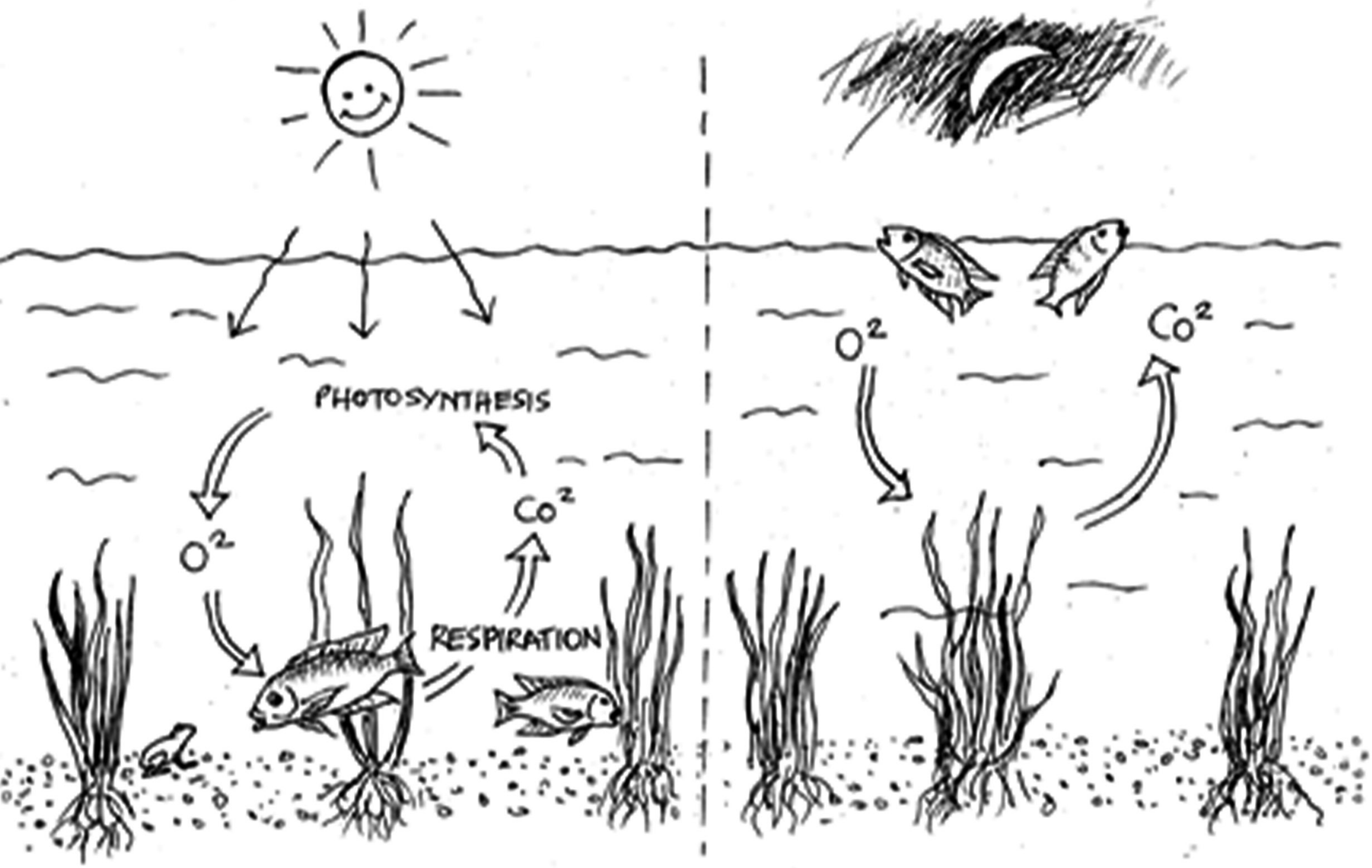

FISH AND ITS ENVIRONMENT

Module I of 8

Fish and its Environment

Module I

FOREWORD

The growing demand for fish in Malawi and the Southern African Development Community (SADC) region requires additional efforts by the governments to increase fish production from aquaculture. All Malawi's development policies (Malawi Vision 2063, Malawi Growth and Development Strategy III 2017-2022, National Fisheries and Aquaculture Policy 2016, National Aquaculture Strategic Plan 2021) emphasise the need to promote aquaculture development in order to enhance production from aquaculture to supplement the dwindling capture fisheries production and cannot satisfy the ever increasing demand for fish. The development policies also emphasise the need to pursue sustainable practices and climate smart technologies.

Up until now, there were many reference materials which extensionists from both government and non-governmental organisations have been using to train farmers in aquaculture principles and practice. These manuals, however, were not coherent, often providing conflicting recommendations and were not vetted by the Department of Fisheries under the Ministry of Forestry and Natural Resources as proper training materials for aquaculture. Hence, it is timely that this new aquaculture manual has been developed for use in the aquaculture practice. This manual will become a nationally recognised tool for training in aquaculture practice.

The target users of this aquaculture manual are extensionists from government and non-governmental organisations, fish farmers and trainers of these groups. The manual contains technical information as well as training plans to help the trainers to conduct training in an orderly manner.

The Ministry of Forestry and Natural Resources remains committed to foster the development of aquaculture in the country for nutritional and food security, income generation and job creation.

Yanira Ntupanyama, PhD.
Secretary for Forestry and Natural Resources

PREFACE

This Technical Manual for Trainers on Good Pond Aquaculture Practices has been developed to address the gap that existed when the country did not have a universal, nationally recognised manual as basis for training our extension agents, fish farmers and for use by non-government organisations engaged in the aquaculture sub-sector. This manual will be a reference material for guiding aquaculture practices in Malawi. Accordingly, the manual has been developed to support the implementation of the National Fisheries and Aquaculture Policy 2016 which highlights sustainable aquaculture development as policy priority number 2 and the National Aquaculture Strategy (2021-2029).

There are several challenges that exist in the aquaculture sub-sector that need to be addressed for the benefit of fish farmers and extension workers. The major challenges include: lack of harmonised approaches and information to guide all players in the value chain, inadequate supply and access to inputs i.e. quality fingerlings and feed, unavailability of market structures to aggregate production and measures to increase the resistance of the sector against risks related to climate change.

It is expected that this aquaculture manual will become the necessary tool for all actors along the aquaculture value chain mainly for technical know-how regarding aquaculture production. Where possible, trainers or users may be guided by the aquaculture experts from the Department of Fisheries under the Ministry of Forestry and Natural Resources.

Friday Njaya, PhD.
Director of Fisheries

ACKNOWLEDGEMENTS

The Department of Fisheries (DoF) in the Ministry of Forestry and Natural Resources is grateful to all stakeholders, too numerous to mention, who contributed to the development of the nationally recognized Technical Manual for Trainers on Good Pond Aquaculture Practices. The DoF acknowledges the financial and technical support from the Aquaculture Value Chain Project for Higher Income and Food Security (AVCP) funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ).

The Department also acknowledges the efforts and technical contributions from all the government officers, academicians, technicians and practitioners who took part in the development of this manual. Thanks should also go to the team that finally edited the manual.

Special recognition and gratitude are extended to the GIZ Food and Nutrition Security Program (FNSP) for contributing the chapter on nutritional benefits of fish and all individuals who were involved and contributed in the development of this manual.

INTRODUCTION

Fish do not only live in water but they also get oxygen and food which is necessary for their survival. There should be a balance between the wellbeing of the fish and the environmental conditions. The fish is negatively affected if the environmental conditions are not optimal. The relationships between cultivated fish species and their environment are largely dependent on the biological characteristics of the fish and the degree of intensification of the culture. Therefore, consideration of culture systems should be made with regards to the type of fish species being raised.

For example, in extensive and semi-intensive systems, based on natural production, stocking fish species of different feeding habits together enables a more efficient utilization of pond resources. In polyculture systems only a proper combination of ecologically different species at adequate densities will utilize the available resources efficiently, maximize the synergies between fish and their environment and minimize the antagonistic ones. Synergistic interactions among fish species may be explained on the basis of two interrelated processes: increase of food resources and improvement of environmental conditions. The knowledge of fish and its environment enables choosing adequate combinations of fish species, stocking rates, input types and rates, and other management decisions according to the specific local conditions: climate, quality of water supply and pond fertility.

The of this module is to provide trainees with knowledge and understanding of the different species of fish cultured in Malawi, the different environmental parameters that affect the growth of these species and the different aquaculture systems in which these species can be raised. Skills on identification of the different fish species cultured in Malawi will be enhanced.

CONTENTS

Description of fish species cultured in Malawi

INTRODUCTION

There are thousands of different types of fish in Malawi, but only a few types grow well in ponds. Availability, pond conditions, capacity to grow and breed in captivity, markets and other factors determined the selection of the current fish species being cultured in the country's ponds. Tilapia is one type of fish that thrives in small ponds, and is now being raised in warm countries of Africa, Asia and the Americas. There are more than 100 different types of tilapia found in Africa. Each type looks and behaves slightly differently. In Malawi, we have our own tilapias which were researched upon and found to be suitable for fish farming and we also have catfish which is being cultured. This chapter is therefore discussing common fish species being used in the aquaculture sector in the country. Advantages and disadvantages of each fish species and a note on the status of exotic species in the country has been presented.

AIM

The aim of this module is to provide trainees with knowledge and understanding of the different species of fish cultured in Malawi, the different environmental parameters that affect their growth and the different aquaculture systems in which these species can be raised. Skills on how to identify these species will be enhanced.

Objectives

Participants know

- Different indigenous fish species cultured in Malawi
- Advantages of some species over others
- The status of exotic species in Malawi

Acquired skills

- Identification of the different fish species
- Classify fish species cultured in Malawi

- Acquired attitudes
- The fish species we have in the country grows well in ponds
- Available fish species in Malawi are profitable

- Relevance to fish production
- Knowing a good species in relation to environmental conditions will lead to good fish growth and god yields
- Session Overview: This chapter has one session on different indigenous fish species cultured in Malawi

- Materials: Flip- chart paper, markers, study notes, posters – images of fish species or live fish, hand nets, fish harvesting net, buckets, water

- Mode of delivery: Lectures, group discussions and practical

- Duration: 90 minutes

1.1 Species farmed in Malawi

There are thousands of different types of fish in Malawi, but only a few types grow well in ponds. Availability, pond conditions, capacity to grow and breed in captivity, markets and other factors will determine the best choice of species for your pond. Tilapia is one type of fish that thrives in small ponds and there more than 100 different types of tilapia found in Africa. Each type looks and behaves slightly differently. In Malawi, we have our own tilapias which were researched upon and found to be suitable for fish farming.

In general, tilapias feed on a low trophic level and are between herbivore and omnivore in terms of feeding behaviour. They eat a wide variety of natural food organisms including phytoplankton and zooplankton, algae, some aquatic macrophytes, benthic invertebrates, other fish larvae, detritus, and decomposing organic matter. Tilapias are often considered filter feeders because they can efficiently harvest plankton from the water. Natural food may account for 30–50% of their growth even when they receive heavy supplemental feeding. The nutritional value of the natural food supply in ponds is important, even when fish are cultured intensively, especially in outdoor systems.

1.1.1 Cultured species in Malawi

i. Chambo (Oreochromis karongae)

Oreochromis karongae locally known as Chambo is one of the cultured fish species on farms in Malawi. It is grey and has vertical lines on its body. Compared to makumba, chambo does not breed very well in ponds but it has a higher growth rate than makumba, makanana and Chilunguni. A mouth brooder, it takes a while for chambo to reach sexual maturity, which means that they spend a lot of energy on growing rather than breeding. It has a low fecundity.

They usually reach sexual maturity at around 70g. Chambo mainly feed on plants that naturally grow in fertilized pond water (phytoplanktons), protein-based feeds including soya, and plant wastes like maize bran.

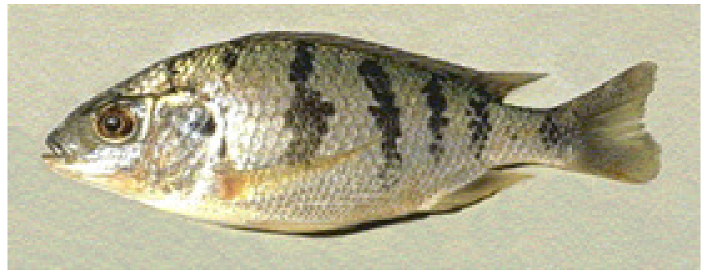

Fig 1.1 Chambo - Oreochromis karongae

ii. Makumba (Oreochromis shiranus)

The makumba is well distributed across the country, but it has low growth rates. However, where total quantity is more important than individual size, this fish is recommended because it has the capacity to feed efficiently on phytoplankton in fishponds. The makumba has four anal spines, lacks a genital tassel, and ripe males have a bright red margin on the dorsal fin. Makumba breed easily under pond conditions and reach sexual maturity at an early stage (around 20g). Because they use more energy for breeding than growing, they must be well fed or their growth rate will be reduced. Makumba grow well in fertilized ponds but the size of harvest depends on the quality and quantity of feeds used. They respond well to a variety of food and can feed on external feeds such as maize bran and rice bran. They grow better when only males are raised.

Fig 1.2 Makumba (Oreochromis shiranus)

iii. Chilunguni (Coptodon rendalli)

The Chilunguni is indigenous to Malawi and is well adapted to all water bodies of Malawi. However, it is not widely distributed among farmers in Malawi. This fish is commonly described as a red-breasted tilapia and is known by several local names, including Chilunguni, nyungusale, katakuzi, nyakalua, mgoma mbungu, and many others. The Chilunguni is brightly coloured with 5-7 olive vertical bars, a bright red spot on the throat and breast, and a distinct black spot on soft dorsal rays called "the Tilapia spot."

Fig 1.3 Chilunguni (Coptodon rendalli)

Young and adult Chilunguni are plant feeders that live in areas with plenty of vegetation. Its ability to digest aquatic plants makes this fish especially important in combination with other tilapia species. Some of the vegetation on which the Chilunguni feeds includes sweet potato, cassava and papaya leaves, black jack/ chisoso, elephant/napier grass, mwamuna aligone and others. It has a high reproduction rate and produces about 5,000 – 7,000 fry per brooder and breeds about 8 times each year. The Chilunguni has a better growth rate than the Makumba because it starts breeding at a slightly older age. However, since its eggs are laid in shallow areas, the number that hatch and survive is low because many eggs and hatchlings die from high temperatures and predators.

iv. **Makakana** (Oreochromis mossambicus)

Oreochromis mossambicus is a dull greenish or yellowish, and weak banding coloured oreochromine cichlid fish native to Southeastern Africa. Oreochromis mossambicus is laterally compressed, and has a deep body with long dorsal fins, the front part of which has spines. It is a freshwater and brackish water inhabitant. It lives in warm, weedy pools of sluggish stream, canals, and ponds. It is omnivorous, and feeds on almost anything from algae to insects but also crustaceans, and fishes. It can be reared under hypersaline conditions and spawn all year around when kept in warm water (above 20° C). Adults reach up to 39 cm in standard length and up to 1.1 kg. Size and coloration may vary in captive and naturalized populations due to environmental and breeding pressures. It lives up to 11 years.

Oreochromis mossambicus is a popular fish for aquaculture. Due to human introductions, it is now found in many tropical and subtropical habitats around the globe, where it can become an invasive species because of its robust nature. These same features make it a good species for aquaculture because it readily adapts to new situations. Oreochromis mossambicus, like other fish such as Nile tilapia and trout, are opportunistic omnivores and will feed on algae, plant matter, organic particles, small invertebrates and other fish. Feeding patterns vary depending on which food source is the most abundant and the most accessible at the time. In captivity, it has been known to learn how to feed itself using demand feeders. During commercial feeding, the fish may energetically jump out of the water for food.

Oreochromis mossambicus displays territorial behaviour, it is a mouth brooder and exhibits high levels of parental care as well as the capacity to spawn multiple broods through an extended reproductive season and has high fecundity.

Fig 1.4 Makakana (Oreochromis mossambicus)

v. **Mlamba** (Catfish – Clarias gariepinus)

Mlamba can be grown successfully in combination with other species like makumba and makakana. Combining mlamba with either makumba or makakana improve the growth of both species because its cannibalistic nature controls the makumba or makakana population. Mlamba is rarely reared together with Oreochromis karonage and Coptodon rendalli due to the fact fingerlings of these two species delays its breeding and fingerlings are sometimes a challenge. The fish is characterized by a large flat armored head, with no spine in the dorsal fin. It has a long base with no scales. One of the most unique features of mlamba is their ability to breathe air, which enables them to live in extremely high population density and greater yields in various culture systems. However, the mlamba is not widely accepted in Malawi for cultural and religious reasons.

The growth rate of the mlamba is better than the tilapia; however, it does not spawn easily in ponds and tanks. It has low fry survival rates due to cannibalism if the pond is not well managed.

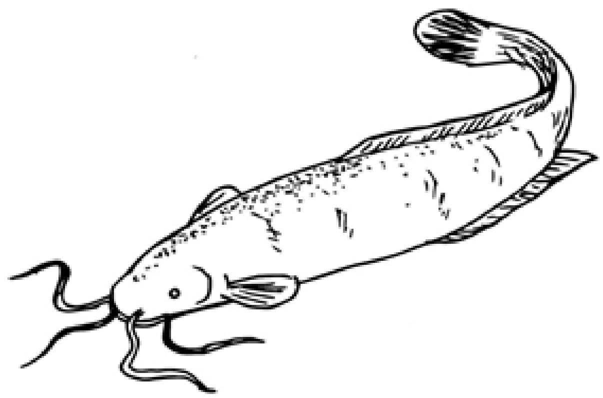

Fig 1.5 Mlamba (Catfish – Clarias gariepinus)

Table 1.1 Summary of the cultured fish species

	Short Description	**Key features**	**Lifecycle and mating**
Oreochromis shiranus	• Can occur at temperatures ranging from 23.0 – 42.0oC · Feeds on detritus and phytoplankton · Males are fast growers	· Dorsal spines (total) 15 -18 · Dorsal soft rays (total) 10 – 13 · Anal spines: 3 -5 · Anal soft rays: 9 - 11 · Maturity: Lm13.5, range 17cm, max standard length 39.0cm male	· A maternal mouth brooder · Males builds basin shaped nests in shallow water · Females brood eggs and young in the mouth till they reach 10mm
Oreochromis karongae	• A heavily built tilapia species · Rounded head, short jaws · Males are black with white margin to the dorsal and tailfins · Genital tassel can be long, branched, pinkish to bright yellow · Feeds on phytoplankton and on diatom sediment	· Dorsal spines (total) 15 -17 · Dorsal soft rays (to-tal) 10 – 12 · Anal spines: 3 · Anal soft rays: 8 – 10 · Head length 30.8-36.0% of SL · Maturity: Lm 28.9, range 20-38cm, max standard length 42.0cm male	· A maternal mouth brooder · Males builds basin shaped nests in shal-low water and defends them · Courtship mainly oc-curs in the morning · Females brood eggs and young in the mouth, guards fry until they are about 24mm

Oreochromis mossambicus	• Can survive at extended temperature range 8-42.0oC · Natural temperature range 17-53oC · Males are fast growers · Feeds on zooplanktons, small insects and their larvae · Juveniles carnivorous, omnivorous · Fecundity high	· Dorsal spines (total) 15 -18 · Dorsal soft rays (total) 10 – 13 · Anal spines: 3 · Anal soft rays: 7 – 12 · Snout long, forehead with relatively large scales, starting with 2 scales between the eyes followed by 9 scales up to dorsal fin · Maturity: Lm15.4, range 6-28cm, max standard length 39.0cm male	• Female and non-breeding male silvery · Breeding male black with white lower parts of head and red margins to dorsal and caudal fins · Polygamous, maternal mouth brooder · Reaches sexual maturity at 15cm length · Stunted fish may breed at 6 – 7 cm & at an age of over 2 months
Coptodon rendalli	· Both sexes look very similar although males are usually larger · Prefers quiet, -well vegetated water · Can survive in temperature range of 8-41oC · Juveniles feed on plankton, adults feed on leaves & stems of under water plants, algae, vegetative detritus, insects	· Dorsal spines (total) 15 -17 · Dorsal soft rays (total) 10 – 13 · Anal spines: 3 · Anal soft rays: 9 – 10 · Large, deep-bodied with a steep head profile · Narrow head, small mouth, appearing brownish with white belly, some with bright red bellies · Maturity: Lm17.7, max total length 45.0cm male	· A substrate spawner · Male & female form pairs to rear the young · Eggs & larvae are guarded by male and female · Prefers a sloping spawning ground near marginal fringe of vegetation · Builds nests in shallow water where both parents guard eggs and young
Clarias gariepinus	· Presence of an accessory breathing organ enables it to breathe air under very dry conditions · Can remain in muddy substrates of ponds, gulp atmospheric air through the mouth · Can leave water using its strong pectoral fins and spines · Head somewhat between rectangular and pointed in dorsal outline; snout broadly rounded; eyes supero-lateral and relatively small · Feeds on wide variety of prey like insects, plankton, invertebrates, fish	· Dorsal spines 0 · Dorsal soft rays (total) 61 -80 · Anal spines: 0 · Anal soft rays: 45-65 · Has gill rakers varying from 24-110; the number increase with fish size, gill rakers long, slender & closely set Maturity: Lm30.8, range 34cm >, max TL 170cm male	· Oviparous. Spawning takes place during the rainy season · Fish make a literal migration towards the shallow areas to breed and return to the river · Juveniles return to deeper water when they are between 1.5 and 2.5cm · First sex maturity occurs when females are between 40-45cm, males between 35-40cm · Eggs are greenish · Incubation lasts about 33 hours at 25oC

1.2 Use of exotic species

The introduction of exotic fish species to areas where they do not naturally belong is a global problem. Apart from cases of exotic species, there are also many more cases of species transplant within the same water shed, this is the issue which mainly affects most of African and indeed Malawian water ecosystems. What is of great concern to ecologists, environmentalists, biologists and genetists alike is what happens next after an introduction has occurred.

The use of exotic species is restricted in Malawi. The Fisheries Conservation and Management Act (1997) restrict the introduction of exotic species in order to protect Malawi's fish biodiversity. The Fisheries Act No. 22 of 2011 gives mandate to the Department of Fisheries to regulate and approve applications of exotic introductions.

There are several exotic fish species that were introduced in the country. Government introduced Common carp in early 1976 as a promising fast growing exotic fish species. However, it was shown that the fish grew fast only when it was stocked at low densities (0.1 - 0.2 fish/m2) in polyculture with O. shiranus (Msiska 1992) and Noble (1993) found out that standing stocks at harvest did not significantly improve over monoculture of Oreochromis shiranus. Government banned Common carp (Cyprinus carpio) in 1992 out of fear that escape from containment could cause serious harm to Malawi's endemic fish species, and this is enforced under the Fisheries Conservation and Management Act (1997)

Another exotic fish species cultured is the rainbow trout, Onchorhynchus mykiss which is still being cultured on Zomba Plateau, in some parts of Mulanje and in the rivers around Nyika. The fish did not spread to other parts of the country due to its tolerance to very low temperatures (temperate fish). Oreochromis niloticus is also not allowed to be grown in Malawi although it is grown in our neighboring countries like Zambia and Tanzania.

Exotic fish species introduced to neighboring countries is a threat to Malawi because we share the same catchment. With farmer to farmer sales of fingerlings, the introduction of Oreochromis niloticus may be inevitable in near future either through introduction in Lake Malawi as the fish has been spotted in Lake's catchments area on Tanzania side or through illegal transfer of fingerlings among farmers along the borders. Oreochromis niloticus is sold in supermarkets in major cities of Malawi and selling at relatively cheaper price and bigger in size than the local tilapia. It is likely that the imported Oreochromis niloticus would flood the market in near future thereby gaining bigger market share than Malawi tilapias. It is foreseen that Government would be pressured upon by fish farmers to legalize culture of Oreochromis niloticus or other fast growing fish species in the country.

Summary

The chapter has looked at the different fish species cultured in Malawi. The species were selected looking at their availability, pond conditions, capacity to grow and breed in captivity, markets. Tilapias are best suited for culture in ponds as they feed on a low trophic level and are between herbivore and omnivore in terms of feeding behaviour. They eat a wide variety of natural food organisms including phytoplankton and zooplankton, algae, some aquatic macrophytes, benthic invertebrates, other fish larvae, detritus, and decomposing organic matter.

The main cultured species in Malawi include Chambo (Oreochromis karongae) and they are grey and have vertical lines on its body. They are mouth brooders, have higher growth rate and their main challenge is the availability of seed as they take a while to reach sexual maturity, which means that they spend a lot of energy on growing rather than breeding. The other species is Makumba (Oreochromis shiranus) which is well distributed across the country, but it has low growth rates. However, where total quantity is more important than individual size, this fish is recommended because it has the capacity to feed efficiently on phytoplankton in fishponds. The makumba has four anal spines, lacks a genital tassel, and ripe males have a bright red margin on the dorsal fin. Makumba breed easily under pond conditions and reach sexual maturity at an early stage (around 20g). Chilunguni (Coptodon rendalli) is indigenous to Malawi and is well adapted to all water bodies of Malawi.

However, it is not widely distributed among farmers in Malawi. This fish is commonly described as a red-breasted tilapia and is known by several local names, including Chilunguni, nyungusale, katakuzi, nyakalua, mgoma mbungu, and many others. The Chilunguni is brightly coloured with 5-7 olive vertical bars, a bright red spot on the throat and breast, and a distinct black spot on soft dorsal rays called "the Tilapia spot." Makakana (Oreochromis mossambicus) is a dull greenish or yellowish, and weak banding coloured oreochromine cichlid. It is laterally compressed, and has a deep body with long dorsal fins, the front part of which has spines. It is a freshwater and brackish water inhabitant. It lives in warm, weedy pools of sluggish stream, canals, and ponds. It is omnivorous, and feeds on almost anything from algae to insects but also crustaceans, and fishes. Mlamba (Catfish – Clarias gariepinus) can be grown successfully in combination with other species like makumba and makakana. Combining mlamba with either makumba or makakana improve the growth of both species because its cannibalistic nature controls the makumba or makakana population. Mlamba is rarely reared together with Oreochromis karonage and Coptodon rendalli due to the fact fingerlings of these two species delays its breeding and fingerlings are sometimes a challenge. The fish is characterized by a large flat armored head, with no spine in the dorsal fin. It has a long base with no scales.

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Classification of aquaculture systems

2

INTRODUCTION

Aquaculture systems range from very extensive, through semi-intensive and highly intensive to hyper-intensive. When using this terminology the specific characterization of each system must be defined, as there are no clear distinctions and levels of intensification represent a continuum. The selection of an aquaculture system to adopt in a particular project, is determined by several factors including the following: (i) project objectives and target users, (ii) marketability of culture species, (iii) availability and level of technology, (iv) availability of production inputs and support facilities and services, (v) investment requirements, and (vi) environmental considerations. In this session we are going to discuss how different types of aquaculture systems are classified.

AIM

The aim of this chapter is to provide trainees with knowledge and understanding of the different aquaculture systems, their advantages and disadvantages of each system over the other. The participants will also gained knowledge and understanding of enclosed and open water fish culture facilities.

Objectives

· Participants know
- Different aquaculture systems
- Advantages and disadvantage of each system
- Open and closed culture systems

Acquired skills

- Classifying aquaculture systems
- Stocking densities for different culture systems

· Acquired attitudes
- Aquaculture is a profitable enterprise worth practicing

· Relevance to fish production
- Fish farmers should be aware of the different production systems as this will help them know the different needs and challenges as these affects the success of the aquaculture enterprise.

· Session Overview: This chapter has one session which looking at the different aquaculture systems, their challenges and also the open and closed culture systems.

· Materials: Flip- chart paper, markers, study notes, posters

· Mode of delivery: Lectures and group discussions

· Duration : 60 minutes

2.1 Classification on the basis of intensification

An important characteristic feature of aquaculture is its intensification. Intensity is defined by a number of parameters like facility size, stocking density, feeding/manuring, water quality management, yield etc. There are three main categories of aquaculture based on intensification as follows:

2.1.1 Extensive

This is the adoption of traditional techniques of aquaculture e.g. dependence on natural productivity and little control over the stocks. Herbivores fish species suit very well in this category. It is the least managed form of farming system and it is characterized by large ponds ranging from 1 to 5 ha in area. Stocking density is >0.5 pcs/sq m (Fish) and no supplemental feeding or fertilization is provided. Harvest is about 500 to 2000 kgs /ha

2.1.2 Semi-intensive

This is the adoption of mid-level technology, partial dependence on natural productivity, fertilization, supplementary feeding, with stock manipulation, medium level inputs and medium rate of production. The fertilizer increase natural food and/or supplementary feed are given. Stocking density is higher due to improved nutrition which leads to a corresponding higher yield. Culture facilities can be smaller than in extensive culture, smaller ponds of 0.5 to 1 hectare in area. Stocking density can range from 10000 to 15000 fish/ha. Natural food is developed by fertilization and with or without supplemental feeding. Harvest ranges from 2500 to 10000 kgs of fish. Examples of semi-intensive culture are the ones practiced by most small scale fish farmers in Malawi.

Many Malawians are practicing semi-intensive aquaculture due to land limitations. The average land holding size per household in Malawi is 1.2 hectares while average land per capita is 0.33 hectares (GoM 2010). This means that size of the land does not really require one to have ponds of more than a hectare to be in the semi-intensive category but the level of inputs and management invested.

2.1.3 Intensive

This is the adoption of full complement of culture techniques including scientific pond design, fertilization, supplemental feeding or only feeding without fertilization; full measure of stock manipulation, disease control, scientific harvesting, high level inputs and high rate of production. Intensive fish farming system is a well-managed form of fish farming. To achieve maximum production of fish from a minimum quantity of water, this system involves small ponds, tanks or raceways with very high stocking density (10-50 fish/m3 of water)

2.2 Classification on the basis of salinity

2.2.1 Freshwater farming

This is the farming of aquatic animals and plants in zero saline water. Since Malawi is a landlocked country and has only inland waters, this is the type of aquaculture that is practiced.

2.2.2 Brackish water farming

Brackish water is a mixture of seawater and freshwater with a salinity of less than 30ppt. Estuaries, backwaters, creeks and mangrove waterways are brackish in nature

2.2.3 Marine water farming

This involves farming of aquatic animals and plants in sea water. It is also referred to as Mariculture

2.3 Classification on the basis of number of species stocked for farming

2.3.1 Monoculture

In this type of fish farming, only one fish species is reared in a culture system. The simplest (to manage) and most reliable grow-out system of stocking fish is the monoculture of tilapia (especially Oreochromis shiranus – makumba, Oreochromis mossambicus – makakana). Tilapia has a remarkable ability to utilize a wide variety and large proportion of available food items within the pond, feeding on phytoplankton, detritus, soft macrophytes, and sometimes zooplankton and insect larvae. Catfish grown in a monoculture system as it does well.

2.3.2 Polyculture

This type of culture involves two or more different fish species in one rearing facility. Polyculture is normally practiced in ponds. Polyculture practices give higher yield than monoculture. The principal requirements of different species for polyculture are that the fish should have different feeding habits, occupy different columns in a pond system, attain marketable size at the same time and display non predatory behavior.

Polyculture can also be used as a way of controlling prolific brooding in tilapia when mixed sex fingerlings are stocked in a grow-out pond. If not properly managed, after a month or two tilapia of even less than 20g can reach maturity, breed and can quickly over populate a pond. Stocking a few predator fish like catfish at 5–10% of tilapia population will help to control over population. In this case, farmers can sell the grown mlamba at the harvest, and therefore, the would-be wasted resources were converted to mlamba body to recoup the economic value. This intended predation on the tilapia fry is not a mainstream technique for achieving the goal, though.

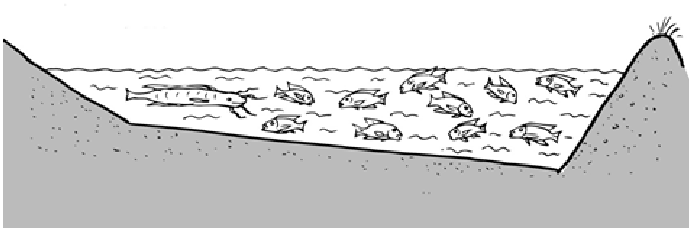


Fig 2.1 a polyculture of catfish and tilapia (makumba or makakana)

An alternative solution is to stock an all-male tilapia population. Male tilapia takes longer to reach maturity than females and single sex prevents breeding in the pond. All male fingerlings can be acquired from certified hatchery operators doing sex reversal. Hand sexing of tilapias is another alternative of having all males.

Socioeconomics of Polyculture

Polyculture has been practiced for a long time for socioeconomic reasons. It is said that polyculture is always the best method, although monoculture systems dominate commercial farming. Well-managed polyculture systems could result in high profits but it will largely depend on the management

– it needs to be done properly, understanding the requirements of each species. A farmer who wants to practice polyculture needs to understand the disadvantages as well so that he or she can either avoid or overcome them.

- **Advantages**
  - Maximum utilization of available food in the culture system, which results in the highest production per unit of culture system.
  - Farmers can enjoy different species if they consume at home.
  - Fewer risks as some species may still survive if there is water quality or any management problems.
  - Less risk of market price fluctuation. If the price of one species is low, the price of another species may still be high.
  - Low feeding costs are possible because fish mostly consume natural food from various parts of the culture system such as the bottom, column and surface.
- **Disadvantages**
  - Relatively more complicated and difficult to manage.
  - Farmers have to know about the culture methods of more than one fish species.
  - Farmers need to worry about marketing

many species, and it is sometimes difficult to find a good price for all the culture species.
- The total cost of management and operation is high because it requires additional items, facilities and skillful people.

2.4 Classification on the basis of enclosure used for culture

2.4.1 Pond culture

This is a very common method of fish culture in Malawi and other parts of the world. Water is maintained in an enclosed area by artificial construction of dike/ bund.

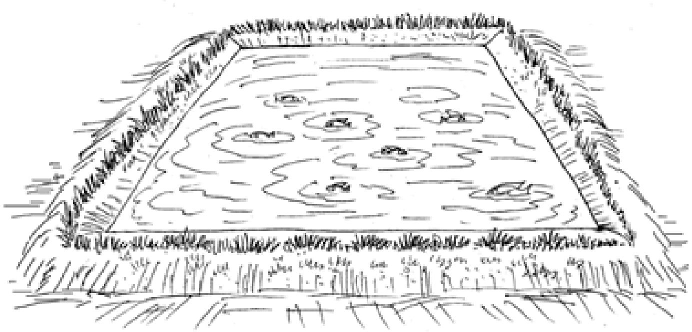


Fig 2.2 Fish pond culture

i. Advantages

- Low investment cost
- Less labour demanding
- Easy to manage

ii. Disadvantages

- Possibility of theft
- Relatively low production
- High water consumption (low stocking densities)
- Chemical contamination

2.4.2 Cage culture

This involves rearing of fish from juvenile stage to commercial size in a volume of water enclosed on all sides. Cage culture is suitable to water areas which cannot be drained like lakes.

Advantages of Cage Culture

- Effective use of existing water bodies
- Technically simple
- Lower capital cost
- Easier stock management and monitoring

Disadvantages of Cage Culture

- Vulnerable to external water quality problems eg. Algal blooms, low oxygen etc.
- Stock is more vulnerable to predators such as birds.
- Growth rates are significantly influenced by ambient water parameters
- High investment cost

Fig 2.3 Cages

2.4.3 Pen culture

Pen culture is defined as raising of fish in a volume of water enclosed on all sides except bottom. This system can be considered a hybrid between pond culture and cage culture.

i. Advantages

- Intensive utilization of available space
- Suitability for culturing many varied species
- Ease of harvest
- The flexibility of size and economy
- Availability of natural food and exchange of materials with the bottom

ii. Disadvantages

- High demand for oxygen and water flow
- Pollution

- Rapid spread of diseases
- Risk of theft
- Conflict with multiple use of natural waters

2.4.4 Raceway

Raceway culture is defined as raising of fish in running water. Raceways are designed to provide a flow-through system to enable rearing of much denser population of fishes. There are two different types of raceways as follows:

a) Linear type

- Ponds arranged in sequence
- The volume of water entering each pond is larger as the same water is used repeatedly from pond to pond
- Occurrence of disease in initial ponds may directly affect the other connected ponds

b) Lateral type

- Ponds laid out in parallel
- The volume of water entering each pond is smaller but a fresh supply of water is always ensured.
- There is no transfer of disease from one pond to another.

i. Advantages

- High stocking density and high yields produced per unit area

ii. Disadvantages

- Needs continuity of water supply
- High investment cost

Fig 2.4 Raceways

2.4.5 Recirculating Aquaculture System (RAS)

A Recirculating Aquaculture System (RAS) can be defined as an aquaculture system that incorporates the treatment and reuse of water with less than 10% of total water volume replaced per day.

Recirculating aquaculture systems (RAs) were initially designed to maintain water temperature within the production unit

The basic components of the RAS are the:

i) Biofilter to remove soluble waste, mainly ammonia
ii) Production tank(s) for fish rearing
iii) Filtration unit comprising a sedimentation tank and filter to non-soluble waste particles

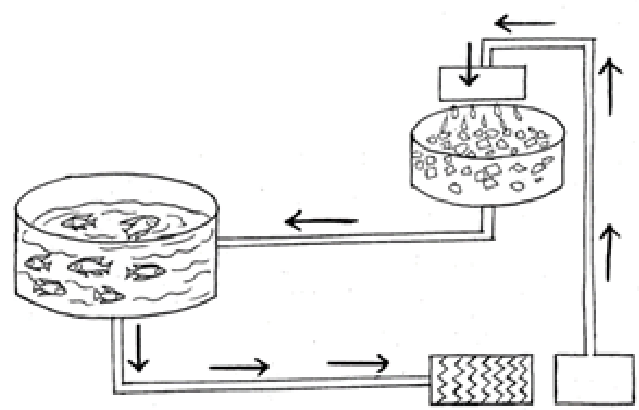


Fig 2.5 Key components of a RAS system

2.4.6 Aquaponics

Aquaponics system refers to a food production system that couples aquaculture with hydroponics. The nutrient rich aquaculture water is fed to hydroponic grown plant, involving nitrifying bacterial for converting ammonia into nitrates. The system therefore is a closed-system permaculture with three components: Fish, Plants and Bacteria. These three components live side-by-side and work together to create an environment that is mutually advantageous. This means that the correct balance of each is required for the system to be healthy and functional. An aquaponic system functions when bacteria process fish waste, converting it into nitrates. This provides the plants with the nutrients they need to grow in a highly accessible form. The aquaponics cycle begins when fish are fed, and create waste. This waste is largely ammonia, which can be fatal to fish at high levels. Therefore, nitrifying bacteria break it down into plant food. In absorbing this food, plants filter the water, which is then returned to the fish tank.

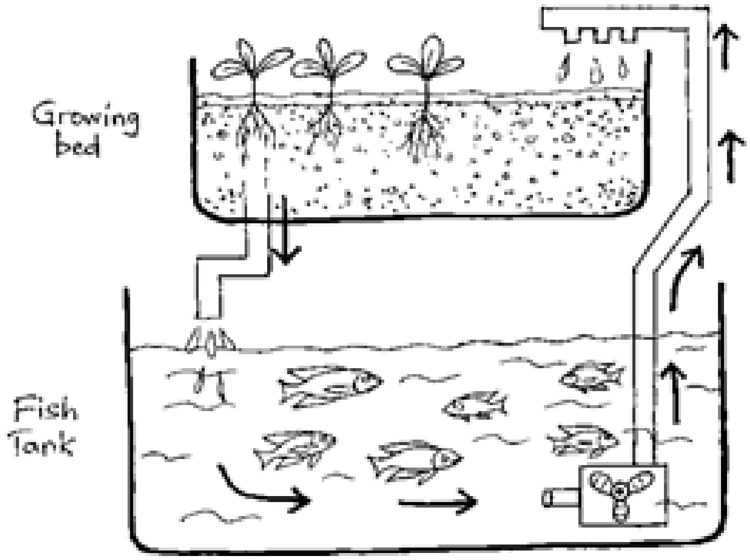


Fig 2.6 An Aquaponics system

2.5 Classification on the basis of different farm integration

Integrated agriculture aquaculture (IAA) systems are operated with the objective of optimizing nutrient cycling on the farm in order to increase overall farm production and productivity. Waste from one activity is converted into a resource for another activity. IAA leads to increased diversification, intensification, improved natural resource efficiency, increased productivity and increased sustainability.

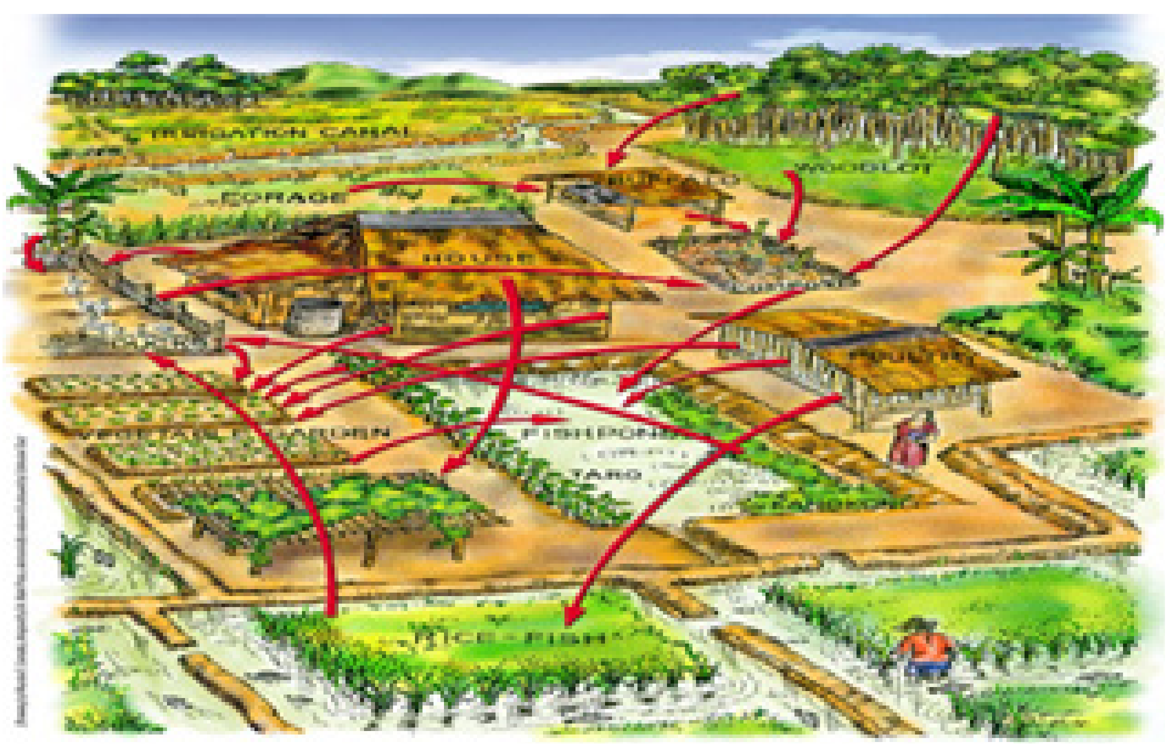


Fig 2.7 the IAA Model

Components of a well implemented IAA complements each other and it is a better way of managing available resources for improved production and increased incomes. In order to further improve resource utilization like water, feed and labour, there is need to use improved Integrated Agriculture Diversified farming Systems designs as they will allow matching resource use like water user with its availability. These designs focus on reducing water conflicts, increasing water productivity and maintaining environmental flows in areas where farmers have constructed river diversions. Some of the key characteristics of these designs include: (i) climate smart agriculture practices that promote minimum tillage and crop residue usage, (ii) intensification of production through adoption of best management practices for crops and fish as a means of increasing water productivity, (iii) drip irrigation, tank culture of catfish, early maturing maize varieties and use of hanging home gardens where vegetables are grown in vertical containers close to the homestead and irrigated with minimum amounts of water. This reduces quantity of water required to produce marketable produce, (iv) rainwater harvesting and improved wells to reduce water abstraction from rivers.

2.5.1 Types of Integrated agriculture-aquaculture systems

There are three major types of integrated fish farming systems and these include:

a) Livestock /poultry cum fish farming
b) Crop cum livestock cum fish farming
c) Crop cum fish farming

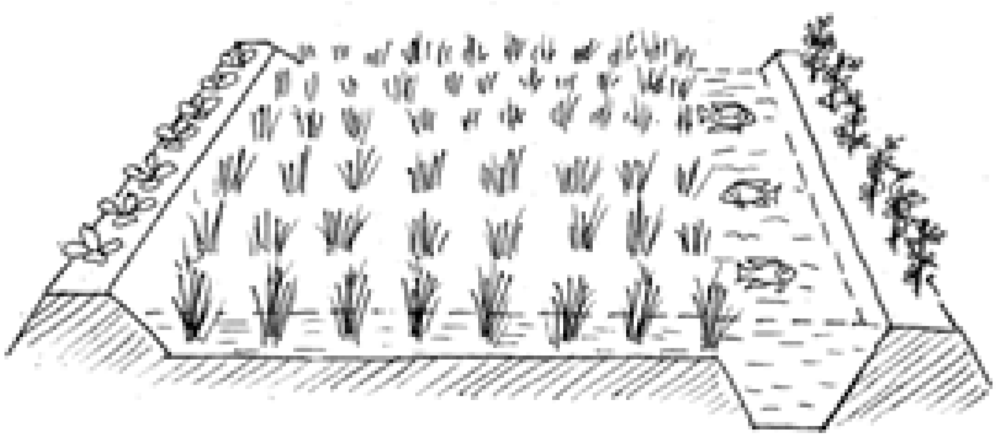


Fig 2.8 Rice fish integration

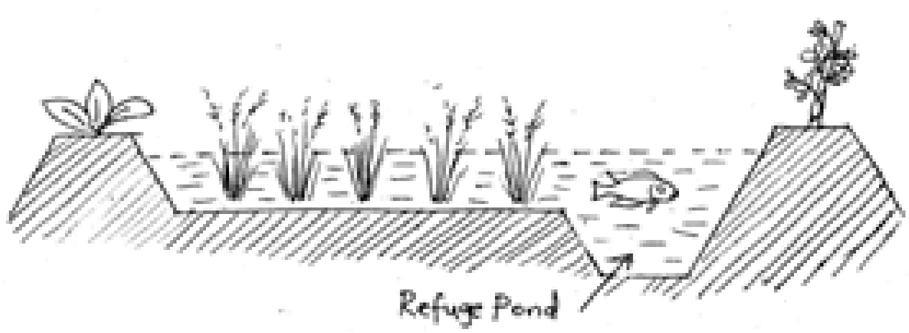


Fig 2.9 a refuge area in a fish rice integration pond

Summary

The chapter has classified aquaculture systems basing on a number of factors like intensification where intensification has been defined by a number of parameters like facility size, stocking density, feeding/manuring, water quality management, yield etc. There are three main categories of aquaculture based on intensification and these are (a) extensive which termed as an adoption of traditional techniques of aquaculture as it is dependent on natural productivity and little control over the stocks, (b) Semi-intensive which is an adoption of mid-level technology, partial dependence on natural productivity, fertilization, supplementary feeding, with stock manipulation, medium level inputs and medium rate of production.

Many Malawians are practicing semi-intensive aquaculture due to land limitations. The third one (c) is intensive which is the adoption of full complement of culture techniques including scientific pond design, fertilization, supplemental feeding or only feeding without fertilization; full measure of stock manipulation, disease control, scientific harvesting, high level inputs and high rate of production.

Aquaponics, raceways, recirculating systems and cages have been highlighted as other fish farming systems and they require high investments

Classification on the basis of number of species stocked for farming has been seen. These include (a) mmonoculture where only one fish species is reared in a culture system. The simplest (to manage) and most reliable grow-out system of stocking fish is the monoculture of tilapia (especially Oreochromis shiranus – makumba, Oreochromis mossambicus – makakana). The other one (b) is polyculture which involves two or more different fish species in one rearing facility. Polyculture is normally practiced in ponds.

Classification on the basis of enclosure used for culture and integration has been presented. Integrated farming systems have traditionally been practiced and generally accepted to be a sustainable farming practice, but it requires careful management. Various forms of integrated farming are still practiced and the include fish-poultry, fish-livestock, fish-rice and fish-vegetable amongst others.

Water Quality Characteristics

3

INTRODUCTION

In aquaculture, water quality refers to all the physical, chemical and biological attributes of water that affects yields. The physical and chemical characteristics of water directly affect fish physiology and consequently its production performance. When water quality is suboptimal, fish become stressed. This results into poor growth, ill health and mortality. As fish lives and performs everything in water, understanding good water quality for fish is therefore important. It will not only help the fish to eat but to use its energy to grow. This will help the farmers to spend less for good growth of the fish.

AIM

The purpose of this chapter to is provide participants with some background knowledge and understating on the different water quality parameters for good fish growth. The chapter tries to enhance participants' skills in water quality management who, at various times are confronted with water quality problems and issues.

Objectives

- Participants know
  - Different water quality parameters that affect fish
  - The impacts of different water quality parameters on fish growth and health

Acquired skills

- Measuring different water quality parameters
- Using Secchi Disc
- Good fish feeding and pond fertilizing skills

- Acquired attitudes
  - Selecting a good site with good water quality will enhance fish growth
  - Good water quality is key to good fish growth and maintaining a healthy fish crop

- Relevance to fish production
  - Good water quality leads to increased incomes as there is good growth for fish, they are not stressed and not making them not vulnerable to pathogens and diseases

- Session Overview: This chapter has one session which looks at water quality, its impact to fish growth, good husbandry practices to maintain good water quality and how to measure water quality

- Materials: Flip- chart paper, markers, study notes, posters, secchi disc

- Mode of delivery: Lectures, group discussions, practical

- Duration: 90 minutes

1.1 Water quality

Water quality is the summation of all physical, chemical, biological, and aesthetic characteristics of water that influence its beneficial use. And water quality in aquaculture is any characteristic of water in production systems that effects survival, reproduction, growth, and production of aquaculture species, influences management decisions, causes environmental impacts, or reduces product quality and safety can be considered a water quality variable. Other factors being equal, aquaculture species will be healthier, production will be more efficient, environmental impacts less, and product quality better in culture systems with “good” water quality than in those with “poor” water quality. Knowledge of water quality principles will help the fish farmer

- Determine the potential of a water body to produce aquaculture species,
- To maintain or to improve water quality in the culture system,
- To minimize problems of fish stress and fish health,
- to produce higher-quality fish farming products,
- To reduce environmental impacts of effluents,
- And to realize more efficient production and greater profits.

The physical and chemical characteristics such as suspended solids, temperature, dissolved gases; pH, mineral content and presence of toxic material in water are largely influenced by water source. Site selection, weather conditions, facility design and production management all affect water quality during production. Hydrological aspects such as water low rates and volume are all important for water quality management

Fig 3.1 Activities in a catchment affects water quality

1.2 Water quality parameters and their impact on fish growth and survival

1.2.1 Water Quality Monitoring

Monitoring water quality is quite important but if cage culture is carried out in communal water bodies, there is no way that a farmer or a group of farmers can control or improve the water if the quality deteriorates. The following water quality parameters should be monitored or analysed on a regular basis, preferably weekly:

- Temperature (°C or F);
- DO (mg/l);
- pH;
- Salinity (ppt), if the site is in a brackish water area; and
- Chlorophyll or Secchi disc visibility.

1.2.2 Water Quality parameters and the growth, health and survival of fish

The main water quality parameters affecting growth of fish are temperature, light, permanent chemical constituents in the water such as salts and organic compounds, oxygen concentration and the presence of fish metabolites which inhibit growth.

i. Temperature

Temperature is a pacesetter. The warmer the temperature, the faster the decomposition of organic matter and fish metabolism implying a higher demand for oxygen. However, the solubility of oxygen in water falls with an increase in temperature. Water temperature in ponds and outdoor tanks is influenced by ambient temperature and frequency of water exchange.

Growth rates of fish as such are also influenced by water temperature. Tilapias are susceptible to cold water temperatures, and will not over-winter in most temperate climates. Most hybrid tilapia will stop eating at water temperatures below 16°C, and will begin to die at around 13°C. Water temperatures between 25-32°C are preferred for raising hybrid tilapia in intensive culture.

ii. Dissolved oxygen (DO)

Dissolved oxygen is the most important factor controlling growth, and constant dissolved oxygen content below a critical level is considered to reduce food consumption (food conversion efficiency) and growth. The dissolved oxygen of water is limited to a few mg/l in contrast to the 21% oxygen content of the air. Increasing dissolved oxygen content allows for higher stocking densities in the production facilities.

The oxygen concentration has an effect on daily feeding rates and total food consumption. Growth of fish is largely dependent on consumption of feed, its assimilation and conversion into body tissues. Furthermore, reduced feed consumption resulting from lower dissolved oxygen concentrations means a significantly reduced growth rate even if feed conversion ratio is not affected.

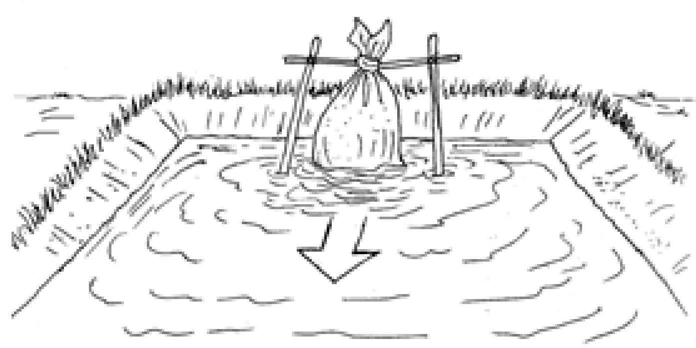


Fig 3.2 Good fish feeding and Fig 3.3 Good pond fertilizing helps maintain good water quality

Monitoring the pond to measure DO should be done in the morning and afternoon. More desirable time to measure Dissolved Oxygen (DO) and temperature in the pond is 06.00 hrs (morning) and 14.00hrs (afternoon). The fish may be seen gulping for air on the surface or swimming towards the inlet because the incoming water will be carrying fresh air. To correct this situation, stop adding fertilizers and add more water into the pond. Checking fish activity if they are in good condition is a good practice. There is need to flush the water if fish are swimming sluggishly, swimming in an irregular manner or look excited.

iii. Turbidity

Turbidity is the relative clarity or cloudiness of water due to suspended solid particles dispersed within the water column. Suspended solids are usually visible to the naked eye and may be organic or inorganic. In ponds, turbidity from green water is good indication of pond productivity. However, in indoor tanks, clear water is preferred. A simple way to check the pond's turbidity is by dipping a hand to the elbow level in the pond water. If one is able to clearly see the palm of the hand, then the pond needs to be fertilized. If you faintly see the hand, then its good water quality but if you don't see the hand after dipping, the pond is over-fertilized. You need to flush the water or topping up. You can also use a Secchi Disk to measure the turbidity of water.

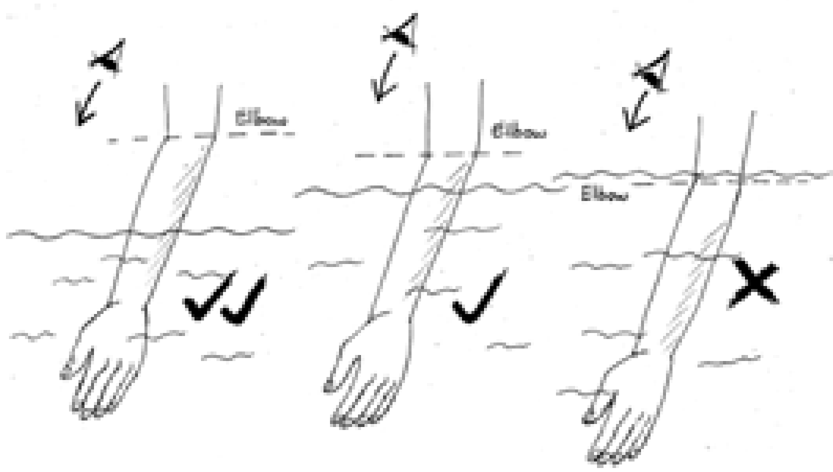


Fig 3.4Using hand to measure turbidity

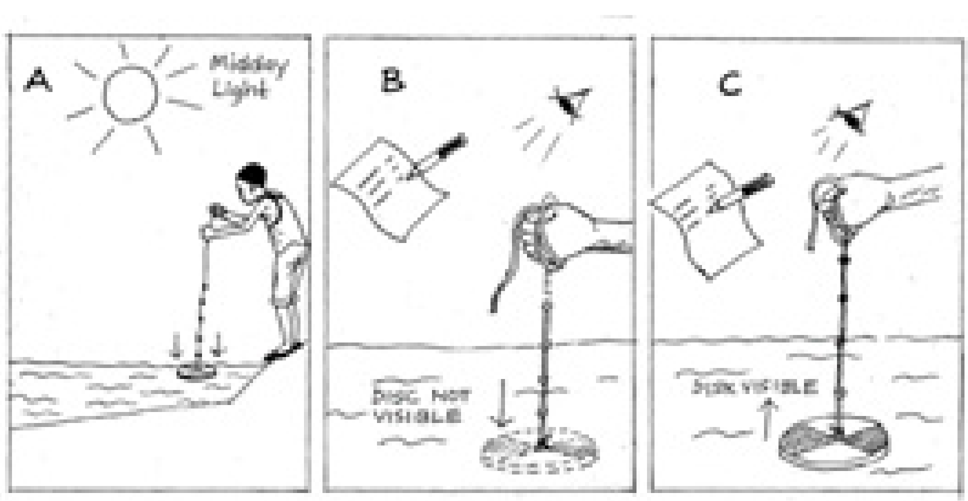


Fig 3.5 Using to Scecchi disc to measure turbidity

Table 3.1 Interpretation of Secchi disc visibility

Secchi disc depth (cm)	Comments
Less than 20 cm	Pond too turbid. If pond is too turbid with phytoplankton, there are likely to be prob lems with low dissolved oxygen concentrations early in the morning. When turbidity is from suspended soil particles, productivity will be low
20 – 30 cm	Turbidity becoming excessive
30 – 45 cm	If turbidity is from phytoplankton, pond is in good condition
45 – 50 cm	Phytoplankton becoming scarce
More 60	Water is too clear. Inadequate productivity

iv. pH

pH affects the solubility and chemical forms of various compounds some of which can be toxic. In general, tilapias can tolerate a pH range of 6 to 8.5 but cannot survive a pH range below 5 as well as a pH above 11. When pH is outside the range, fish are stressed, growth is reduced, feed intake is reduced and there is higher feed conversion ratio (FCR)

v. Ammonia

Ammonia is the by-product of protein metabolism by fish and bacterial decomposition of organic matter. Ammonia occurs in two forms depending on the acidity of the water. The unionised form of ammoia (NH3) is more dominant when the water is alkaline and the ionised form, ammonium (NH4) when the water is acidic. Total Ammonium Nitrogen (TAN) is the combined measure of the two.

Fish biomass excretes catabolites, especially ammonia which may accumulate in the pond thereby poisoning the fish and inhibit their growth. The appetite and growth of tilapia fingerlings is depressed at un-ionized ammonia concentration as low as 0.08mg/l. However, the total ammonia requirement for tilapia growth ranges between 0.5 to 1 mg/l.

Table 3.2 Most desired values of some water quality parameters in tropical and subtropical aquaculture (boyd, 1979, wetzel, 1983).

Parameter	Value
Oxygen (mg/1)	>5
pH	7–8
Carbon dioxide (mg/1)	0–10
Ammonium (mg/1)	<0.6
Hydrogen sulphide	Absent

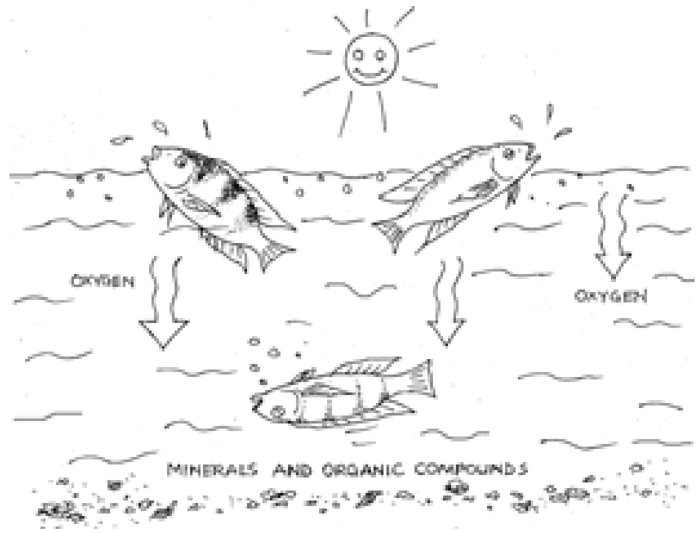
1.2.3 Impact of water quality

i. Impact of water quality on fish growth

Fish performs all its activities in water. And fish growth depends on water quality. Proper feeding of fish and levels of pond fertilization work together to make efficient and effective increase in fish production at all times. Poor management of these things will negatively affect the water quality. Good or poor water qualities will therefore positively or negatively affect fish growth and even reproduction. Waters ranging in pH from 6.5 to 8.5 are generally the most suitable for fish production. Most cultured fish will die in waters with pH below 4.5 and 10 or above. Fish reproduction and general performance can be greatly affected at pH below 6.5 and above 8.5. In the presence of environmental stress such as low dissolved oxygen, high temperature and high ammonia, the ability of the fish to maintain its internal environment (i.e metabolism, catabolism and reproduction) is reduced. They become less active and consume less food. Therefore monitoring of water quality parameters which include temperature, dissolved oxygen (DO2), dissolved carbon dioxide (DCO2), pH, conductivity, chemical oxygen demand (COD) and biological oxygen demand (BOD) is very important.

ii. Impact of water quality on fish health

Water quality is the most important factor affecting fish health and performance in aquaculture production systems. Fish live and are totally dependent on the water they live in for all their needs. Different fish species have different and specific range of water quality aspects (temperature, pH, oxygen concentration, salinity, hardness) which they can survive, grow and reproduce. Within tolerance limits, each species has its own optimum range, that is, the range within which it performs best. In stressed conditions, due to poor water quality, fish tissues most especially gills are damaged, and hemorrhages may occur in the gills and on the lower part of the body. Water temperatures also have a great influence on the initiation and cause of a number of fish diseases. Sudden temperature changes should be avoided in fish ponds as fish may die, showing symptoms of paralysis of respiratory and cardiac muscles. We should avoid constructing smaller and shallow ponds as they are often affected by sudden temperatures changes. And it is very important for fish farmers to ensure that the physical and chemical conditions of the water remain, as much as possible, within the optimum range of the fish under culture all the time. Outside these optimum ranges, fish will exhibit poor growth, erratic behavior, and disease symptoms or parasite infections.



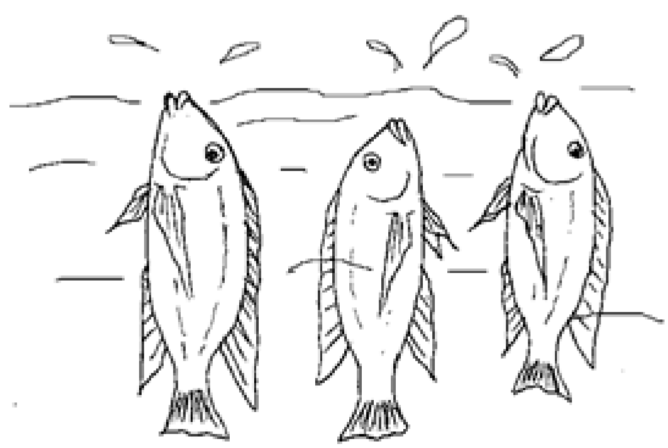


Fig 3.6 and Fig 3.7 Too much minerals and organic compounds affects fish health

1.3 Methods of maintaining good water quality

To maintain good water quality, a fish farmer has to follow the following things

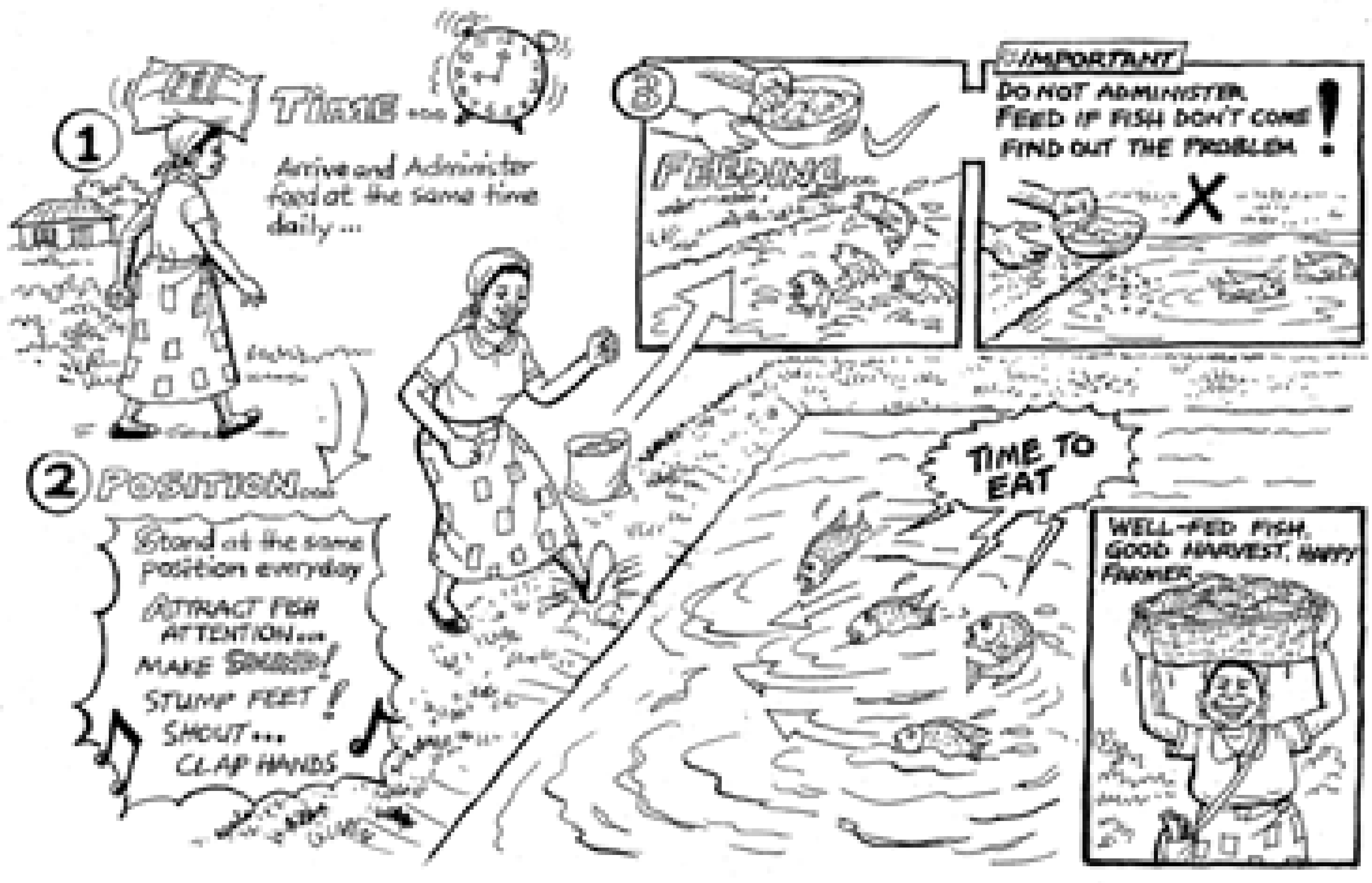


Fig 3.8 Good aquaculture husbandry to maintain good water quality

- Good site selection to ensure a water supply of adequate quality, control of suspended solids in incoming water,
- Liming ponds to neutralize acidity,
- Proper fertilization to enhance phytoplankton growth,
- Regulation of stocking and feed rates,
- Control over feed quality and feeding techniques,
- Mechanical aeration,
- Water exchange,
- Proper use herbicide and algicide
- Treatment of effluents by sedimentation or wetlands.

Table 3.3: implications of Secchi disc visibility or depth

Secchi disc depth (cm)	Remarks	Recommendations
<20	Too green	Stop fertilization and feeding for 1 week
20 – 30	Very green	Stop fertilization and reduce feed
30 – 40	Appropriate	Feed and fertilize normally
50	Too little plankton	Increase fertilization rate

Summary

Water quality in aquaculture is any characteristic of water in production systems that effects survival, reproduction, growth, and production of aquaculture species, influences management decisions, causes environmental impacts, or reduces product quality and safety can be considered a water quality variable. Other factors being equal, aquaculture species will be healthier, production will be more efficient, environmental impacts less, and product quality better in culture systems with "good" water quality than in those with "poor" water quality.

When selecting a site for fish farming, the quality of the source water should be carefully evaluated. Natural water quality may not be adequate, and treatment may be necessary to correct water quality problems. For example, if ponds are built on highly acidic soils, water in ponds may be so acidic that heavy liming is required. Water sources also may be highly polluted from anthropogenic sources, and this pollution can have serious effects on production. Investors should consider water quality limitations at a prospective site and estimate the cost of overcoming these

Once it is decided to start an aquaculture project at a given site, the next problem with water quality arises from water quality deterioration caused by management inputs to enhance production. The most common and problematic inputs are manures, fertilizers, and feeds needed to increase production. These nutrient sources result in greater production, but they also lead to dense phytoplankton blooms, dissolved oxygen depletion, and increased concentrations of toxic metabolites. As the production level increases and water quality deteriorates, water-treatment methods such as aeration, water circulation, and water exchange must be used to maintain tolerable culture conditions. Even with water quality management inputs, the efficiency of production cannot be maintained at a constant level as production rises. The objective in aquaculture, as in other businesses, should be to optimize profits and reduce risks instead of maximizing production. Periodic water monitoring of water parameters such as pH, temperature, dissolved oxygen and Chlorophyll or Secchi disc visibility must be done.

The Pond Ecosystem

INTRODUCTION

A healthy pond is an ecosystem where a great diversity of animal and plant species may be found. An ecosystem is a basic unit in the ecology, formed by the interaction of plants, animals and microorganisms forming biotic factors with their physical environment or the abiotic factors. A pond ecosystem refers to the freshwater ecosystem where there are communities of organisms that are dependent on each other and with the prevailing water environment for their nutrient survival. In a pond, any change in the water may affect the plants and animals living in there. If people pollute the water, some plants and animals may die. Therefore, a pond ecosystem refers to the fresh water ecosystem on which different organisms depend for their survival to fulfill their nutritional needs. Ponds have a specific depth which allows sunlight to reach its bottom, permitting the growth of plants that grow in there. The components of a pond ecosystem includes both biotic and abiotic. Biotic (living) fish, aquatic animals, microbes, plants, phytoplankton and this follows a food chain. Abiotic (nonliving) and includes physical and chemical interactions. Pond ecosystem is a balance of fish, bacteria and plants which all support each other. Pond ecosystem works well in ponds which are allow the penetration of sunlight through it. A pond ecosystem is a living ecosystem itself.

AIM

The aim of this chapter is to help the participants understand the components of a pond ecosystem which includes both biotic and abiotic, their relationships and their impacts on fish survival and growth. The chapter will further help the participant to acquire skills on how to measure and deal way with pond turbidity.

Learning Outcomes for module

Upon completion trainees should:

Session Overview

This chapter is divided into three sessions namely:
Session 1: The main components of a pond ecosystem
Session 2: Factors affecting pond productivity
Session 3: Turbidity in ponds

Mode of delivery: Lectures
Total time allocated: 60 minutes

Objectives

- Participants know
  - More about a pond ecosystem
  - Factors affecting pond productivity
  - The impacts of turbidity in ponds
  - How to improve pond productivity

- **Acquired skills_**
  - Controlling turbidity in ponds
  - Measuring turbidity

- Acquired attitudes
  - Fish farmers should always monitor the pond environment to ensure that fish are growing without much stress

- Relevance to fish production
  - A healthy environment will lead to good fish growth as they will go in a stress free environment not prone to pathogens and diseases.

- Chapter Overview: This chapter is looking at pond lay out, designing and construction.

- Materials: Flip- chart paper, markers, study notes, posters, Secchi disc, pH meter,

- Mode of delivery: Lectures, group discussions, practical

- Duration: 75 minutes

4.1 Main components of a pond ecosystem

4.1.1 Biotic

i. Producers

The main producers in pond or lake ecosystem are algae and other aquatic plants, such as azolla, hydrilla, potamogeton, etc. These are either floating or suspended or rooted at the bottom. The green plants convert the radiant energy into chemical energy through photosynthesis. The chemical energy stored in the form of food is utilized by all the organisms. Oxygen evolved by producers in photosynthesis is utilized by all the living organisms in respiration.

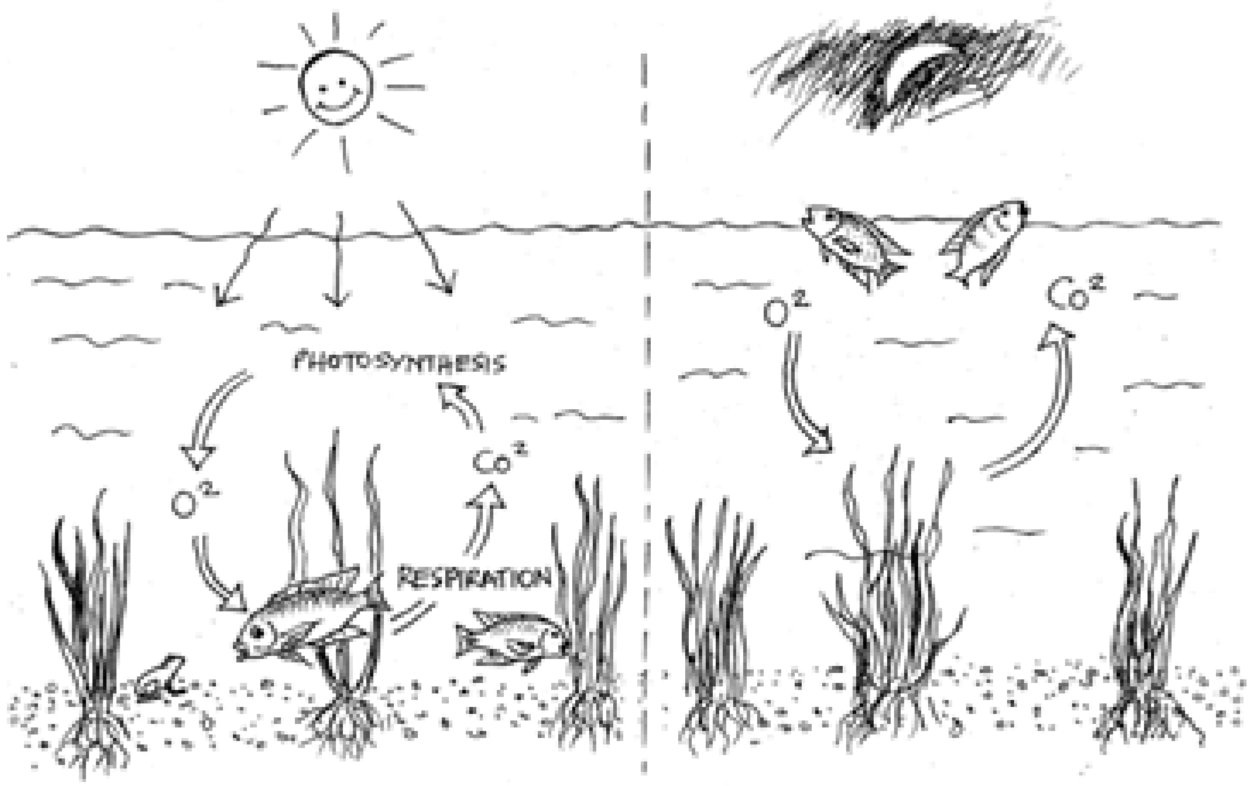


Fig 4.1 a pond ecosystem

ii. Consumers

In a pond ecosystem, the primary consumers are larvae of frogs, tadpoles, fish and other aquatic animals which consume green plants and algae as their food. These herbivorous aquatic animals are the food of secondary consumers. Frogs, big fishes, water snakes, crabs are secondary consumers. In the pond, besides the secondary consumers, there are consumers of highest order, such as water-birds, turtles, otters and monitor lizards.

iii. Decomposers and Transformers

When aquatic plants and animals die, a large number of bacteria and fungi attack their dead bodies and convert the complex organic substances into simpler inorganic compounds and elements. These micro-organisms are called decomposers; chemical elements liberated by decomposers are again utilized by green plants in their nutrition.

4.1.2 Abiotic

Abiotic factors are non-living factors that can have an impact on the ecosystem. The main factors of ponds include water quality, temperature, light, soil, and seasonal change. Water is an important abiotic factor as all the living aquatic things rely on it and its quality is crucial for living organisms in the pond. The temperature could impact the ecosystem if they are at the extremes. Water that is too warm will not have as much oxygen for the fish and they will in return become weak and prone to parasites and diseases. Too low of a water temperature also puts the aquatic ecosystem under stress and the fish can die off in large amounts. pH is also taken into consideration because too low or too high of acidity in the water can clog a fish's gills and reproduction will be more challenging. Good soils promote good productivity in the pond and also sustain life of the living things. Light is also an abiotic factor in this ecosystem. The plants need light for photosynthesis so they can produce oxygen not only above the water but below as well to sustain healthy oxygen levels for aquatic organisms. Fish also need light in the form of heat from the sun to keep the water at a regular temperature. The change of seasons has an impact on the pond.

4.2 Pond Productivity: Phytoplankton, zooplankton, algae

The presence of natural food produced in a pond is the result of interplay of various factors like climate and fertility status of the pond soil and water. Phytoplankton being the primary producers in an aquatic environment depends upon all these factors. Increase in primary production means increase in pond productivity. With the adoption of suitable management measures through fertilization, the fertility status of the pond soil and water could be maintained which will help in an increased primary production.

4.2.1 Factors affecting pond productivity

The pond bottom soil greatly influences the pond water for productivity. In ponds, not influenced by external factors, the physic-chemical properties of water which govern the biological production are more or less reflections of the bottom soil. Pond soils are formed on primary soils where the pond has been constructed. The productive potential of a particular soil is guided by its physical and chemical conditions. Soil texture is one of the important physical factors while soil reaction (pH) and nutrient status are the chemical factors which determine water holding capacity and productivity of the pond to a greater extent.

4.2.2 Soil reaction (pH)

The pH of the soil is considered one of the single important factors affecting pond productivity. It does not only influences the soil microbial activity but also affect the availability of nutrients to pond water – either native or when applied externally. Calcium ammonium nitrate, urea and ammonium sulfate are more effective in enhancing primary production; survival and growth of fish for moderately acidic, slightly acidic to neutral and alkaline soils respectively. In general, slightly acidic to slightly alkaline soil pH is considered favorable for productivity.

4.2.3 Nutrients

The various basic elements (carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, iron, sulphur, etc) need for the existence and nutrition of biologically productive organism in aquatic environment are obtained from the soils and atmosphere for the enrichment of pond water. Among these elements, nitrogen, phosphorous, carbon and potassium are of importance compared to calcium, magnesium, iron, sulphur, etc). Nitrogen being a basic and primary constituent of protein and chlorophyll is necessary for the formation of living matter in a larger quantity.

4.2.4 Nitrogen in Aquaculture Ponds

Nitrogen is a major nutrient affecting the productivity of aquatic ecosystems because it is an essential component of protein and other constituents of cellular protoplasm. Aquatic animals meet their requirement for nitrogen by ingesting food that is either produced naturally within the pond or supplied by the aquaculturist as manufactured feed. In pond cultures that depend on natural foods to support animal growth, nitrogen is important because it is a key plant nutrient that may be in short supply relative to the amount needed for rapid plant growth. In cultures provided with manufactured feed, nitrogen is important as a constituent of feed protein and as a waste product of animal metabolism. The nitrogen in animal wastes may contribute to the development of excessively high phytoplankton standing crops and may also lead to the accumulation of two nitrogen-containing compounds, nitrite and un-ionized ammonia, that can be toxic to aquatic animals at relatively low concentrations. Nitrogen is also of concern in aquaculture because waters discharged from ponds may be enriched with inorganic and organic combined nitrogen to the point where the discharge may degrade the quality of receiving waters.

Nitrogen may occur in water as dissolved nitrogen gas, various combined inorganic compounds, and as myriad organic compounds. Nitrogen is the major gas in the atmosphere; it constitutes 78.1 % of the total gases in the air. Nitrogen is not very soluble in water (about half as soluble as oxygen and more than 50 times less soluble than carbon dioxide), but because the atmosphere is so enriched with the gas, water in contact with air contains relatively high concentrations of dissolved nitrogen gas (Table 2.5). As with dissolved oxygen and carbon dioxide, the equilibrium concentration of dissolved nitrogen declines with increasing temperature and salinity.

4.2.5 Fertilization and feeding

Fertilization is a means of increasing fish production. The natural productivity of a pond can be greatly enhanced by the use of fertilizers. It stimulates the growth of natural food by providing some essential elements which might be found to be deficient in a pond. Elements added as fertilizers or manures are utilized by phytoplanktons which are the primary producers in aquatic environment. Nitrogen, phosphorous and carbon are the major important elements added to ponds either as inorganic or organic fertilizers. To obtain an economic return of added fertilizers or manures, suitable forms and optimal dosages are decided on the basis of soil texture, reaction and nutrient status of individual elements present in the soil so as to have a balanced aquatic environment for production.

In order to achieve better results of fertilization, inorganic fertilizers are preferred for highly clay soils rich with organic matter, while a combination of inorganic and organic fertilizers are suitable for loamy soils with moderate organic matter. Organic manures with a limited quantity of inorganic fertilizers are desirable for sandy or sandy loamy soils. The mode and frequency of application of fertilizers and manures are of significance for proper maintenance of nutrient levels for production of aquatic organisms.

Feeds applied to ponds to enhance production only can be partially converted to animal biomass. Thus, at moderate and high production levels, the inputs of nutrients and organic matter to culture units may exceed the assimilative capacity of the ecosystems. The result is deteriorating water quality which stresses the culture species, and stress leads to poor growth, greater incidence of disease, increased mortality, and low production.

Effluents from aquaculture systems can cause pollution of receiving waters, and pollution entering ponds in source water or chemicals added to ponds for management purposes can contaminate aquacultural products. Thus, water quality in aquaculture extends into the arenas of environmental protection and food quality and safety.

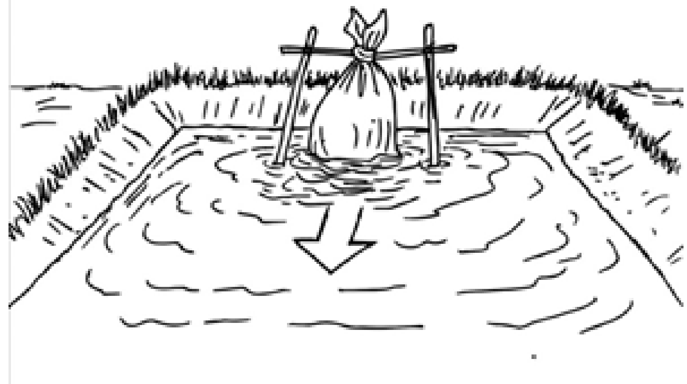


Fig 4.2 Suspended manure bag for pond fertilization Fig 4.3 Feeding affects pond productivity

4.2.6 Liming

Problems with low-alkalinity water and acidic bottom soils in ponds can be solved by liming. Application of liming materials is not a type of fertilization. Liming is a remedial procedure necessary in acidic ponds to improve conditions for growth and survival of aquatic animals and to enhance the response of plankton to fertilization. The first step in pond fertilization is the application of lime. Liming raise the soil pH to a desirable level (near neutral) for establishing a string buffer system, stimulates microbial decomposition of organic matter which favors mineralization of nitrogen and other nutrients from organic matter.

- Importance of liming
- Improves the structure of the soil in the pond
- Improves and stabilizes water quality
- Facilitates manure's ability to efficiently increase the availability of natural food.
- Lime helps to unlock nutrients from soils
- It reduces toxicity of harmful compounds including disinfecting the environment
- One of the most important effects, which can be measured and used to regulate liming, is that it modifies the total alkalinity of water in a pond
- Supply calcium (as $Ca2+$) and carbonates thus increasing carbon dioxide in water
- Prevent wide fluctuation of pH by establishing a buffer of $CO2$ -CHO- $CaCO3$.
- Counteract toxic effect of excess magnesium, sodium and potassium ions.
- Act as prophylactic by killing unwanted fish, bacteria and other fish parasites.

  Earth ponds are conditioned by liming, preparing the ponds and treating them with various types of enriching limestones which are chemical substances rich in calcium (Ca).Water's total alkalinity is the measurement of the total concentration of substances like calcium (Ca) and magnesium (Mg), which are typically alkaline, in carbonates and bicarbonates. Liming of ponds is not always necessary. It can be done on a new pond or a pond that is already in use. However, in certain cases, it can be both a waste of money and harmful to the fish. Before a decision is made, specific characteristics of the pond's water and soil should be studied carefully.

- The effects on the soil at the bottom of the pond are:
- Improved structure;
- Accelerated decomposition of organic matter;

- Increased pH.

All these factors will result in faster and more efficient exchange of minerals and nutrients between the soil at the bottom of the pond and the water, as well as reduced demand for dissolved oxygen

- The following points should be considered:

- If the pH of the soil at the bottom of the pond is lower than 6.5, liming is justified.
- If the bottom of the pond is very muddy because it has not been emptied and drained regularly, liming will improve soil conditions.
- If there is a risk of contagious disease or if you need to fight enemies of fish, liming can help, particularly in drained ponds.
- If there is too much organic matter, either in the soil at the bottom, or in the water, liming is advised.
- If the water's total alkalinity is lower than 25 mg/l CaCO3 liming is justified.

The lime requirement of ponds is the estimated amount of liming material needed to neutralize the acidity of bottom mud and increase the total hardiness and total alkalinity of the water the water to at least 2mg/l. According to the soil pH, lime at the following rates is usually applied:

pH	Dose of lime (CaCo3 kg/ha)
4.0 – 4.5	1000
4.5 – 5.5	700
5.5 – 6.5	500
6.5 – 7.5	200

These may be modified depending on the mechanical composition of soil. The dose may be increased or decreased by 50% for clay and sandy soils respectively.

4.3 Light penetration: pond depth, turbidity

Water pond depths have a bearing on fish as they affect fish growth, feed utilization, mortality rates, body composition and their breeding. Some studies have shown that growth performance and survival are significantly affected by pond depth and water temperature. Fish weight gain was lowest (250g per fish) feed conversion poorest (3.15), and mortality highest (41.5%) at 50cm depth, whereas 100 – 200cm depth produced the best growth rates at warm water temperatures (>21oC). At 100 – 200cm, weight gain was significantly increased to 243 - 362g per fish and mortality reduced to 21 – 27% (El-Sayed, et al, 1996). To indicate that depth has a bearing on mortality, the mortality rate significantly reduced at 300cm. studies done by Kapute et al (2016) indicates better growth of all fish species thus Oreochromis shiranus, Coptodon rendalli and Oreochromis shiranus in deeper ponds suggests that pond water depth is a management parameter which famers can adopt to improve fish growth irrespective of species. Unpublished results by JICA Project in a study which was done in Chingale showed that O. karongae and C. rendalli exhibited higher breeding performance in ponds that were more than a meter deep. Deeper ponds entail more water volume, that is, lower volumetric stocking density which provides more space and relatively more natural food for the fish. Implicitly, there was more available oxygen and low water deterioration rate from fish wastes. When surface water becomes warmer due to high temperatures, fish seek refuge at the deeper end to avoid stress (Walberg, 2011). This indicates that fish growth is greatly affected by pond depth.

4.3.1 Turbidity in ponds

Turbidity is caused by the presence of suspended particles and organic matter (flocs) in the water column. Pond water contains suspended solids of different kinds which have effects on the water turbidity. Turbidity caused by dissolved or suspended organic of inorganic solids, algae and other suspended substances can have an adverse effect on fish farming even on a cage culture system. The substances may originate from soil erosion, agricultural runoff, industrial or sewage discharge, presence of other fish species. They may have a direct toxic effect, or induce pH fluctuations, or may cause physical harm to the gills that trigger stress and secondary diseases. Prevailing high levels of turbidity will cause gill damage inducing the gill epithelium to proliferate and thicken. Turbidity levels below 100mg/l will cause little effect to most species.

Fig 4.4 poorly constructed dikes leads to high turbidity

With a 10% turbidity, light will reach the bottom of the pond. Water turbidity is caused by the presence of these suspended particles in varying quantities;

i. Mineral turbidity

This is caused by high content of silt and/or clay particles, which turn the water a light brown, sometimes reddish color. It may occur when the water supply is turbid or a bottom feeding fish stirs up the mud.

ii. Plankton turbidity

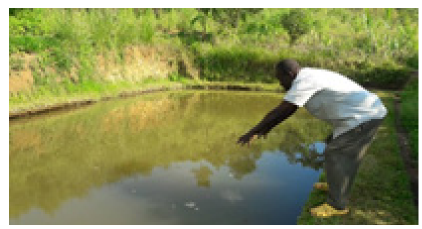
This is caused by a high content of minute plants and animals which color the water in various shades of brown, green, blue-green, depending on which plankton species is dominant. Algae or phytoplankton blooms are often responsible for sudden oxygen depletion in freshwater systems. Blooms typically develop during the warm months in areas receiving rich nutrients, particularly phosphorous influxes or upwelling of nutrients from lower depths. Under optimal conditions of high temperature, light levels and nutrient concentration heavy algae blooms may develop resulting in the oxygen depletion. In freshwater system the most problematic group of algae are the diatoms and cyanobacteria (blue-green algae), which often also cause an associated flavour in the flesh of the fish. Site prone to the occurrence of algal blooms must be avoided.

iii. Humic turbidity

This is caused by the presence of detritus, humus and dead organisms. Sometimes they can make water to turn to a dark brownish color. It can have its origin from the water supply, although it can be caused by an excess of organic matter entering the pond.

Mineral and humic turbidity reduce the amount of light that penetrates the water. With a 40% turbidity, light will not reach the bottom of a pond. In highly turbid waters, light penetrates only a short distance, and photosynthesis is reduced. Oxygen production during daytime is relatively small. Both the growth of fish and their natural food organisms can be badly affected. In addition, mineral turbidity can directly affect fish by injuring their breathing organs, reducing their growth rate or perverting their production.

4.3.2 Common pond water colors:

Colour	Meaning	Pond example
Red	Some plants can cause a reddish water colour, this can be a problem because it hinders sunlight to enter the water column	 Fig 4.5
Brown	Brown water is caused by mud and suspended particles which are entering the pond from the inlet	 Fig 4.6
Green	Green water is caused by phytoplankton which is preferred to have productive ponds and prevent predation by birds	 Fig 4.7
Deep Green	Deep green water is caused by excessive phytoplankton. This can lead to fish mortalities due to lack of enough dissolved oxygen. Stop fertilizing, flash and refill with fresh water	 Fig 4.8
Clear water	Not enough nutrients in the pond. Leads to growing of aquatic weeds, high predation and poor fish growth. Primary productivity has to be boosted by fertilization.	 Fig 4.9

4.3.3 How to measure turbidity

i. Secchi disc method

The Secchi disc transparency can be used as a simple method for measuring water transparency or turbidity in a fish pond. A secchi disc can easily be made by cutting out a circle of diameter 20 cm from a piece of wooden board or metal. Paint it white and black in equal quadrants. In the center, drill a small hole and pass a string or piece of wood through. Attach a small weight like a stone below the disk and graduate the piece of string or wood at 10 cm intervals.

Take Secchi disc Readings:

Step 1: Take secchi disc readings during the day at about mid-day when there is no shadow.

Step 2: Position yourself such that there is the least amount of shadow falling over the secchi disc. Hold the rope or board from which the secchi disc is suspended upright and release the secchi disc into the water, so that it is lying flat.

Step 3: Slowly lower the secchi disc into the water to the point where it starts becoming invisible and you cannot clearly see it. Read from the measurement.

Step 4: Slowly raise the secchi disc out of the water until it just starts to become visible. Measure this depth.

Step 5: Get the averages of these two readings. This will give you the secchi depth.

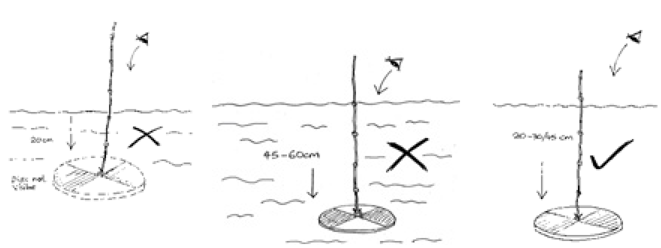


Fig 4.10, Fig 4.11 and Fig 4.12 acceptable and unacceptable Secchi disc visibility levels

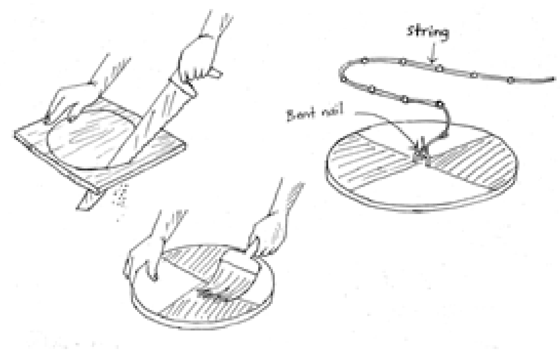


Fig 4.13 Making a Secchi disk

ii. Hand method

Practical exercise:

1) Stretch one arm and immerse it vertically into the water until your hand disappears from sight.
Note the water level along your arm:

- If it Is well below your elbow, plankton turbidity is very high;
- If it reaches to about your elbow, plankton turbidity is high;
- If it reaches well above your elbow, plankton turbidity is low.

Meaning of Secchi Disc and Arm Method Readings:

Secchi Disk Reading (cm)	Arm Method	Meaning
Less than 20 cm	Well Below elbow	Pond too turbid. If pond is turbid with phytoplankton, there will be problems with low dissolved oxygen concentrations especially at night. Do not add more fertilizer or manure. When the turbidity is from suspended solids (e.g. clay) productivity will be low. If there is a foul smell, flush the pond.
20 – 30 cm	Reaches about elbow	Turbidity is good for tilapia production. Do not add more fertilizer.
30 – 45 cm		Turbidity (from phytoplankton) is in a good condition, but tilapia growth will improve if more plankton can be produced so continue fertilizer applications
45 – 60 cm	Reaches well above elbow	Phytoplankton is becoming scarce. Add more fertilizer to you pond. If you do not get a bloom you may have to check your pH. Also make sure the pond is not leaking and being flushed.
More than 60 cm		Water is too clear. Inadequate productivity and danger of aquatic weed problems. If there are aquatic weed growing in the pond, weed them out before fertilizing the pond.

4.3.4 How to control turbidity

Pond bottoms should always be cleared of excess mud as when fish moves around in the pond, they stir the water thereby bringing about turbidity. Right quantities of manure should be applied to avoid algal bloom which can also bring about turbidity. Screening water from inlet canals and making settling tanks can help in minimizing turbidity brought about by water. Pond liming before fish stocking helps to control turbidity in the pond water. Adding fresh and clean water can clear turbidity brought about by fertilizers applied in the pond water.

Fig 4.14 Pond mud leads to turbidity

Fig 4.15 pond with a lot of turbidity

4.4 Carrying capacity

A pond can produce and maintain only a certain weight of fish. This is called carrying capacity. Pond carrying capacity is largely determined by management practices which includes nutrient inputs, water quality, and if you have mixed species (polyculture). Earlier work on semi-intensive culture of tilapia using manure or inorganic fertilizers indicated that carrying capacity might reach 2,000 to 3000 kg/ha (Diana et al 1991, Knud-Hassan et al 1991). If the initial capital costs are high, depending on the level of management, the carrying capacity systems must also be high to provide for cost effective fish production. As stocking density is increased in fertilized ponds, carrying capacity remains the same and density dependent growth occurs. Thus the ultimate size of fish at harvest is more consistent regardless of stocking density. Increasing the carrying capacity or size of fish at harvest of tilapia requires more intensive management which largely requires supplemental feeding. Supplemental feeding increases fish growth rate stocked at high density and results in a higher carrying capacity for the pond.

4.4.1 Supplemental feeding

If all the natural food organisms existing in your pond are consumed by your fish you can add supplemental feeds in order to increase the carrying capacity. If there is not enough natural food in your pond due to for instance high stocking densities the fish must be fed with complete feeds.

Fig 4.16 fish feeding by hand

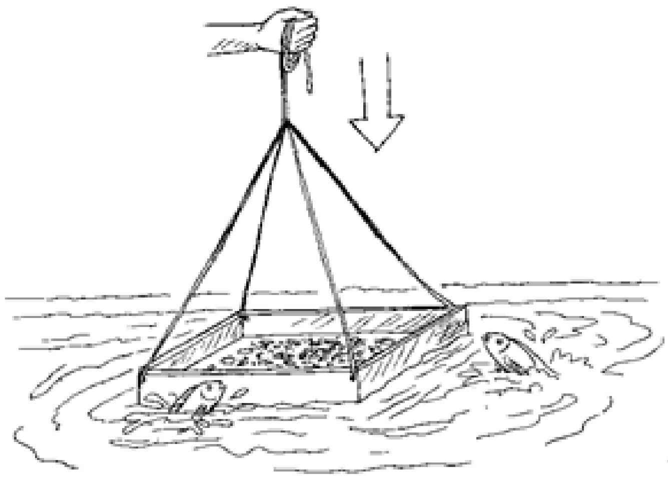


Fig 4.17 fish feeding using a tray

a. Natural food

The primary productivity of your pond water and hence the availability to produce natural food organisms can be increased by adding inorganic and organic fertilizers. This is one measure to increase the carrying capacity of your pond.

b. Water quality

The carrying capacity of your pond can be further increased by maintaining a good water quality. Your fish needs dissolved oxygen and low ammonia levels. Through the increased supply of feed the oxygen levels may drop and the ammonia levels rise. There are several ways to improve the water quality in order to have a higher standing stock of fish in your pond. Through aeration the oxygen levels in the water can be increased, and partially exchange of water will reduce ammonia levels. Depending on your scale of operation through more investment and interventions the stocking density can be increased.

4.4.2 Feeding impact on nutrient balance

Aquaculture requires optimization of nutrition to efficiently raise fish for the purpose of food production. For good fish growth, a farmer needs to know the nutrients and energy sources essential for fish health, growth and reproduction. A nutrient balance is often defined as the difference between the nutrient inputs entering a farming system (mainly feeds and fertilizers as in the case of fish ponds) and the nutrient outputs leaving the system (the uptake of nutrients for fish). Diets for fish must supply all essential nutrients and energy required to meet the physiological needs of the growing fish. Protein is required in the diet to obtain amino acids, which are utilized to synthesize new proteins or maintain existing proteins tissues while excess protein is converted to energy.

Nutritional strategies to reduce wastes include improvements in feed formulations without affecting growth and production efficiency, inclusion of feed ingredients with high phosphorus bioavailability. The use of feed additives to improve the apparent digestibility of phosphorus, and processing-refining of ingredients is done too. Buildup of surplus nutrients in excess of immediate fish needs can lead to nutrient losses, representing not only possible cause of economic inefficiency in nutrient use by farmers, but also a source of potential harm to the environment through water pollution.

Summary

A pond ecosystem refers to the fresh water ecosystem on which different organisms depend for their survival to fulfill their nutritional needs. In a pond, any change in the water may affect the plants and animals living in there. If people pollute the water, some plants and animals may die. Ponds have a specific depth which allows sunlight to reach its bottom, permitting the growth of plants that grow in there. The components of a pond ecosystem includes both biotic and abiotic.

A pond has to be productivity and this means there is phytoplankton and zooplankton. The presence of natural food produced in a pond is the result of interplay of various factors like climate and fertility status of the pond soil and water. There several factors that affect pond productivity and these include soil and its texture, Soil reaction (pH) and available pond nutrients. Nitrogen is a major nutrient affecting the productivity of aquatic ecosystems because it is an essential component of protein and other constituents of cellular protoplasm.

Fertilization and feeding also affects pond productivity. The natural productivity of a pond can be greatly enhanced by the use of fertilizers. It stimulates the growth of natural food by providing some essential elements which might be found to be deficient in a pond. The way we feed our fish can positively or negatively affect the productivity of our ponds. Pond lining is necessary as it improves the structure of the soil in the pond and stabilizes water quality. It further facilitates manure's ability to efficiently increase the availability of natural food and it also unlocks nutrients from soils. Lime acts as a prophylactic by killing unwanted fish, bacteria and other fish parasites. We should always check pH so that it should be within the acceptable range. Turbidity has to be controlled and measured using a hand or a secchi disc. Turbidity in ponds affects fish growth, feed utilization, mortality rates, body composition and their breeding. Turbidity caused by dissolved or suspended organic of inorganic solids, algae and other suspended substances can have an adverse effect on fish farming even on a cage culture system.

FISH AND ITS ENVIRONMENT

Module I of 8