophyta*); however, small amounts of manure will lead to the presence of *Navicula rostellata* and *Cyclotella stelligera*.

After each manure application, the nutrient content of the water increases, resulting in a planktonic peak. Phytoplankton that are easily digested by silver carp reach a peak after 4 days; those phytoplankton that are not so easily digested attain a climax in 5–10 days. Zooplankton reach a peak in 4–7 days. Protozoans will be the first zooplankton to reach a peak, followed by rotifers, cladocerans, and, finally, copepods. Protozoans multiply by binary fission, increasing the population very rapidly, and, therefore, reaching a peak first. Rotifers usually multiply by parthenogenesis, producing an average of 10–20 eggs during their lifetime. This process is less productive than binary fission and, therefore, rotifers reach a population peak slightly later than protozoans. Cladocerans also reproduce parthenogenically, but the span between hatching and sexual maturity is longer than that of rotifers; therefore, the cladoceran population peaks later. Copepods take longer time than cladocerans to get mature and its population becomes maximized later. The timing of manure application is crucial when preparing a nursery pond. Ideally, the peak in plankton population should coincide with the feeding demand of the fish fry.

Varieties of inorganic manure

Inorganic manures are also referred to as chemical fertilizers. According to composition, chemical fertilizers can be divided into three groups: nitrogenous, phosphoric, and potash fertilizers. The advantages of inorganic fertilizers are their exact composition, their fast effect, the lack of pollution, their beneficial effect on oxygen content (requiring no decomposition), the small amount required, and their convenient utilization. However, when chemical fertilizers are applied in ponds, the first link of the food chain is principally phytoplankton, which are not as nutritious to zooplankton as are bacteria. Therefore, the zooplankton population in ponds treated with inorganic manure often lags far behind that in ponds treated with organic manure. Moreover, in most chemical-fertilizer ponds, the predominant phytoplankton is *Chlorophyta,* which is not as nutritious as the predominant phytoplankton in ponds treated with organic manure (*Chrysophyceae, Bacillatiophyceae,* and *Cryptophyceae*). Another disadvantage is that the effect of inorganic fertilizer is rather short and it is difficult to control the water quality. Taking all these factors into account, therefore, the result of chemical-fertilizer application alone is no better than that of organic-fertilizers application.

Nitrogenous fertilizers

Liquid ammonia — Molecular formula: NH_4OH or $NH_3.H_2O$. Nitrogen content: 12–16 per cent. Liquid ammonia is an aqueous solution of ammonia, which is an important product of small-scale nitrogenous fertilizer factories and is easily synthesized at a low cost. Aqueous ammonia is readily volatilized and should not be exposed to the air for a long time.

Ammonium sulphate — Molecular formula: $(NH_4)_2SO_4$. Nitrogen content: 20–21 per cent. Ammonium sulphate is produced from liquid ammonia directly neutralized with diluted sulphuric acid. When pure, it is a water-soluble white crystal: 75 kg of ammonium sulphate will dissolve in 100 L of water at 20°C. It is easily conserved and applied.

Urea — Molecular formula: $CO(NH_2)_2$. Nitrogen content: 44–46 per cent. Under high heat and pressure, ammonia and carbon dioxide react to form urea. It is a white crystal with a high solubility in water. However, urea does not ionize when dissolved in water and, therefore, cannot be directly absorbed by plants. It can be utilized by plants only after it has been broken down by urease, excreted from urea-decomposing bacteria, and transformed into ammonium carbonate. This process is temperature dependent in normal ponds. At 20°C, total transformation into ammonium carbonate requires 4–5 days; at 30°C, 2 days.

Phosphoric fertilizers

Calcium superphosphate — Main contents: $Ca(H_2PO_4)_2.H_2O$ with 12–18 per cent P_2O_5. Subsidiary contents: $CaSO_4.2H_2O$, about 50 per cent. Calcium superphosphate is usually a white powder, and apt to absorb moisture. It is corrosive and has an acidic odour because it contains some free acids.

Methods of Inorganic Manure Application

Nitrogen is an essential nutritional element of plants. It is also an essential component of proteins, accelerates the formation of plant chlorophyll, and stimulates photosynthesis. For these reasons, nitrogen content is a decisive factor in phytoplankton production.

Nitrogen is commonly lacking in pond water, so nitrogenous fertilizers should be added. Generally, nitrogenous fertilizer should be used as an additive because of its quick effectiveness. A nitrogenous fertilizer with ammonium must not be mixed with strong alkaline materials e.g. lime; this would result in the volatilization of the ammonium. When using a nitrogenous fertilizer containing ammonium, the toxicity of ammonia must be considered. In aqueous solution, an equilibrium exists between ammonia (NH_3) and ammonium (NH_4^+).

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

In an acidic state, the equilibrium shifts to the right and the concentration of ammonium ions increases. In an alkaline state, the equilibrium shifts to the left and the ammonia concentration increases. At a water temperature of 25°C, the percentage of nitrogen as NH_3 at various pHs is as follows: ph 6, 0.05 per cent; pH 7, 0.49 per cent; pH 8, 4.7 per cent; pH 9, 32.9 per cent; pH 10, 83.1 per cent; pH 11, 98 per cent.

Ammonia is toxic to fish. It poisons juvenile rainbow trout at 0.3–0.4 mg/L. Chinese carps can tolerate concentrations up to 13 mg/L. Ammonia concentrations below this inhibit growth. The maximum NH_3 concentration permitted for fish farming is 0.1 mg/L. Therefore, the amount per application must be strictly controlled. In addition, ponds pH must be closely monitored to avoid applying NH_3 in strong alkaline water (e.g., just after pond clearing with lime); liquid ammonia is also alkaline itself. The amount of unionized ammonia increases with increasing water temperature. Therefore, special care is needed when nitrogenous fertilizer in the ammonia form is applied in the summer and the autumn.

The application amount of the nitrogenous fertilizer depends on its nitrogen content. In a pond with an area of 1 mu and a water depth of about 1.5 m, 1.5–2 kg N may be applied as base manure. After this, 0.5 kg N/mu is applied 3 or 4 times monthly. In average, 10 kg N are needed for the whole culture period. For example, if the nitrogen content of ammonium sulphate is about 20 per cent to apply 2 kg of nitrogen to a 1-mu pool as base manure, 10 kg of ammonium sulphate is required. The amount of ammonium sulphate required for a culture period can be calculated in the way: 50 kg.

To apply, make a solution and spread it near the dikes. In the case of liquid ammonia, put the container underwater and open the lid to let the liquid ammonia slowly diffuse out. In this way, volatilization can be avoided.

Most water sources lack phosphorus. Phosphoric fertilizer, besides being utilized by phytoplankton, will also accelerate the reproduction of azotobacteria and complement the nitrogenous fertilizer. The application amount can be calculated based on the phosphoric acid content of the fertilizer. A 0.5–1 kg/mu is used as base manure, the amount used for a culture period is about 5 kg. The method of calculation and application is the same as that for nitrogenous fertilizer.

Potassium is also an essential nutritional element of plants. However, it is usually sufficient in the water and there is no particular need to apply potash fertilizer.