A MANUAL FOR TILAPIA

FEEDing PAKISTAN

SOY FED AQUACULTURE PROVIDES A SUSTAINABLE SOLUTION

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A MANUAL FOR TILAPIA

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Tilapia *"Is Ideal for Aquaculture"*

Preface

Aquaculture is among the fastest growing agricultural sector in the world. Global demand for aquaculture supplies and equipment is expected to grow 11.6 percent annually through 2014. The Asia/Pacific region will continue to dominate both production and consumption. Aqua feed will remain the largest product segment and be the fastest growing.

Fish production serves to both increase our nutrition and to generate income. Statisticians predict that much of the vital protein food necessary to nourish our ever-increasing human population, of which perhaps half is underfed even today, will have to come from fish. As catch from the world's oceans remains static, it is up to aquaculture to fill in the gap for the world's fish needs. As developing countries gain wealth, their citizens look to fish as one of the first nutritional supplements when their economic situation has improved. All of this shows that those people who are involved in fish production will find a growing market demand.

Fish is highly rich in protein & vitamin A & D and a source of phosphorous. The large amount of most commercial oil is provided by fishes. It is observed that different fishes & by-products made from fish oils are used as Ayurvedic medicines which help in treatment of duodenal ulcers, skin disease, night blindness, weakness, loss of appetite, cough & cold, bronchitis, asthma, tuberculosis, etc.

Therefore the picture looks very promising for fish farmers who are able to produce for a given market as their customer base is forever expanding as long as they can assure a quality product.

Tilapia production is a very likely prospect because it has many qualities of fish selected as an aquaculture species as we will read in this manual.

Tilapia is the second most cultured fish species in the world, and its production is increasing each year. Mono-sexed Tilapia culture is a relatively new phenomena being developed under FEEDing Pakistan program in Pakistan.

The major goal of this document is to extend information and knowledge of Best Management Practices (BMP) for Tilapia Fish Farming in Pakistan. The guidelines mention in this manual can be used by fish farmers, service providers, academia, students and entrepreneurs on Tilapia production as reference document.

Elizabeth Hare
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1. The FEEDing Pakistan Program (Promoting the Aquaculture Sector)

The American Soybean Association (ASA) was founded in 1920 by U.S. soybean farmers and currently advocates for their interests through voluntary farmer membership of 21,000 farmers in 30 states where soybeans are grown. Overseas activities began in the mid-1950s and to date, ASA has served in more than eighty countries globally. In 2000, ASA expanded and focused its international role and founded the World Initiative for Soy in Human Health (WISHH) whose mission is to create sustainable solutions for the protein demands of people in developing countries through the introduction and use of soy products.

With approximately 187 million people, Pakistan is the sixth most populous country in the world. The demand for fish in the country that is traditionally a fish consuming state is likewise increasing rapidly. However, with the standard methods of aquaculture production in Pakistan, fish farmers have been unable to take advantage of this opportunity. Pakistan's aquaculture has primarily been based on predominantly carp farmed extensively in ponds, though various species of tilapia were introduced into the country between the 1970's and 1980's. Farming success has greatly been limited by the non-availability of fish feed in the market. Current average yields from extensive carp farming are below one tone per acre per year.

ASA/WISHH is currently implementing a three and half-year project funded by the U.S. Department of Agriculture (USDA) focused on the aquaculture sector in Pakistan, through the project 'FEEDing Pakistan'. The initiative's overall primary objectives are to improve national nutrition indices and attain economic growth through improving the performance of and expanding the aquaculture sector. To accomplish these goals, the program reaches local fish farmers, Pakistani governmental officials and commercial members of the aquaculture industry. Capacity building and improving access to quality fish feed are key components of the 'FEEDing Pakistan' project. The project has as a result, brought industry stakeholders to the U.S. for training and provided in-country technical assistance to stakeholders to build local technical and commercial capacity. Among the key outputs in this area has been the training of a Pakistani feed miller to utilize U.S. soybean meal to make high-protein fish feeds. No commercial soy-based floating extruded fish feeds were produced in the country prior to the FEEDing Pakistan program. The company now sells soy-based, extruded fish feed commercially throughout Pakistan.

On-farm feed trials using this feed were conducted with sex-reversed GIFT Tilapia between 2012, 2013 and 2014. The new extruded soy-based fish feed, fish demonstrated a four to five fold increase in average growth rates, yielding 2-7 tons of fish per acre with feed conversions (FRC's) ranging between 1.2-2.0 depending on farmer's individual management practices.

Results from the trials are promising and show that feed-based tilapia farming is a viable farming enterprise for both small farm families as well as large commercial farms.

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2. Introduction

2.1. General Principles Of Aquaculture Of Interest To Tilapia Farmers

The success of a tilapia farm is measured by its profitability. This depends on the yield and market price of fish on the one hand, and the cost of production on the other. The main factors that affect the profit and cost are:

1. ***Markets***. In commercial farming, market conditions are the main determinants upon which all management decisions are made, down to what species are stocked, what size is harvested, and what other management options are affordable based upon the price you are likely to receive.
2. ***Pond Water Quality.*** Maintaining optimum water quality in ponds for growth, e.g. through controlling water levels, fertilizing ponds optimally, and assuring adequate oxygen are all important for fish production.
3. ***Feeds and Feeding Methods***. Feeding the correct quality feed for the different stages of growth and using feeding methods that ensure greater growth per unit of feed given (i.e. lower feed conversions).
4. ***Stock Quality***, i.e. the size and quality of fingerlings stocked.
5. ***Farm management**, e.g. controlling stocking densities based on pond carrying capacity, determining at what size to harvest and harvesting before ponds get to their carrying capacity, proper management of staff so they know what is expected of them. (See figure).*

Figure 1. Hand Illustration of the Five Basic Components of Commercial Fish Farming. (Adapted from Schmittou et al., 1998)

The work involved in pond grow-out of tilapia is like a circle, with a series of steps that, when completed, take you back to the start. This is called the *"pond cycle"*

To get a good fish yield, the farmer must understand the basic steps involved in each pond cycle and the interactions between them:

1. *Preparation of the Pond for Stocking*
2. *Application of lime and fertilizer*
3. *Stocking*
4. *Feeding*
5. *Daily maintenance*
6. *Sampling (of fish to determine feeding rate)*
7. *Harvesting*
8. *Marketing*
9. *Continuous record keeping*

2.2 Carrying Capacity

It is recommended that fish be stocked based on the pond's carrying capacity *vis-à-vis* the targeted market size. This is because a pond is an ecosystem which has a maximum load that it can safely support. If overloaded beyond its limits, instead of having a favourable environment for production, the result is a polluted system that cannot support production. The pond's water quality will then start to deteriorate because as a system the pond can no longer effectively break down and assimilate wastes. If the situation worsens, fish eventually experience disease and mortality.

Once a pond's carrying capacity has been attained, the fish will cease to grow no matter how long they stay in the pond. Production and returns actually start to diminish ('point of diminishing returns') prior to reaching the carrying capacity. The carrying capacity for static green water tilapia monoculture ponds in southern Uganda when fed nutritionally-complete diets is 10 tons/ha (or 1 kg/m^2).

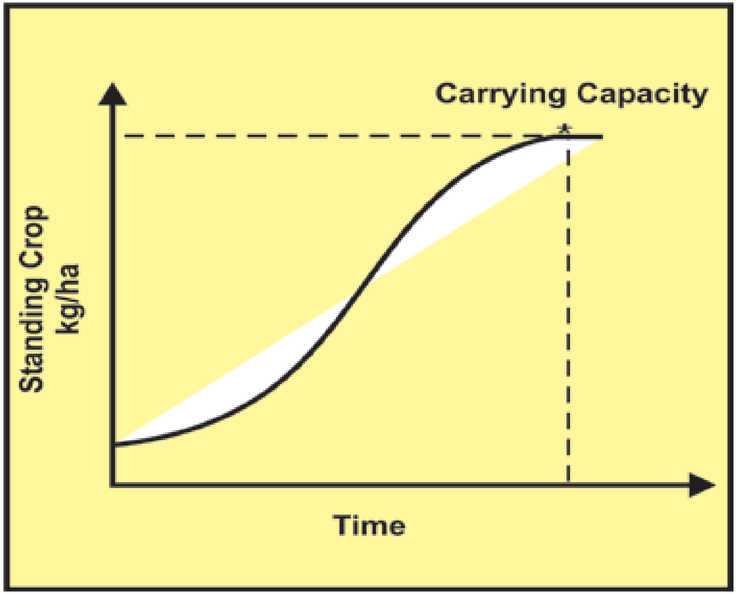


Figure 2. Carrying Capacity. Carrying the biomass at which production **stops**. It is a function of species, management practice, and the environment (Veverica, 2007).

Table 1. Factors that Affect Carrying Capacity

Management Factor	How Carrying Capacity Becomes Affected
Water Depth	1. Shallow ponds are often more turbid (muddy) and do not allow sunlight to act to enhance natural production and recycle wastes. There is less room for sunlight to act. 2. Ponds become shallow when the sides fall in and the soil gets distributed in the pond bottom. 3. Ponds also become shallow when the water inlet gets lower due to erosion 4. There is more dilution of wastes in a deeper pond* but too deep is dangerous due to stratification.
Feed Quality	Feed that is poorly digested or disintegrates quickly when in water, results into higher levels of waste being produced that cumulatively deteriorate water quality.
Feeding techniques	Uneaten food left in the pond becomes waste.
Species Stocked	Some species are more tolerant to poor water quality.
Number of Fish Stocked	The more fish that are stocked, the more dissolved oxygen is used up, the more feed is fed and the more waste is produced.

How do I know my pond is close to reaching carrying capacity?

Typically, if one is measuring water quality on a regular basis, the morning oxygen levels will be habitually low for several hours, and ammonia levels may begin to rise. However, tilapia are so robust that many farmers do not see the need to measure oxygen. A tilapia pond nearing carrying capacity will begin to have the fish coming to the surface to get air for longer and longer periods of time every night/morning. One hour of breathing at surface usually does not result in low production but several hours does. If holding fish in a tank of clear water, a person can see increased breathing rates.

In summary, the following circumstances would lead a person to decide their pond is near or has reached carrying capacity:

- *Decreased feeding response*
- *Less feed gets consumed (it may be difficult to see this if using sinking feed)*
- *Long times of fish piping at the surface*
- *Low growth rates*

What Management Changes to Make When Ponds are at Carrying Capacity.

Ponds managed a certain way can sustain fish in good health up to a certain maximum feed input per day. If the feed that is needed for the fish to grow is greater than the maximum feed your pond can sustain, you have a few choices:

- *Reduce number of fish in the pond. This can be done by partial harvest.*
- *Limit feed input. For tilapia, the maximum feed input is 20 to 40 kg of feed per acre per day. Exceeding this rate will result in low oxygen levels for several hours in the night through early morning , which will reduce growth rate and increase the feed conversion ratio (amount of feed needed to produce 1 kg fish weight gain). If you limit the feed input, the fish will grow slowly.*
- *Increase water exchange. This will remove some of the wastes that are accumulating.*

- *Aerate, if possible. This will provide oxygen for the fish at the time when the oxygen levels are low (usually early morning) and it will help convert some of the wastes to less toxic forms. However, this will cost money and the farmer should keep track of expenditures in electricity and aerator purchase so an informed decision can be made as to the financial advantages of aeration.*

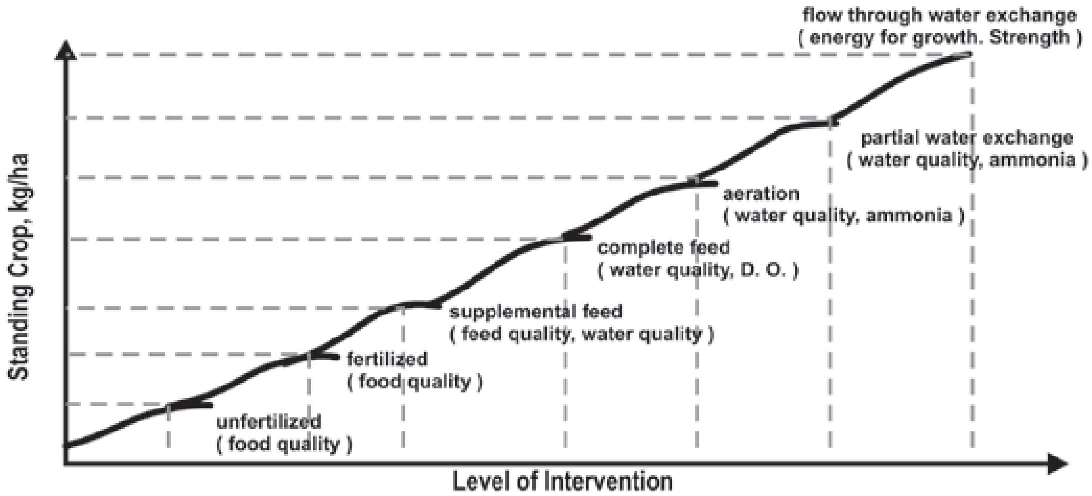


Figure 3. Level of Intervention versus Standing Crop at Carrying Capacity. (Adapted from Lovshin, 2006).

The reason why there is a limit on how much production can be sustained at the different management levels is because of limits in access to feed, feed quality and water quality. The sections below, discuss how these constraints come into play to limit production at the different management levels:

a. Management Level 1 – Unfertilised Pond: Unfertilised and unfed ponds are the lowest, most extensive level of fish production management in ponds. At this level, the amount of food available to the fish for production depends entirely on how much can be produced by natural productivity. The amount of natural productivity depends on the soil fertility, water depth, the amount of shoreline and any leaf litter or other organics that enter the pond. Ponds at management level 1, should therefore be managed as 'static water'. If water is allowed to continuously flow through such ponds, the natural food generated gets washed out. At this management level, food quantity, is the first limiting production factor. An unfertilised earthen pond can only generate enough plankton to sustain a tilapia production of not more than 200 kg/acre (50 grams of fish/m^2). Therefore, low stocking rates are advised at this level. This is because the number of fish stocked and the size, to which they are to be grown for market, must be matched to the amount of food that can be provided naturally by the pond. This level of management is therefore not suitable for commercial tilapia grow-out operations where investment costs are counted. This is because the cost of pond construction and the value of land cannot be covered by the value of fish produced.

b. Management Level 2 – Fertilised Ponds: In fertilised ponds, extra nitrogen, phosphorus, lime and possibly organic material like manure are added to the pond to enhance natural productivity. The ponds are managed as 'static water' to avoid washing away the nutrients added and plankton produced. Such ponds are able to generate much more phytoplankton as food for the fish than unfertilised ponds. Therefore, more kilograms of fish can be sustained in the pond to the point whereby, the fish start consuming the phytoplankton at a rate faster than it can be regenerated. At this management level, the amount of plankton that can be produced is usually the first limiting production factor.

Maximum standing crops have been reported at about 1 to 2 T/acre when fertilization is well-balanced and organic loading is not too high. Ponds fertilized with inorganic fertilizer at optimum rates for tilapia production have produced up to 1.2T/acre. Inorganic combined with organic fertilizer can produce maximum standing crops of 2T/acre.

c. Management Level 3 - Supplemental Feed: At this level of management, feed typically rich in energy is added to supplement the food produced through natural production. Supplementary feeding is often done in combination with fertilisation. The strategy is to provide an alternative source of energy to the fish, while the plankton provides the fish with their protein and vitamin requirements. Therefore, static pond water management should be done at this level, because natural productivity is still an important source of nutrition for the fish. By fertilising the pond and feeding the fish a supplementary feed, the farmer in this case has some control over the amount of food available to the fish.

However, the farmer has no direct control over the type of phytoplankton produced in the pond or the levels of protein and vitamins contained in the plankton. Hence, feed quality is often the first limiting factor to increased production.

Supplementary feeds are often agricultural by-products (e.g. sunflower cake, rice bran maize bran, etc.). They may or may not be processed before feeding to the fish. It is recommended that they are processed (e.g. by cooking or pelletizing) before they are fed to the fish in order to improve palatability and digestibility. Their water stability (even when cooked on-farm) is poor, and once administered to the fish in the pond, the food easily falls apart, sinking to the pond bottom. This increases organic loading in the pond, with its negative effects on water quality (see section 5.2.3. above). Hence, when managing such a system, the stocking rates and biomass must be maintained at a level whereby the protein/energy balance from the different feeds is 'just right' and the quantity of supplemental feed required to feed the fish adequately does not reach levels that have a negative impact on water quality. Typically, the higher the protein content of the supplemental feed, the better the production. A well-fertilized pond using chemical fertilizer at the optimum rates, coupled with an agricultural by product that is high in energy used as feed (such as wheat bran) have produced 2.5 T/ha of tilapia but morning oxygen levels will be low most of the time.

d. Management Level 4 - Complete Feed

At this level of management, the fish are provided all their nutritional requirements through a nutritionally complete feed pellet which may be sinking or floating. The biomass of fish produced is limited by the effect of feed metabolism on water quality. As feed quantity increases, water quality starts to deteriorate. Dissolved oxygen (D.O.) is usually the first water quality parameter to drop and become the limiting factor for fish production. Therefore, there is a maximum limit as to how much feed can be safely added to a pond based on the minimum accepted dissolved oxygen level or maximum waste load during a daily diurnal cycle for the species being reared. Static-water ponds fed nutritionally complete diets are therefore, largely managed to ensure that key water quality parameters (dissolved oxygen and ammonia) are maintained within the optimal range for production.

Therefore, there is a **'maximum safe feeding allowance'**, based on the lower limits of dissolved oxygen and other water quality parameters (notably oxygen in the case of tilapia) that the fish being cultured can withstand without compromising production and returns. Feed quality plays a big part because poor quality feed generates more wastes than high quality feed.

The total amount of feed added each day to a tilapia grow-out pond should therefore, not result into dissolved oxygen levels falling to below 1.0mg/L for lengthy periods of time. At the beginning of the growth cycle, ponds are managed as static-water to benefit from the fertilizing effect of the feed wastes. However, as feeding rate increase, the management may change to provide better water quality. In non-aerated fertilised tilapia grow-out ponds fed nutritionally-complete diets, the 'maximum safe feeding allowance' is therefore 8 to 10 g feed /m^2/day (100 kg/ha/day, or 40 kg/acre per day). This means when your fish are about harvest size, the daily total feed requirement for the pond should not exceed 10 g/m^2/day. Even at these levels, there will be low oxygen levels for about 1 to 2 hours every morning. This limit is variable depending on the water quality in the pond and the quality of pellet a farmer is using.

e. Management Level 5 - Aeration

At this level of management, fish are fed high quality nutritionally complete feeds. The limiting effect of feed metabolism on dissolved oxygen levels is overcome through aeration. Therefore, a higher biomass can be supported up to the point whereby the accumulation of ammonia in the system, as a result of the nitrogenous wastes of the fish becomes the limiting factor. Fish density, biomass and feeding rates, are therefore controlled to ensure that ammonia levels are kept within the recommended range. Pond water management is static. Tilapia ponds receiving intensive aeration but little or no water exchange have produced 7 to 8 T/acre. Wastes for the feed can result in a high amount of phytoplankton production which, in turn can supply additional food for the fish. However, if the pond levees were not well compacted intensive aeration will cause immense amounts of erosion and the pond could become very muddy, thus negating the fertilizing effect of the wastes.

f. Management Level 6 - Partial Water Exchange

At this level of management, the fish are also fed high quality nutritionally complete feeds. The limits of feed metabolism on dissolved oxygen levels are overcome through aeration, while ammonia accumulation is managed through partial water exchange to wash out and dilute wastes. More fish can be raised for the parameters given, however, at a higher cost because the water must be pumped (usually) and electricity for aeration must be used. At these densities of fish, the feed must be of very high quality and no nutrient should be deficient.

The carrying capacity at management level 5 is lower than that of management level 6. The reason for this is that one is depending entirely upon the bacterial population (whose population size is limited by the nutrients available in the pond to sustain it), and the amounts of dissolved oxygen available to the bacteria to live and oxidise ammonia into nitrates. At management level 5 therefore, one is dependent upon another biological parameter that one must manage yet have no direct control over because the performance and survival of bacteria and phytoplankton is subject to the highly variable environmental conditions in the pond.

In management level 6 the accumulation of wastes is physically managed by removing a proportion of the pond water that has a high nutrient load and replacing it with good quality water. This results in a reduction of the concentration of wastes in the water. At this level, it is up to the manager to decide how much water and how often water should be exchanged, to achieve the desired levels of water quality. Trickling small amounts of water will have little effect. In order to see some additional benefit from water exchange, more than 10% of the water must be exchanged daily. If the water is cold, this can have a negative impact on tilapia growth. Hence, the upper limits on how much can be produced for this level, depend not just on the feed, but on the water resources the manager has at hand as well as the costs of using this water effectively. As the frequency of water exchange becomes close to continuous, then the next level is reached.

g. Management Level 7 - Flow through Water Exchange

Usually, this management level is practiced in tanks made of concrete, fibreglass of wood-frames holding a plastic liner. At this level of management, the fish must be fed high quality nutritionally complete feeds. The limits of feed metabolism and feeding on dissolved oxygen levels, ammonia and organic loading, are overcome by continuously allowing good quality water to flow through the pond. This dilutes and washes away wastes before they accumulate to levels that reduce water quality for production. Fish density at this level is very high. However, the amount of fish that can be raised in such a system is limited by what flow rates are required to effectively wash out wastes and replenish water quality.

Water flow rates should not exceed the capability of the fish in the system to withstand the currents, as the fish shall instead, start using their energy to withstand the currents rather than for growth. A water current of 5 meters per minute is generally taken to be the maximum recommended water current for market sized tilapia. Current rate can be slowed down by making tanks wider or deeper.   If the water must be pumped, it is often best to also use aeration so the water is needed only for reducing waste loads, not for adding oxygen.

This level of management is often used for holding tilapia in tanks before sale. In this case, the fish are not being fed and the amount that can be held for short periods of time can be fairly high (more than 200 kg in one cubic meter) but the true amount depends on how good the aeration is. Tilapia grown in cages can reach these densities as well, if the water quality in the lake where the cages are placed is good and the cages are constructed in a way that there is good water exchange between the lake and the cage.

2.3. About Tilapia

The ‘Tilapia’ is a group of cichlid fishes native to Africa. They are among the oldest and most economically important cultured fish species in the world, being second to carp. Tilapia is the most widely farmed fish on the planet. Globally, tilapia culture ranges from rural subsistence farming to large-scale commercial operations depending on intensity of management employed. The use of different culture systems (earthen pond, concrete tank, raceway, or cage) and management strategy (extensive, semi-intensive, intensive, monoculture, polyculture, mono-sex culture, and mixed sex culture) depends on the farmer’s resources, site characteristics, environmental conditions, socio-economic factors, technological know-how and market demand. Production costs and yields vary from country to country depending on the level of management used. Currently, tilapia is farmed in at least 85 countries.

Tilapia is favoured for aquaculture because of they grow relatively fast and are hardy fishes that can tolerate a wide range of water quality conditions. They also eat a wide range of food types, breed easily and can be reared at high stocking densities. This means that the fish are ready for harvest in less than one year and they require less space to farm, which is economical for the fish farmers. These characteristics have earned tilapia the title "*The Aquatic Chicken*". Between the 1990's and early 2000's, improvements in stock quality, feed availability, reproduction management through sex reversal and hybridization as well as the expansion of consumer markets in virtually every part of the world, resulted into a surge in global supply. Though several species of Tilapia are cultured commercially, the Nile Tilapia (*Oreochromois niloticus*) is the predominant cultured species worldwide.

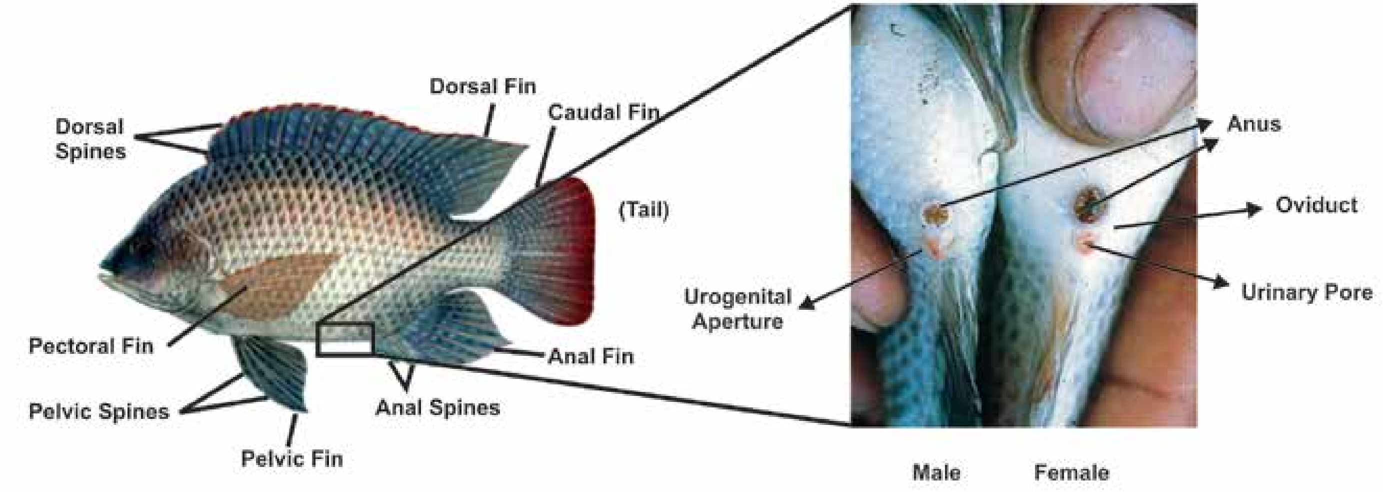
2.3.1. General Characteristics

Tilapias have a small head, light vertical stripes, thick body, and light colored belly. Tilapia of the *Oreochromis* genus are mouth-brooders, which means that eggs and larvae are reared and protected in the adult's mouth. The female collects the fertilized eggs into her mouth from a circular pit or nest built (and aggressively defended) by the male.

- Tilapia have a rapid growth rate.
- Tilapia have versatile feeding habits and can grow well on a purely vegetable source of protein. They also consume phytoplankton, some aquatic plants, snails (occasionally) and bacterial films that grow on decomposing organic matter.
- Tilapia can withstand moderately low water temperatures such as less than 15^{o}C if only for a short time.
- Tilapia can tolerate harsh environmental conditions and their growth rate can recover once conditions get better.
- Male and female Nile tilapia have similar growth rates for the first few months, but as they reach sexual maturity, the males continue fast growth, whereas the growth rate of the females slows down, since they are expending more energy producing eggs and incubating them in their mouths. If the fry are not removed, they continue harboring the young for up to 2 weeks.

- Because the males will attain large size at faster rate (2 to 3 times that of females), and because the reproduction of tilapia tends to lead to overcrowding of the pond, all-male tilapia culture is practiced when the market size required exceeds 300g.
- Even if the females make up only 1% of the population, in one acre, stocked at one fish per square meter, this would mean there are 40 females in the pond and these 40 females can produce 500 fry each, every 2 to 4 weeks. So stocking a predator fish is often advised even if practicing mono-sex culture.

The figure below shows key external anatomy and how to distinguish males from females. Nile tilapia exhibits some differences in color between the sexes but looking at color is not a certain way to distinguish the sexes. The genital openings must be examined. Males have one opening form which exits the liquid wastes and the sperm. Females have separate openings for the eggs and for the liquid waste. The male genital papilla is longer than the females' and can be either rounded or pointed. Females have a rounded papilla.



2.3.2. Cultured Species of Tilapia

Chitralada (popular stain of Nile Tilapia):

- Very fast growing fish
- Very deep bodied, rosy colored.
- Natural Nile tilapia coloration tends to be paler than GIFT.

GIFT Tilapia (most widely cultured selected strain)

- Growth starts off a little slow, but quickly picks up and grows quickly to a large size.
- Shape of Gift tilapia short and fat, stocky body (wide girth makes it appealing when sold live).
- Natural Nile tilapia coloration, but tend to be darker than Chitralada.

Red Tilapia

- Growth not so different than the growth of Niles.
- Most strains have some of *Oreochromis mossambicus* mixed in with the *O. niloticus.*
- Shape is short and round with big girth.
- Color can range from very pale to almost white to an orange or red color of the Taiwanese red. Very few black spots, but red and white coloration is still a little patchy. Some of the fish can have a wide mouth, like a duck's bill, inherited from the *O. mossambicus*.

3. Pond Construction / Preparation

3.1.1. Site Selection:

Selecting a suitable site to construct a pond is important because the site affects the productivity of the pond and therefore the profitability of the enterprise. The following factors should be taken into consideration when selecting a pond site:4 3.1.1. Water

Water Supply:

An assured water supply of sufficient quantity and adequate quality is the most important factor to be considered when deciding on the suitability of a fish pond site. Therefore, the investigations for a proper water source should be most thoroughly conducted in site selection.

A permanent source of water is preferred. The source of water may be an irrigation canal, river, creek, reservoir, lake, spring, rainfall runoff, and deep wells. Water can be supplied via feeder channel, storage tank or pipeline by gravity or by pumping to the ponds.

The quantity required should be sufficient to fill ponds in 4 days or less. Not all of the ponds need to be filled at a go. Ponds can be filled in turns. However, there should be a steady supply that allows topping off to replace for seepage and evaporation.

Sites prone to flooding should be avoided and if flooding is known to occur, these sites should be protected from flooding.

Water Quality:

Quality of water is one of the most significant factors to be considered in site selection. It should be investigated by taking a number of water samples from the proposed water source for laboratory analyses of physical, chemical, biological and micro-biological properties, including health hazards. Water test procedures should be in accordance with the relevant Standard Classification in the country on water quality. From a production point of view, emphasis should be placed on the following:

(i) Physical properties - temperature, colour, odour, turbidity, transparency, suspended solids.

(ii) Chemical properties - pH, dissolved oxygen, biochemical oxygen demand, free carbon dioxide, alkalinity, salinity, dissolved solids, all as regards both useful and toxic qualifies; also whether pollutants of agricultural or industrial origin are present, and if so, to what extent. Know what types of agricultural processes are going on in the watershed form your supply. Pesticides can build up in the groundwater and make fish farming very unproductive and resulting fish unhealthy.

(iii) Biological properties - quality and density of plankton. This can be altered by the pond management.

(iv) Micro-biological properties - species and quantity of parasites-avoid using water that has been coming form sewage lagoons.

3.1.2. Slope of the Land

The land should be gently sloping to allow filling of ponds and draining of ponds under gravity, otherwise water will have to be pumped into and/or out of the pond which is costly. The preferable land slope is

between 2-4%. It is easier to obtain the correct levels when constructing a pond on gently sloping land, which in turn reduces pond construction costs. Ponds must be able to fill, drain and dry fully so that, problems arising from leftover fish that impact on survival or growth of the next crop can be prevented. Where slope is relatively steep, ponds are smaller. When slope is gentle, ponds are larger so the needed drop in elevation can be obtained.

3.1.3. Soil Characteristics

The following points should be considered when soil quality is examined:

- Clay, clay loam, and sandy loam soils with deposits of organic matter of about 16% are best for fish ponds.
- Avoid sandy, rocky, or stony soils because these do not retain water in the ponds.
- Some of the methods to determine if the soil will hold water are:

  1. Squeeze a handful of wet soil. Its shape is retained when the grip is released.

  2. Make a soil ball. It will not crumble into pieces if thrown into the air.

- Avoid areas with thick deposits of organic debris since these are poor materials because such debris cannot be compacted.
- Consider also the pH value of the soil in selecting the site. The most desirable range of pH is 6 to 8.

For liner tanks/ponds: liner must be installed so there are no folds that tilapia can bite to scrape algae off liner. Biting/scraping can lead to liner failure and loss of water and fish.

3.1.4. Access to the Site

Preferably the selected site should be close to transportation routes for the purposes of marketing and supply of inputs, such as feed, to the site. However, often the site is either close to markets or close to inputs and somewhat far from markets. Inputs such as feed are required in greater quality than the output (fish), so one direction will require more transport than the other.

3.1.5. Other Factors to Consider

In densely populated areas and areas close to industrial establishments, public health concerns must be taken into account. For example, levels of contamination of influent water (e.g. sewage, chemicals from plants, etc.), spread of water associated infectious diseases (e.g. abandoned ponds with stagnant water become breeding grounds for mosquitoes and other parasites), etc.

Proximity to public utilities such as electricity is advantageous because management options such as the use of water pumps, aerators, refrigeration become possible at a more economical cost.

When running commercial establishments, skilled operators are necessary if the farm is to run efficiently. Providing conducive working environment for personnel is therefore important.

The facilities requiring frequent attendance, such as the hatchery, rearing and nursery ponds, holding ponds or tanks and pumping station should be as near as possible to the center.

3.2. Designing and Planning the Layout of Pond

A pond is more than just a hole dug in the ground. A pond should be able to hold water and sustain production during the production phase. Hence, it should be possible to fill the pond with water and drain it after the fish have been harvested, manage the fish and water in the pond during production, as well as harvest fish from the pond. To enable this, the following are the key features of a pond as well as other factors that need be taken into account for the pond to function:

3.2.1. Elevation

Construct the pond so the bottom at the drain is one and a half meters or more lower than the source of water supply but slightly higher than the drainage area to obtain at least an average water depth of one meter for maximum production.

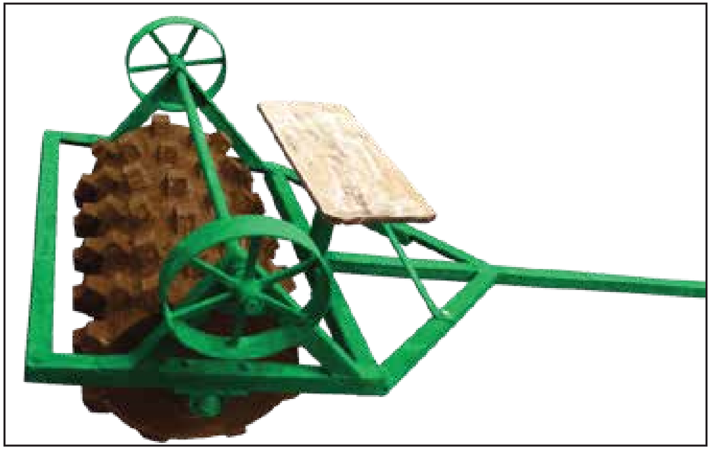
3.2.2. Pond Size and Shape

Size: The pond size depends on whether the pond will be used for breeding, nursery or production purposes. The production pond varying in size from 1 acre to 10 acres can be efficiently managed, however, ponds as small as 0.05 acres can also be used for raising fish.

Shape: Rectangular ponds are usually the easiest to build and manage. However, ponds must sometimes be built with irregular shapes to fit the topography and shape of the available space. Rectangular ponds allow for a net that is the length of the shortest distance to be used for harvesting. Square ponds of the same surface area would require a longer net than rectangular ponds.

3.2.3. Pond Walls/Dykes/Embankment/Levees

The pond walls must be strong enough to hold the required volume of water and well compacted to prevent seepage of water through. Hence the preference for loamy soils with clay (clay is impermeable to water when compacted) where earthen ponds are the option. To achieve the required level of compaction necessary, soils used must be free of debris (sticks, stones, roots, rubbish, etc) and it is important that the soil is compacted layer-by-layer, ensuring that each layer being compacted at a time is not more than 15 cm thick. After compaction, the height of each layer should be reduced to about a third to a half of the original layer thickness. In areas with permeable soils, core-trenching or the lining of the pond often become necessary.



At left is a photo of a home-made "sheepsfoot compactor" that can be pulled by a small walk-behind tractor or by oxen. It can be transported to site by using the wheels. Once on-site the drum can be filled with water and the driver can sit on the seat. Such a compactor can greatly increase the strength of pond levees provided the soil has some moisture when compacting.

The average recommended water depth for a fish pond is about 1 meter (0.8 m in the shallow end, gradually deepening to about 1.2 m at the deep end). The pond walls therefore need to be sloped so that they can hold this volume of water without collapsing in. (Figure 4 and table 2) show how a pond wall should look and what typical average wall slopes are for the various sizes of ponds.

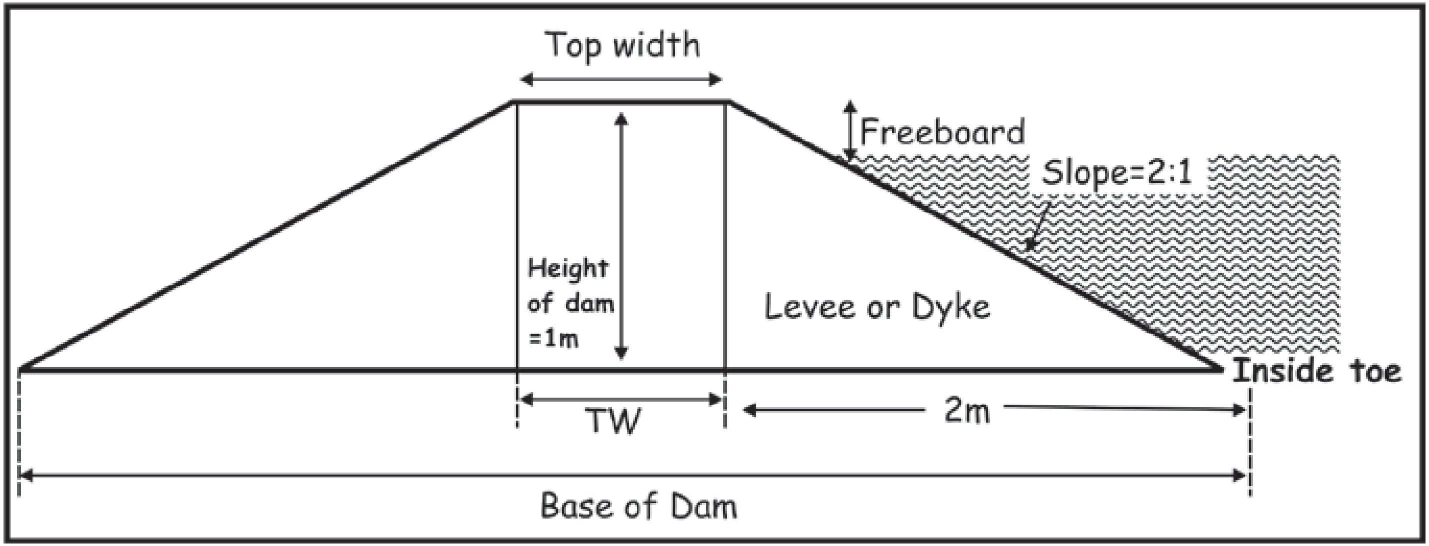


Figure 4. Parts of the Pond Wall for a levee height of 1 meter (adapted from Isyagi et al, 2009)

A slope of 2:1 that is recommended for most small ponds means a horizontal distance of 2 meters from the inside toe to where the top width starts (edge of the pond from above) measures and the height of 1 meter from the floor/base of the wall to the top of the pond wall (see figure 4 above).

Table 2. Recommended Levee Slopes for Production Ponds

Size of Pond	Recommended Slope
1-40 acres	4:1 to 7:1
0.5 to 1 acre	2:1 to 4:1
0.25 to 0.5 acre	2:1
≤ 0.25 acre	1.5:1 to 1:1

N.B. The larger the pond, the gentler the slope should be on the side levees. Large ponds have a greater surface area to perimeter ratio. This makes it possible to obtain the greater amounts of earth needed to make gentler slopes from within the pond during construction. Calculations made in the southern USA, where large ponds are used for catfish farming have shown that the savings in pond levee renovation are best justified by the higher earth-moving costs when the levee slope is about 4:1. Less slope than that, the pond requires renovation after only a few years. More than 4:1, it requires too much soil but the levees can last a very long time.

<u>3.2.4. Freeboard</u>

This is the distance between the pond water surface and top of dike. High freeboard makes pond management difficult and it wastes soil. It also reduces the capacity of the wind to aid in mixing the pond water layers. Too little freeboard makes for always moist soil on the top of the dike which will result in rutting and potholes from vehicles on the dikes as well as ponds flooding over when it rains. Recommended freeboard for small ponds is 20-30 cm. For larger ponds (more than an acre), a 50 cm freeboard is recommended because waves may be higher than in small ponds.

3.2.5. Inlet

The point through which water is let into the pond from the water source is the inlet. Water is tapped off the supply channel often using a pipe (where it can flow into the pond by gravity) or pumped in. The inlet pipe should be set at least 20 cm above the desired pond water level to prevent back-flow and fish escaping. Likewise it is important that the inlet pipe is also screened. Screening prevents rubbish and wild fish entering the pond and fish escaping from the pond. See figure 5.

As much as possible, each pond should have an independent inlet and outlet. This makes it possible to manage each pond as an independent unit (notably harvesting, water quality management, stock and disease control) without stressing the fish in the following pond.

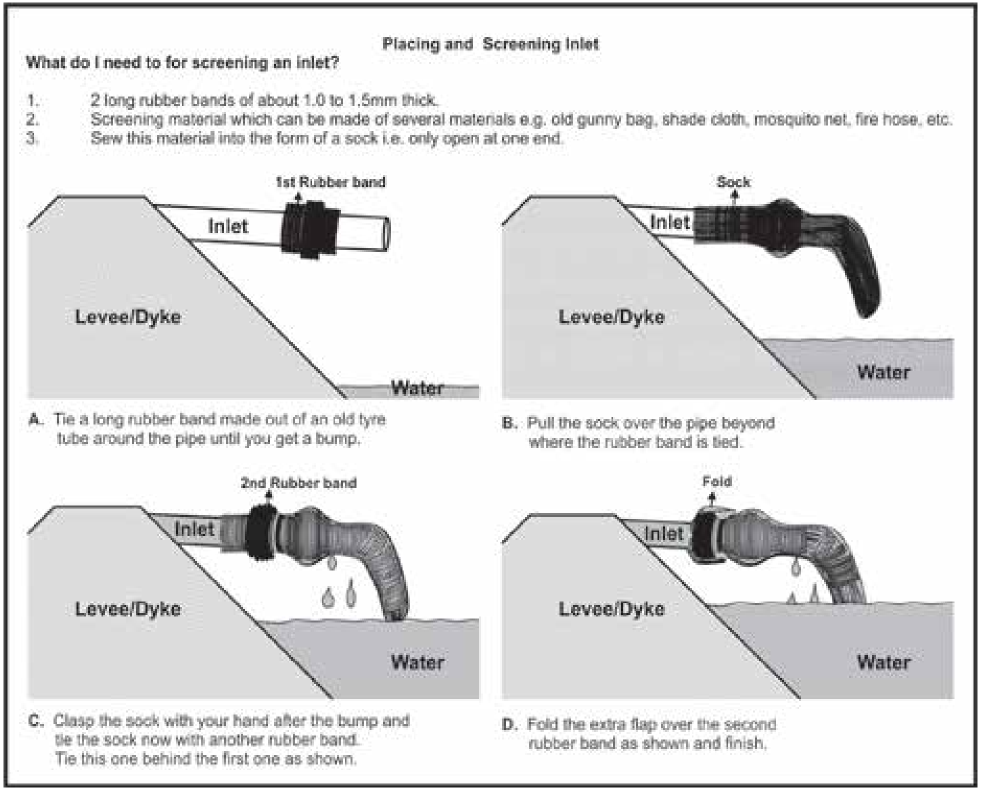


Figure 5. Fixing and Screening Inlet Pipe. Adapted from Isyagi et al, 2009.

3.2.6. Outlet

After constructing the wall a trench is dug and the outlet installed, after which the earth is returned and compacted. The outlet comprises a stand-pipe to permit overflow and the control of water levels in the pond. An anti-seep collar made of concrete placed around the bottom drainage pipe is necessary as it prevents water from the pond seeping along the drainage pipe. The anchor collar additionally helps keep the pipe down (see figure 6)

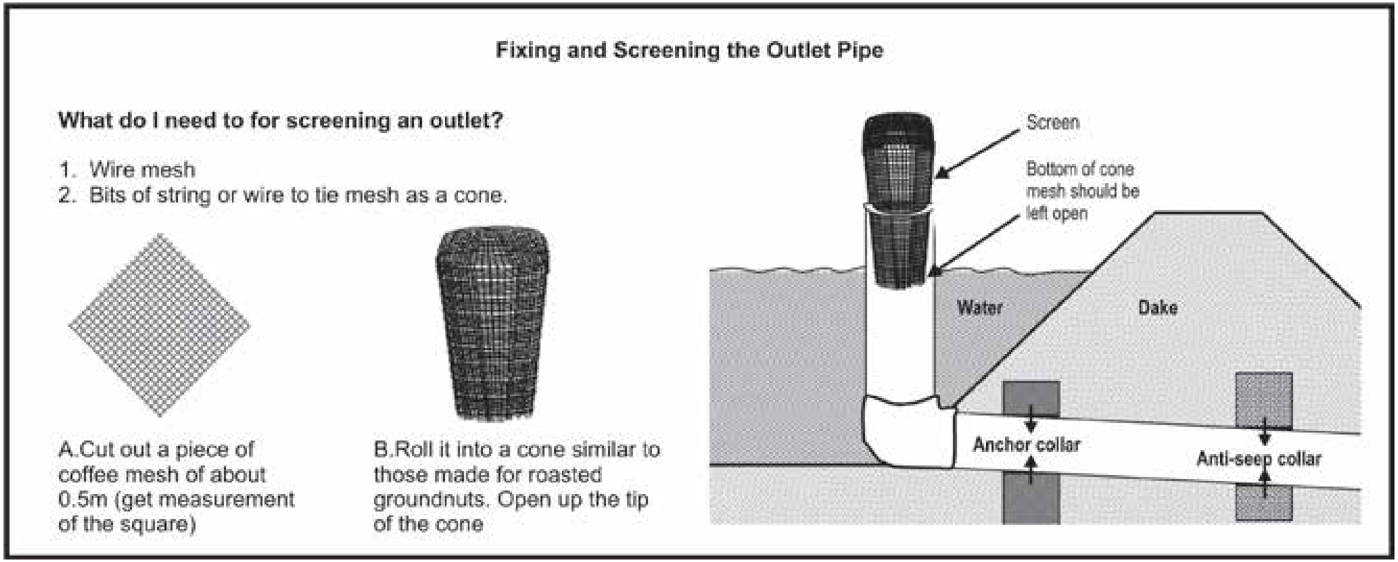


Figure 6. How to Screen the Outlet Pipe. Adpated from Isyagi et al., 2009.

3.2.7. The Slope Of The Pond Bottom

- The pond bottom must have sufficient slope for good drainage. In general, slopes with a drop of 2 cm for every 10 meters along the pond bottom are appropriate.
- If the slope is too gentle, the pond will not be easily drained.
- If the slope is too steep, it may be too shallow at one end or too deep at the other end.
- For large ponds, it is impossible to remain within the 2% slope limit and at the same time stay within the recommended water depths. In these circumstances, the shallow end of the pond can be almost flat and then the slope can begin to increase going towards the drain. This fulfills the need to encourage the fish to follow the water down and will also allow for sufficient water depth in the shallow end. See figure 7.

***Wind direction**. Wind plays a role in fishpond design. Strong wind generates wave action that destroys the sides of the dikes. To minimize this, position the longer pond dimensions parallel to the direction of the prevailing wind to lessen the side length of the dike exposed to wave action. Some wind is useful in that it helps to mix the pond. Therefore, avoid higher than necessary freeboard .*

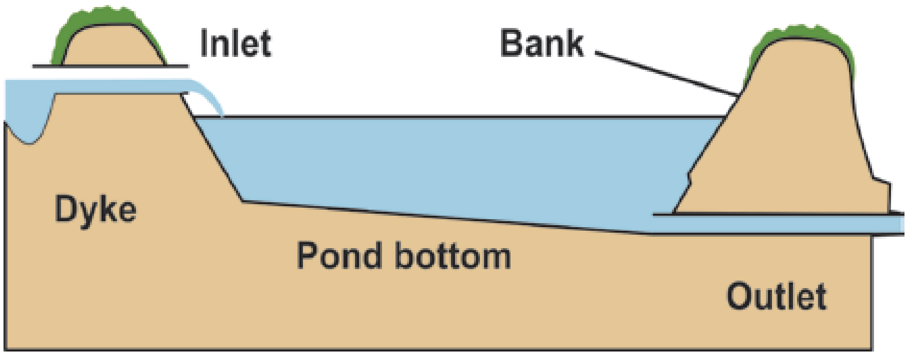


Figure 7. Slope at Pond Bottom

3.3. Types of Ponds

3.3.1. Dam Pond/ Embankment Pond

These are also called embankment or barrage ponds. These ponds are made by building an embankment, dam, and dike or similar above –ground structures across a water courseway and narrow valley. The slope of the land plays a very important role in planning such ponds. A good site usually is one where a dam can be built across a narrow section of a valley, the side slopes are gently sloping or steep and there is slow decrease in the evolution along its length to permits a large area to be flooded (see figure 8)

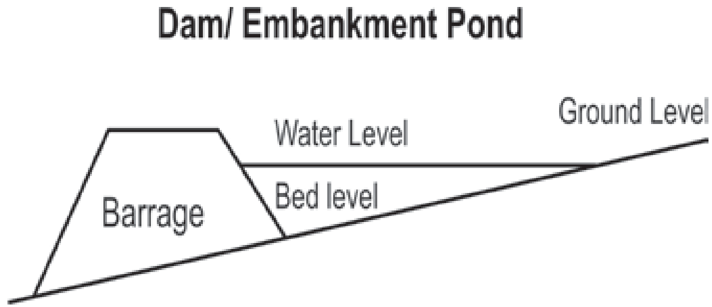


Figure 8. Cross-Section of Dam/Embankment Pond

3.3.2. Excavated Ponds

These ponds are also called contour ponds. They are simple to build and are formed by digging soil from an area to form a pit or hole in the ground. Excavated ponds can be classified by the way water enters the pond. An excavated pond can be supplied by surface runoff, by water diverted from a stream or a river, by water pumped from a well etc. This type of pond cannot drain because of natural seepage into ponds (figure 9)

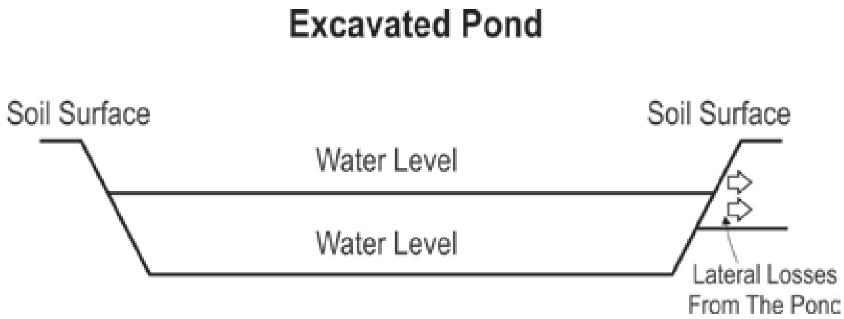
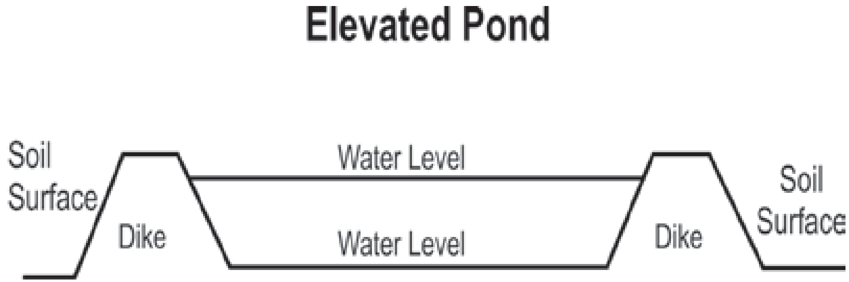


Figure 9. Cross-Section of an Excavated Pond

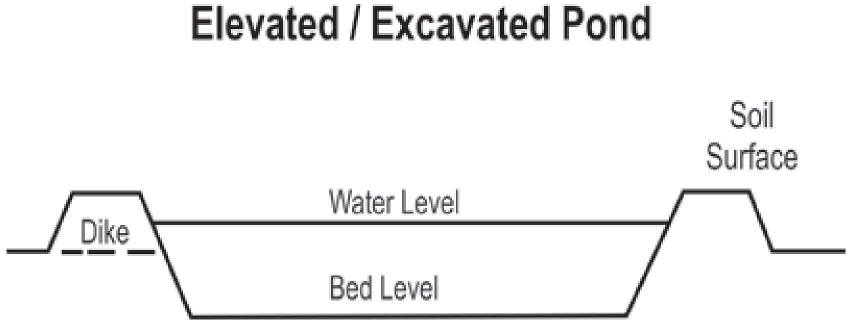
3.3.3. Elevated Ponds

This type of pond contains required levees that are well constructed so they are impermeable. The water supply may need to be pumped depending on the level of the water source gravity often be utilized for drainage.



3.3.4. Excavated/Elevated Ponds

The most appropriate type of pond is combination of excavated/ elevated pond. If the soil has sufficient clay content, the dike can be built from the soil that is removed during pond excavation; thus excavation costs are minimized. It can be partially drained by gravity.



4.1. Preparation of Ponds for Stocking and Pond Maintenance

Pond preparation is necessary prior to stocking, to create a favorable environment for fish growth.

i. The pond should be drained and dried, ensuring that there are no puddles left at the pond bottom. This helps ensure that there are no fish left over from the previous cycle that may cannibalize on fingerlings stocked in the following cycle. In addition, bottom soils become oxidized, enabling bottom mud become less acidic. This favours the release of nutrients into pond water when ponds are refilled making the ponds productive. Drying ponds also helps control parasitic cycles in ponds.

ii. Remove excessive silt and weeds but do NOT put silt on top of pond dikes, otherwise it will run back down into the pond especially if it rains.

iii. Level the bottom of pond to make sure it drains well the next harvest.

iv. Repair the dykes where they have damage so as to prevent water loss through seepage during the production cycle.

v. Grass should be cut but not completely removed, as it holds the soil.

vi. Tall grass and plants should be removed.

vii. The screens on outlet and inlet pipes should be repaired and replaced before the pond is refilled.

4.2. Liming the Pond

Lime is used to increase the pH of the pond soil, so is often applied when the pond is dry so a spreader truck can distribute the lime evenly on the pond bottom. However, lime can be applied to a pond after it has been filled. Agricultural lime is preferable to hydrated lime because it is more stable and does not cause sudden sharp changes in pH, but rather tends to stablise pH change to around the neutral point. Therefore, agricultural lime can be applied while there are fish in the pond. Hydrated lime causes pH spikes that can result into fish dying, hence it should be used cautiously if being applied to stocked ponds. (Table 3) below gives guidelines on what criteria need to be taken into account when deciding whether or not to lime a pond. Although soil and water quality often go hand-in-hand, any one of the criteria, (the soil pH, the total alkalinity of the water and the pH of the water) can justify liming. If liming is needed and it is not done, the phytoplankton will not grow well and the water will not get green, thus reducing the natural food available in the pond.

Table 3. Pond Liming Guidelines

	Use Lime	**Don't Use Lime**
pH of Soil	Less than 6.5	Above 7.5
Alkalinity of water	Less than 25mg/l CaCo3	Above 50mg/l CaCo3
pH of water	Less than 6.5	7.5 or above

4.3. Fertilizing

Fertilizer is used to promote plankton "blooms" that help process nutrients from the fish waste as well as contribute to the natural food in the pond. Like other plants, phytoplankton needs nutrients such as nitrogen and phosphorus so both organic and chemical fertilizers can be used.

Optimal application rates of N and P have been determined for tilapia production in warm climates and about 6 to 8 kg N/acre/week, and 2 to 3 kg P/acre/week resulted in best tilapia growth and survival. Higher rates of N such as 12kg/acre as used in Thailand can result in fish kills.

Less than 2 kg P/acre is really needed but the clays in the soils tend to remove the P from the water so going a bit high on P is preferred. Also, P in itself is not toxic to fish.

If the pond is muddy or if it is choked with aquatic weeds, fertilizer will not promote the growth of phytoplankton. If the pond requires liming, fertilizer will not produce the desired results until the liming has been done. Applying phosphate fertilizer while liming is also not advised as the lime will cause the P to sink immediately to the bottom.

Whereas organic fertilizers are preferable for soil-based plant growth because the nutrients leach out more slowly, for aquaculture, it is desirable for the nutrients to enter the water quickly. Organic fertilizers such as manures help to settle out clay turbidity and they can also help to seal up a leaky pond. But they use up oxygen in their decomposition and this can lead to low growth or even death of tilapia. As a rule, organic fertilizers are fine if they are free of charge but application should be limited to 200 kg per acre per week. Even if pure manure, this would only provide about 2 to 4 kg of N. Therefore, one can see that some chemical fertilizer is needed if the optimal amounts of N and P are to be applied without driving down the oxygen during decomposition.

Chemical fertilizer is usually labeled with 3 numbers which signify the percentage of nitrogen (N), the percentage of Phosphate (as P_2O_5) and the percentage of potassium in the form of potash-equivalent (K_2O). For example, a mixed fertilizer (one that contains all three nutrients), labeled 20-20-5 contains 20% N, 20% P_2O_5, and 5% K_2O. To know the % P from P_2O_5, multiply by 0.4. To get the % K in K_2O, multiply by 0.83. Due to the fact that the different fertilizers have different compositions, the recommended application rates differ for the various fertilizers (Table 4). In general, the more concentrated the fertilizer, the less expensive to get the proper amount of N and P that is needed. Urea has the highest percentage of N and is easy to dissolve in water. For P, triple super phosphate and diammonium phosphate are most easy to find and are very concentrated.

Table 4. Suggested Pond Fertilization Rates Using the Different Fertilizers

No.	Fertilizer	Kg per acre per Application
1.	Fish pond fertilizer (20-20-5)	18.14
2.	Urea (45-0-0)plus Di-ammonium phosphate (18-46-0)	13 urea PLUS 11 DAP
3.	Liquid ammonium polyphosphate (10-34-0)	20 (and this will be less than optimal N)
4.	Liquid ammonium polyphosphate (13-38-0)	20
5.	Urea (45-0-0) plus triple superphosphate (0-46-0)	17 urea PLUS 11 TSP
8.	Urea (45-0-0) plus Superphosphate (0-20-0)	17 urea plus 25 super-phosphate

Weekly fertilization is recommended until the water color looks green. To determine this a simple instrument called a secchi disk is used to measure the transparency of the water. A farmer can make one from a piece of wood or from a plastic bucket bottom. The function is explained in Appendix 5.4. As the secchi disk visibility approaches 30 cm, the fertilization should be cut to every 2 weeks. Cease fertilizing if the secchi disk visibility is less than 25cm. As feed input increases above 20 kg/acre per day, fertilizing can be reduced because there is sufficient N and P in the feed.

When applying, solid fertilizer should be dissolved in water; never applied as solid or it will fall to the bottom and not be available for the plankton. Liquid fertilizer is highly desirable.

If liquid fertilizer can be obtained, it is best to dilute with water and spread over the pond surface. A change in pond color should be noticeable in a few days.

4.4. Stocking

It is important to choose the right number of tilapia to stock the pond, select the good quality fingerlings of uniform size and transport the fish so they arrive in good health. If the fish arrive in poor health and they die overnight, a farmer may not notice because birds cold have consumed them. Then the farmer will manage as if there are 10,000 fish in the pond for example, when there are really only 3,000. This leads to problems like overfeeding, which in turn can lead to loss of money.

4.4.1. The number of fish to stock

To get a good crop of marketable fish it is necessary to stock the pond with the correct number of tilapia. The number of fish to stock is determined based upon the pond's carrying capacity which in turn depends on the way the pond will be managed (especially the quality of feed to be used and the amount of aeration that will be used).

Stocking rates for the fry phase:

	Hapa in a pond	Tank (depends on aeration)	Pond	Recirulating tanks	In tank with continuous water exchange
Stocking rates	2,000-6,000/m^2	150-750/m^2	75-260/m^3	6,000-12,000/m^3	8,000-18,000/m^3

The fry-rearing phase generally lasts 28 to 30 days. For 21 days after hatching fries are treated with sex reversal fish feed. Fry reared in an adequate oxygen and good water quality situation will be substantially larger than fry reared in constant low oxygen.

Stocking for nursery:

Tilapias have attained an average weight of 0.1 to 1.0g per fish at the end of fry rearing phase.

Small tilapia fingerlings are reared to an advanced fingerling size (10-100g per fish) in nursing ponds before being stocked into grow-out ponds. Direct stocking of these small fingerlings into ponds for grow-out is an inefficient use pond facilities because of the low fish biomass during the early stage of production.

Nursing pond stocking rates vary from 5 to 90 fingerlings per meter square, depending on the final size expected in this phase.

Stocking for Growth phase:

Depending on the desired final weight and the level of pond management, stocking rate is usually 1 to 2 per square meter. The grow-out phase can begin with 2 to 3 fish per square meter and then the fish can be split into 2 ponds later in the grow-out phase and the pond attains carrying capacity. If we expect a carrying capacity of 4T per acre, we should really harvest before reaching the no-growth limit, so let us figure on 3.5 T per acre (875 grams per square meter), then 1 fish per square meter would give the desired large size. If aeration is being applied and very good feed, the carrying capacity can increase, thus so can the stocking rate. If the desired final size is less, more fish can be stocked.

4.4.2. Releasing fingerlings from oxygen-filled bags into the pond

When releasing tilapia in pond, first float the unopened bag in the pond for at least 15 minutes so that fish will take time to adjust in pond water temperature. Take care to not float them out in the hot sun as the air inside the bag will heat up the water like in a greenhouse.

Open the bag and splash in enough pond water to make a mixture of pond and bag water, then wait for at least 15 minutes so the fishes can get used to pond water. Pond water can be added several times to gradually make the change.

Finally sink the neck of the bag down into water of the pond, allow the fishes to swim out by themselves. Observe how the fish swim. If they lie down on the pond bottom, they have been over-stressed during transport and may eventually die.

4.4.3. Time of Day to Stock Ponds

It is recommended that fish be stocked at day time rather than at night because it is difficult to observe the fish condition. As well, oxygen levels can be low at night but this is unlikely if the pond has just been filled and has not received any feed. Avoid stocking the pond more than 2 weeks after it has been filled. Ponds with no fish tend to attract frogs that lay eggs. The tadpoles that hatch from the frogs eggs compete with the fry for food. Tadpoles also predate upon tilapia fry.

4.5. Feeding

There are some key principles that need to be understood by tilapia farmers:

- Small fish need proportionately more food per unit body weight compared to larger fish.
- Smaller fish also need to be fed more frequently than larger fish (just like children)
- Where there is plenty of natural food, less supplementary feed can be used.
- Feed based on the number and size of fish in the pond.
- The better the quality of the feed (low FCR), the less the quantity needed to feed the fish
- The metabolic rate of fish rises with increasing water temperature. Hence, at warmer water temperatures, they consume more food, until it gets too hot. On cooler days or weather, they consequently consume less. They also will eat less when the water is very hot.
- It is therefore recommended for producers to constantly adjust the feeding throughout the production cycle for better results depending on the fishes growth, number of fish left in pond and water quality conditions. You cannot force the fish to eat more than they have the appetite for.
- FCR will be adversely affected by overfeeding, poor feeds, poor pond fertilization and poor fish health.

4.5.1. Amount and frequency of feeding

Tilapia have relatively small stomachs. This means they cannot ingest a large amount of food at once; they are better off eating many small meals. Hence, access to natural food is a plus because the fish can graze all day long. Tilapia can digest many different things because the acidity of their stomachs can become very powerful after their first meal. As a consequence, the first thing the fish eat passes thought their guy relatively undigested, after which the acid kicks in and the following food gets digested very well. When using supplemental feed, it is recommended to benefit from the biology of tilapia. This means to not feed too early in the morning and small meals, feeding a maximum of about 1% body weight per feeding, when the fish are large,

Table 5. Suggested daily feeding rate and frequency for various size of Tilapia

Fish size	Feeding rate (percent of body weight)	Feeding frequency (No. of time/day)
2day old to 1 g	30-10	8
1-5 g	10-6	6
5-20 g	6-4	4
20-100g	4-3	3-4
>100g	2-3	2-3

Source: Modified after Lim (1989)

Table 6. Suggested feeding rate and feeding frequency at different water temperatures.

Water temperature (°C)	Average body weight <100g		Average body weight >100g	
	Feeding rate (percent of normal feeding rate)	Feeding frequency (No./day)	Feeding rate (percent of normal feeding rate)	Feeding frequency (No./day)
32 > to >26	100	4	100	2-3
26 > to >24	90	3	90	2
24 > to >22	70	2	60	2
22 > to >20	50	2	40	2
20 > to >18	30	1-2	20	1
18 > to >16	20	1	10	1
16 > to	No feeding		No feeding	

Source: Modified after Luquet (1991)

Above 32 ^{O}C, feed rate should reduce.

4.5.2. Feed Conversion Ratio: A Very Important Number

The Feed Conversion Ratio (FCR) is described as the amount of food required to produce a unit of fish (see equation 6 below). It is an indicator of the:

i. performance of a feed,

ii. efficiency of the response to feeding, and

iii. cost-effectiveness of using a particular feed.

$$FCR = \frac{\text{total amount of food given } (kg)}{\text{total amount of fish produced } (kg)}$$

The lower the FCR, the less amount of feed is used to produce a kilogram of fish growth, hence, the more efficient is the feed.

Record all feed fed and consumed at each meal/day (see appendix 5 for example).

Feeds that are home-made or incomplete in nutrition often have a high FCR. As well, sinking pellets will give a high FCR because tilapia will not usually pick the feed up for the pond bottom if it falls there. Feeds that are very fine particles often have high FCR. But even the best feed with all of the vitamins and minerals and nutrition necessary can give a high FCR if it is given in too great quantity, or if the pond has reached carrying capacity or if the feed has gotten spoiled.

4.6. Storing Feed

Feed that is bagged should be stored in a cool, dry room that is constructed so rodents cannot get in. This is easier said than done, especially if the door is left open. Good feed sheds have ventilation that has strong wire screening. Feed should be stored on pallets and should be at least 15 cm away from the walls. Stacks should not be too wide because air needs to circulate between the stacks of feed. The different types of feed should be kept separate and the oldest feed should be marked. A well-managed feed shed should be set up so the first feed entered is the first feed to be used. Fish feed loses its vitamin activity with time. Most feeds do contain an excess of some vitamins so it is hard to say how long of storage is too long but in general, it is best to use feed within 3 months of its manufacture. Moldy feed usually develops when feed was bagged when still hot, or if the feed has been touching a concrete wall of floor.

4.7. Frequently asked questions on feeding

Q: When I fill in the feed sheet and write what response is, what constitutes "Excellent" feeding response?

A: When the fish have consumed ALL the feed within a minute of when you gave it. The reaction will be so vigorous, the water will seem to boil with fish. If the fish come up in a vigorous manner but they do not consume all the feed right away, you are probably overfeeding.

Q: What if I calculate how much feed to give my fish in a pond but they do not consume it right away?

A: This can be due to one of the following reasons:

- They aren't there (possibly a hole in the cage, or fish swimming out the pond inlet), or you lost many more than you think after stocking.
- The water cooled down.
- The oxygen levels are low (if less than 2mg/l, tilapia will not feed very vigorously).
- Other water quality is bad, such as high ammonia or nitrites
- Somebody already fed them OR they are being over-fed.
- They do not like the feed-maybe it is moldy.
- The water is very rough; (wait for it to be more calm).
- The fish are sick.

The best thing to do in these circumstances is to solve the water quality problem if you can, and reduce the feed amount to about one half, until they begin feeding vigorously again and then slowly increase it. The worse thing to do is to keep dumping feed into the pond.

Q: How much fish meal is needed in a tilapia feed?

A: None. However, sometimes up to 3% fish meal is added if the price is right because the amino acids in the feed can be balanced easier this way. But for pond production of tilapia at low stocking densities, there is usually enough contribution of natural food that a lower protein feed can be used (about 28%) and an all-vegetable protein is quite feasible. Typically, if the protein in the feed comes from a combination of soy or another pulse and a grain such as maize, wheat or rice, the amino acids can be balanced without using animal protein. For the higher protein needs of young tilapia and fish grown in cages, the balancing of amino acids is very important and if an all-vegetable protein is to be used, a high grade soybean meal and some corn gluten meal is often advised. Some feed manufacturers use supplemental amino acids to balance the feed.

Q: Since feed makes up more than 50% of my production costs, I should use the cheapest feed I can, right?

A: That depends on FCR. The other costs play a minor role but improvements can be made there as well. When deciding what feed to buy, consider both <u>price and FCR</u>. FCR x price is a good indicator of what feed will be most profitable for you. Feed that costs the equivalent of $1/kg and has FCR 1.4 is more profitable than feed that costs $0.75/kg and has FCR 2. Feed that costs only $0.40/kg and has FCR 4 is actually MORE EXPENSIVE. Also, carrying capacity (see other handouts) is higher for feeds with lower FCR because the high FCR feeds produce more wastes that build up in the pond.

Q: Floating feed is expensive; can I feed my tilapia sinking feed and still get good results?

A: Yes, you can, but it is not as easy. Sinking feed is cooked at lower temperatures than floating feed, so it tends to be less digestible. Expect the FCR to be higher. As well, tilapia do not usually pick up feed from the pond bottom so sinking feed must be fed slowly and well distributed so the fish can catch the pellets before they sink to the bottom. In places where there is no floating feed available or it costs MUCH more than sinking, it was found that best results are obtained when a bag of feed is distributed over about 30 minutes. Farmers are advised to compare FCR and price. If your feed costs half the price but the FCR is 2.5 times higher, it is cheaper to use the feed of the higher price.

Q: Can I get an FCR less than 1? How so, to get more fish than the feed I give?

A: You can, and many farmers do when the fish are small. Realize that the feed is dry and the fish flesh contains water. So an FCR of 1 means to that 1 kg of dry feed provided 1 kg of fish growth but that 1 kg of fish is 75% water, so you actually got only 250 grams of dry fish flesh.

4.8. Daily Maintenance

The water volume and water quality must be maintained at optimal levels for production during the course of the production cycle if good yields are to be attained. The water quality is so important because it is the fishes environment.

In ponds it is preferable to maintain static water at the levels of production where one depends on the pond's own assimilating capacity to maintain water quality. Our stocking rates are set with this in mind. In such cases, water is only added to the pond to replace water lost through seepage and evaporation (refer to section 4.4.1 for more details)

The major water quality parameters that affect the fishes well-being and growth are water temperature, dissolved oxygen, pH and salinity. In addition, alkalinity and hardness help us determine how well natural food can be produced in the pond and how much the pH will change over the day. If these are low, liming will be needed. (Table 7) lists the optimum water quality values for tilapia farming.

Table 7. Threshold water quality values for tilapia farming

No.	Parameters	Level	Comments
1	Temperature	26-32 °C	Ideally be about 26°Cto 28°C. An acceptable range of about 23°C to 32°C. Temperature below 18°C and above 33°C are stressful and should be avoided.
2	Dissolved Oxygen (DO)	More than 4 mg/L	Tilapia can survive 0.5 mg/L for a short time but their growth is reduced. The longer the oxygen level is low every day, the lower the growth rate because the fish are using much energy to survive. They will not feed well if less than 3mg/L.
3	pH	6.5-9.0	Short exposure to pH as low as 5 will not result in immediate death but greater than 6 is recommended.
4	Salinity	1-15 ppt	Growth is reduced when salinity is above 12 ppt, except for the red tilapia. Salt level of 2 to 7ppt are highly desirable for tilapia.
5	Free Carbon Dioxide	2-12 mg/L	Tilapia can tolerate higher levels but their activity level is greatly reduced. If the level is high for too long, they will die. Often water from boreholes has high dissolved carbon dioxide.
6	Total Hardness	50-250mg/L as $CaCO_3$	Between 20 and 50 is OK but liming would be recommended
5	Total Alkalinity	50-100 mg/L as $CaCO_3$	

The condition of the ponds and behavior of fishes should be observed at least twice daily, in the morning and evening. Usually this is best done during feeding because often the only opportunity a farmer gets to see the fish is when they come up to the surface to feed (provided the feed floats or if sinking feed, the fish are well trained)). Any problems should be noted on the feed sheet.

If the fish gasp for air early in the morning at water surface and continue to do so after sunrise, it means that levels of dissolved oxygen are too low in the water. Such incidences become more frequent when ponds get to carrying capacity. In such a situation, management adjustments are necessary to maintain minimum accepted levels of dissolved oxygen during the nights otherwise fish growth will start to deteriorate. Among the measures that can be taken are reducing number of fish in ponds, controlling feed input levels and plankton blooms, aerating ponds late at night and into early morning.

It is important to keep a record of all pond activities and inventory, as this enables the farmer make better management decisions.

4.9. Sampling

As a farmer gets to have experience and growth rates are predictable, sampling may be less important and many farmers stop sampling after several years of experience and consistent growth. However, if a new feed is being tried out or if any new management change is being implemented; it is a good idea to sample so that growth can be tracked better.

- Sampling should be done twice in a month when fish are less than 100 g and at least once in month as the fish get larger to find out how much tilapia grown so feed rate can be adjusted. It is better to sample in the cool of the morning or evening. However, too early in the morning should be avoided due to the lower oxygen levels common in early morning.
- Fish should not be fed prior to sampling because handling fish with full stomachs will add to the stress.
- Sampling can be done by cast net or by seining a small portion of the pond.
- Fish should be weighted as soon as they caught and then released in to pond again.

- Measure the weight of 30-50 fish from the pond. This can be done as a batch. Count the fish as they are returned to the pond.
- Record all sampling data in the pond record sheet. Include the number sampled and the total weight, so that anybody checking the record can know what numbers were actually measured and what was calculated. For example it is best to write (50 fish weighed total of 5.5 kg, therefore average weight is 110 g, instead of average weight 110 g.

4.10. Harvesting

If we stock tilapia in April then harvesting will be started end of the November or start of December.

There are two types of harvest.

I. Partial harvest

II. Complete harvest

- Partial harvest is done with seine net or cast net but for complete harvest the pond is seined 3-4 times and then drained to get remaining fish.
- A seine of 1-2 cm mesh size with a height of 2-3m is commonly used. For every 2m of pond width, 3m length seine net is needed. For every 1 meter water depth, at least 1.3 m seine depth is required. A mudline and bag make the seine highly efficient.
- Tilapias are best harvested by seining and draining the pond. A complete harvest is not possible by seining alone. Tilapias are adept at escaping a seine by jumping over or burrowing under it. Typically, only 25 to 40 percent of *O. niloticus* population can be captured per seine haul in small ponds. Other tilapia species, such as *O. aureus*, are even more difficult to capture. However, a well-constructed seine with mud line and bag, pulled by experienced people has been able to take up to 80% of fish in the first pulling and another 10% in the second.

- A 1-inch mesh seine (with bag) of proper length and width is suitable for harvest. Knotless netting is preferred but knotted is acceptable especially if the fish will be slaughtered soon.
- Do not feed the fish one day before harvest. If the pond has very green water, the fish will not have empty stomachs but they will not be so full, either.
- After draining, the pond should be dried and repaired.
- If the pond is to remain without fish for the winter, it should still be filled to prevent erosion of the dikes from the rain and to prevent excessive weed growth in the pond bottom.

4.11. Marketing

Tilapia are being grown and sold in 85 countries. Genetically Improved Farmed Tilapia (GIFT) mono-sex tilapia is a new phenomenon of commercial production since 2012 in Pakistan. The Feeding Pakistan project took the lead to bring tangible success stories of commercial GIFT tilapia production system in Pakistan and entitled it ***"The Blue Revolution"*** in Pakistan. In Pakistan it is also relatively a new phenomenon of growing mono-sex tilapia up to 900 gram after implementation of FEEDing Pakistan program.

Size

Normally it is best to sell the fish at the smallest possible size the market will readily accept because FCR is higher relatively for larger fish. However, if the price per kg is substantially higher for the larger fish compared to the smaller fish, then it may make economic sense to grow the larger size, like in Pakistan larger fish are acceptable to traders and consumers. With good record-keeping a farmer can make a decision based on real data.

Example: a 900-gram tilapia sells for $ 2.00-2.2/kg and the farmer typically gets an FCR of 1.1-1.4 (Table 8) for the entire growing period. Feed costs US$ 800/ton. Fingerlings cost $0.15 each. The farmer figures that in producing a smaller fish, he can hit the market earlier than the others and he can get a much better FCR of about 1.2, and that he can sell his fish for less per kg and still make more money.

Table 8. Example of economics and marketing of small fish verses larger fish sales with two different stock densities.

	A (grow to 900 g)	B (grow to 400 g)
anticipated harvest kg/acre	3600	3600
number fingerlings to stock	4000	9000
cost of fingerlings	600	1350
anticipated FCR	1.4	1.1
amount of feed needed	5040	4032
cost of feed	4032	3168
selling price of fish per kg	2.2	1.6
total revenue	7920	5760
Net	3288	954

Conclusion: Yes, I needed to buy more fingerlings but the improved feed conversion more than made up for this. However, the net gain is not that much more. If feed cost more, it would be more interesting to produce smaller. If the smaller fish sold for much less than $2.00, it is better to produce larger.

In this example of a partial budget, we figure that all other expenses not related to the final size are equal. In fact, there may be less risk involved in growing to a smaller size if the fish are marketed earlier. However, the price of the smaller size needs to be well known, as well as the demand. Note that we used an estimated production per acre the same for each size produced. In reality, the production per acre may be better for the smaller size because the feed conversion is better so there is less wastes entering the water.

4.12. Economics of Polyculture Case Study

In 2014 a first formal case study of monoculture mono-sexed tilapia (GIFT) and polyculture Labeo *rohita* (rohu) and Catla *catla* (thala) with mono-sexed tilapia in Pakistan was carried out under FEEDing Pakistan program of ASA/WISHH funded by USDA. The case study showed the economic potential of polyculture with tilapia fed on soy-based floating feed for additional income and high ROI and BCR (Table 9). The study also observed, there was no report of in-breeding of locally sex-reversed tilapia.

Table 9. Comparison of economics and density in monoculture and polyculture in Pakistan

Pond # at farm	Pond 2	Pond 1	Pond 7	Pond 5
Stocking Detail (# of Fishes/Acre)	Rohu, thaila 700	Rohu, thaila 720 + tilapia 650	Tilapia 3,000 + rohu, thaila 800	Tilapia 7,200
Date of Stocking (Avg. Wt. in grams)	01APR2014 (200 gram)	01APR2014 (Rohu + thaila 200 g), 28AUG2014 (Tilapia 200g)	01APR2014 (Rohu + thaila 200g), 28AUG2014 Tilapia 200g)	21APR2014 (Tilapia 0.2g)
Date of Harvesting	15DEC2014	15DEC2014	15DEC2014	15DEC2014
No. of days	239	239	239	239
Harvested (No. of fish/acre)	Rohu/thaila 700	Rohu, thaila 700 + tilapia 618	Tilapia 2,700 + rohu, thaila 790	Tilapia 6,400
Avg. Wt. (kg)	Rohu/thaila 2.2	Rohu/thaila: 2.0 & tilapia: 1.0	Rohu/thaila: 1.62 & tilapia: 0.750	tilapia: 0.679
Total Calculated Biomass (kg)	1,540.00	2,018.00	3,304.80	4,345.60
Cost Per Kilogram	164.25	137.18	115.21	102.38
Expenses (Rs)	252,937.50	267,835.00	380,750.00	444,911.20
Revenue (Rs)	415,800.00	482,870.00	738,801.00	890,848.00
Profit Per Acre	162,862.50	206,035.00	358,051.00	445,936.80
Return on Investment (ROI)	0.64	0.74	0.94	1.00
Benefit Cost Ration (BCR)	1.64	1.74	1.94	2.00

Source: Evaluation of case study by R.S.N. Janjua, SoyPak (ASA/WISHH) and Tawakkal Tilapia Hatchery, Pakistan 2014

Market location

Often ignored, market location can make or break a business. Some farms can sell directly from the farm (known as pond bank) but the customers are often middlemen and the price offered is lower. It is often recommended to avoid selling farmed fish next to a market that sells wild-caught fish because prices for wild-caught are often much lower. Farmers should not be totally against selling to middlemen just because they pay a lower price. These people have costs of transport and vending of the fish to meet. Yes, they have less risk than the producer but they do render a service. If a farmer wishes to engage in sales of all his fish, he will probably need to hire more people and have a sales point that is different from the farm.

Timing

Due to the seasonal nature of tilapia production in Pakistan, the availability of large tilapia will be high in November and low in April through September. Any farmer who can offer tilapia on the market in the “off-season” will be able to sell at higher prices, thus allowing to spend a bit more in the production of these fish. Farmers in Egypt often keep their fingerlings in a greenhouse over the winter time and early growth in greenhouse can possibly be profitable in Pakistan if the price is indeed higher in the “off-season”.

Product

Tilapias are often sold on ice but for the fish to last more than a day, it is best to gut the fish prior to icing them. Price after any processing must be higher than for whole fish because weight is lost and there is labor involved. When calculating the price of a product that has been processed- either gutted, scaled and gutted or filleted, the “dress-out percentage” should be calculated. For example, if 10 kg of fish are gutted and scaled, the resulting weight is often 8.5 kg. Therefore the dress-out is 85%. For filleting, the dress-out is 25 to 35% depending on several variables such as skill of the workers, whether or not the fillet has had the pin bones removed or if the fish has had the red line of flesh removed (“deep-skinned”). Therefore, fillets should sell for AT LEAST 3 times the price of whole fish.

Product Quality

Fish preservation is meant to reduce the multiplication of bacteria; it does not kill off all the bacteria. Even frozen fish have bacteria and these will multiply fast when the temperature is reduced. The gills are an easy place for bacteria to multiply and are rich in nutrients, so besides removing the guts, many people will remove the gills if the fish is to be held on ice for a long time. Tilapia have very acid stomachs and if they have been kept on ice for too long, or have been squashed by other fish on top of them, the stomach fluids will be released and begin to digest the fish from the inside out.

Fresh fish have red gills, full and clear-looking eyes, and have little to no odor. Their flesh is firm and returns to form when pushed. Appendix 5.5 provides more details. Typically, a gutted tilapia can be held on ice for up to 12 days IF the melted ice is drained off and if the ice is maintained at a 1:1 ratio with the fish, which usually involves adding ice twice a day. If just at ambient temperature of 30C, after 3 hours the fish have reduced from grade A to grade B and after 12 hours the fish have become unacceptable.

4.13. Record Keeping

The records that should be kept include both farm activities such as stocking, feeding, sample weighing, fertilizing and harvesting and natural phenomena such as fish kills, period of low DO, rainy days, floods etc.

These records over a number of years will show the effects of different management methods on profitability. For example, the farmer can examine the records to pinpoint occurrences of lower growth rates, low feed utilization, or fish deaths.

Keep complete record from stocking to harvesting. Below are some examples.

Pond Record Sheet

Name of farm: ____________________ Pond No.:_____________ Area: ____________________ m^2

Fingerling source: _________________ Stocking date: ________ No. stocked: ________________

Stocking density: __________/m^2 Average body weight (ABW): _____ g Total wt: _______ kg

Feed supplier: ______________ Type of feed: _________________ Type fertilizer: ______

Daily feed ration (DFR):___________kg Fertilizer (kg per week):______________

Fish Sampling Data:

Sampling date	Days	ABW of fish (g)	Length (Cm)

Fish Harvesting Data:

Harvest date	Grow-out No. of days	No. of fish	ABW of fish (g)	Harvested weight (kg)

Total fish harvested: _________ kg Selling price: ___________ /kg Total sales: ________________

Total feed used: ____________ kg Feed price: _____________ /kg Total feed cost: ____________

FCR: _________________________

Total fertilizer used: _________ kg Fertilizer price: __________ /kg Total fert. cost: ____________

Fish survival: ________________% Fish losses: _____________ kg Fish given free: _________ kg

Market fee: ___________________ Transport cost: ____________ Labour cost:_______________

FEED SHEET: week of____

Pond	Type of feed	Amount to feed	Mon		Tue		Wed		Thu		Fri		Sat		Sun		Total (Kg)	Observation
			Amount Consumed	Response	Amount Consumed	Response	Amount Consumed	Response	Amount Consumed	Response	Amount Consumed	Response	Amount Consumed	Response	Amount Consumed	Response		

Feeding Response: E – excellent G – good F – fair P – poor

Pond: Size: Function:

Date	Stock	Treat	Sample	Harvest	Drain	Description (Species, number, weights, sizes, where from, where to)	Total #	Total Weight (Kg)

5.1. Useful Formulae

- **Percentage survival:**

% survival = Number of fish harvested x 100

Number of fish stocked

For example:

If you put in 1000 fish and harvested 900, then % survival was 900/1000 x 100 = 90%.

A good survival rate is 90% or more.

- **Average body weight:**

ABW = Total weight of fish in a random sample

Number of fish in sample

For example:

If you caught 500 fish and the weight of the fish was 75 kg, then ABW was 75/500 = 0.150 kg, so ABW is 150 grams.

- **Daily feed ration:**

DFR = Feeding rate x ABW x Total number of fish

Note: Feeding rate is the percentage of fish average body weight to be given as food daily (e.g. 5% of body weight).

- **Total feed requirement:**

TFR = DFR x Feeding duration

- **Feed conversion ratio:**

FCR = Amount of feed given

Fish weight increase

5.2. Measures and Equivalents

Length

1 inch	=	2.54cm		
1 foot	=	12 inches	=	0.3048 m
1 yard	=	3 feet	=	0.9144 m
1 rod	=	55 yards	=	5.0292 m
1 chain	=	22 yards	=	20.117 m
1 furlong	=	220 yards	=	201.17 m
1 mile	=	1760 yards	=	1.6093 km
1 nautical mile	=	6080 feet	=	1.853 km

Surface or Area

1 sq inch	=	6.4516 cm2		
1 sq foot	=	144 sq inches	=	0.0929 m2
1 sq yard	=	9 sq feet	=	0.8361 m2
1 acre	=	4840 sq yards	=	4046.9m2
1 sq mile	=	640 acres	=	259.0 hectares

Capacity

1 cu inch	=	16.387 cm3
1 cu foot	=	1728cu inches = 0.0283 m3
1cu yard 27 cu feet	=	0.7646 m3
1 pint = 4 gills	=	0.5683 liters
1 quart = 2 pints	=	1.1365 liters
1 imperial gallon	=	8 pints = 4.5461 liters
1 bushel = 8 gallons	=	36.369 liters

Conversion Formulae

Non- metric to Metric

Length

To convert..................................	***Multiply by***
Inches into centimeters.............	2.540
Inches into meters......................	2.540 × 10-2
Inches into millimeters...............	25.4
Feet into meters..........................	0.3048
Yards into meters........................	0.9144
Miles into kilometers	1.609344
Miles into meters........................	1609.344
Feet into centimeters	30.48

Area

To convert..................................	***Multiply by***
Sq. inches into sq. centimeters..	6.4516
Sq. feet into sq. centimeters......	929.03
Sq. feet into sq. meters..............	0.092903

Sq. yards into sq. meters……...	0.8361
Sq. miles into sq. kilometers….	2.58999
Sq. miles sq. hectares………….	258.999
Acres into sq. meters………….	4046.856
Acres into hectares…………….	0.40469

Volume & Capacity

To convert…………………………….	***Multiply by***
Cu. Inches into cu. centimeters..	16.3871
Cu. Inches into liters……………….	0.016387
Cu. feet into cu. meters………….	0.0238317
Cu. feet into liters………………...	28.32
Pints into liters..........................	0.56826
Quarts into liters…………………...	1.13652
Cu. yards into cu. meters………..	0.7646
UK gallons into liters……………...	4.54609
US gallons into liters……………...	3.785

<u>Conversion Formulae</u>

Metric to Non-Metric

Length

To convert…………………………….	***Multiply by***
Millimeters into feet……….……	3.281 × 10-3
Millimeters into inches……….……	0.03937
Centimeters into inches……..……	0.3937
Meters into feet……………………..	3.281
Meters into yards…………………..	1.09361
kilometers into yards …………….	1093.61
kilometers into miles…………..….	0.62137

Area

To convert…………………….........	***Multiply by***
Sq. millimeters into sq. inches..	1.550× 10-3
Sq. centimeters into sq. inches..	0.1550
Sq. meters into sq. feet ………..	10.7639
Sq. meters into sq. yards………..	1.19599
Sq. meters into acres …………..…	2.47105× 10-4
Kilometers into sq. miles ……….	0.3861
Sq. kilometers into sq. acres…..	247.105
Hectares into acre………………….	2.47105

Volume & Capacity

To convert…………………………..	***Multiply by***
Cu. centimeters into cu. inches..	0.06102
Cu. meters into feet……………...	35.3147
Cu. meters into cu. yards……….	1.30795
Liters into cu. inches……………….	61.03
Liters into pints..........................	1.7598
Quarts into liters…………………...	0.8799
Liters into UK gallons ………………	0.219976
Liters into US gallons …………….	0.264178

5.3. Disease and Control Measure

DISEASE	AGENT	Type	SYNDROME	MEASURES
Motile Aeromonas Septicaemia (MAS)	Aeromonas hydrophila & related species	Bacteria	Loss of equilibrium; lethargic swimming; gasping at surface; haemorrhaged or inflamed fins & skin; bulging eyes; opaque corneas; swollen abdomen containing cloudy or bloody fluid; chronic with low daily mortality	KMnO4 at 2-4 mg/litre indefinite immersion or 4-10 mg/litre for 1 hour; antibiotics (need 'extra-label use permit' in the USA), e.g. Terramycin® in feed at 50 mg/kg fish/d for 12- 14 d, 21 d withdrawal
Vibriosis	Vibrio anguillarum & Other species	Bacteria	Same as MAS; caused by stress & poor water quality	Antibiotic in feed
Columnaris	Flavobacterium columnare	Bacterium	Frayed fins &/or irregular whitish to grey patches on skin &/or fins; pale, necrotic lesions on gills	$KMnO_4$ as with MAS; indefinite immersion with $CuSO_4$ at 0.5-3 mg/litre, depending on alkalinity
Edwardsiellosis	Edwardsiella tarda	Bacterium	Few external symptoms; bloody fluid in body cavity; pale, mottled liver; swollen, dark red spleen; swollen, soft kidney	Antibiotic in feed
Streptococcosis	Streptococcus iniae & Enterococcus	Bacteria	Lethargic, erratic swimming; dark skin pigmentation; exophthalmia with opacity &	Antibiotic in feed, e.g. Erythromycin at 50 mg/kg fish/d for 12 d (requires

	sp.		haemorrhage in eye; abdominal distension;	extralabel use' permit in the USA)
			diffused haemorrhaging in operculum, around mouth, anus & base of fins; enlarged, nearly black spleen; high mortality.	
Saprolegniosis	Saprolegnia parasitica	Fungus	Lethargic swimming; white, grey or brown colonies that resemble tufts of cotton; open lesions in muscle	$KMnO_4$ or $CuSO_4$ treatments; use 1 mg/litre of $CuSO_4$ for every 100 mg/litre alkalinity up to 3.0 mg/litre CuSO4; formalin at 25 mg/litre indefinite immersion or 150 mg/litre for 1 h
Ciliates	Ichthyophthiriu s multifiliis; Trichodina & others	Protozoan parasite	Occurs on gills or skin	KMnO4, CuSO4 or formalin treatments
Monogenetic trematodes Dactylogyrus spp.;	Dactylogyrus spp.; Gyrodactylus spp.	Protozoan parasite	Occurs on body surface, fins or gills	formalin at 15 to 25 ppm in pond or a dip of 100 ppm for 15 minutes or until stress is evident.,

5.4.How to Use a Secchi Disc with the Reference Water Color Chart and Interpret the Results

(Adpated from Isyagi et al, 2009).

1. **Using the Secchi Disc**

A secchi disc can easily be made by cutting a piece of wooden board or metal in a circle of diameter 20cm. The bottom of a white bucket can also be used. Paint it white and black in equal quadrants as shown. In the center, drill a small hole and pass a string or piece of wood through. Mark the piece of string or wood in cm. If using sting, a weight must be added to the bottom. (Fig. 10)

Figure 10. A Picture of a Secchi Disc

Step 1 – One would think that reading transparency is best when there is full sun but since this is not always possible, a secchi disk reading is supposed to be taken in a shadow because it is easier to make a shadow when there is bright sun compared to making bright sun when it is cloudy.

Step 2 – 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 further into the water to the point where it just starts to become invisible and you cannot clearly see it. Read from the graduated rope or piece of wood attached to the secchi disc, the depth at which the secchi disc started becoming invisible. This is often done in centimetres.

Step 4 – Slowly raise the secchi disc out of the water, and note the depth at which it just starts to become becomes visible. Measure this depth. Usually there is only a 1 cm difference between when it disappears and when it reappears.

Step 5 –Use the average of these two readings. This will give you the secchi depth. The secchi depth is a simple and practical way of assessing how clear or turbid the water is.

Step 6 – Look at the reference colour chart to assess what sort of turbidity you have (whether phytoplankton or clay) .

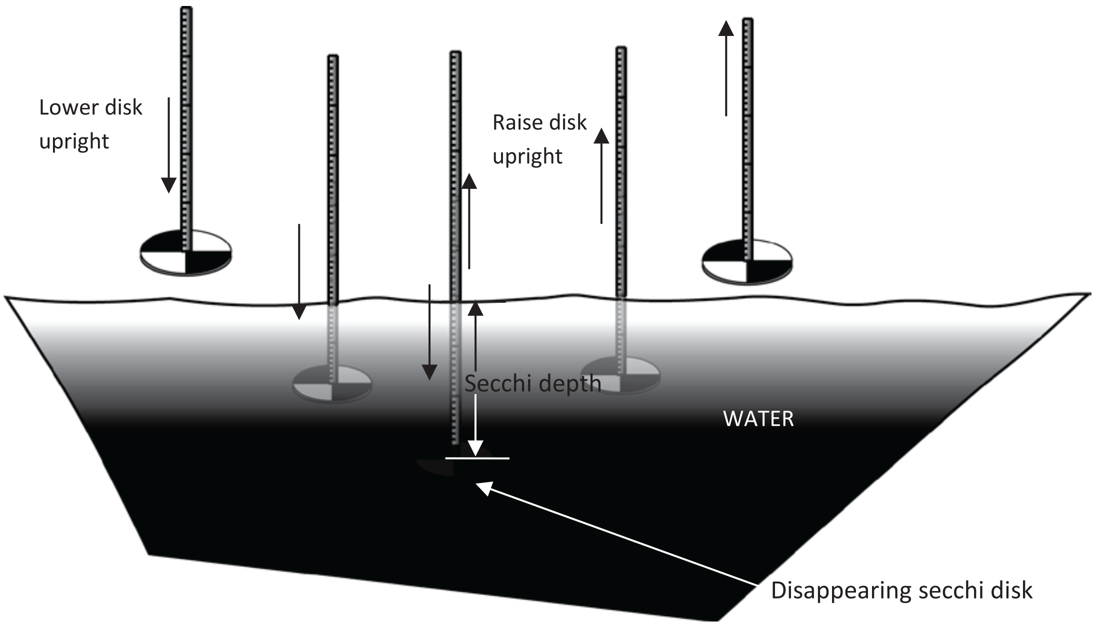


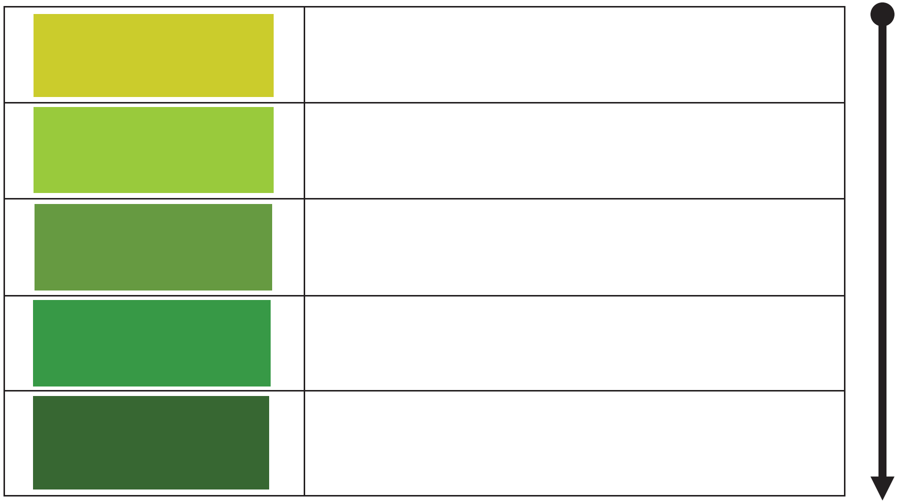
Figure 11: Taking a Secchi Depth Reading

2. The Pond Reference Colour Chart

- This reference chart used with a secchi disc is a tool designed to help you manage the levels of pond productivity (plankton blooms) for tilapia production in ponds. It will help you decide whether or not to add more fertiliser or lime to the pond.
- The colours are an indication of the different kinds of turbidity - clay turbidity and turbidity caused by plankton blooms.

Common Pond Water colours	Your Comments and Personal Notes

Brownish Waters are normally caused by soil particles suspended in the water column. Clay is among the causes. The colour of the water in this case will often be similar to that of the pond. However in the event of a rain downpour, the water in pond may take on the colour of the soil around it if there has been some wash-off into the pond. Ponds with brownish water are often not fertile. Ponds stocked with bottom feeders such as catfish will however tend to be muddy because of the behaviour of the fish.



Greenish colours indicate plankton productivity. The green often ranges from brownish-yellow-bluish green depending on the type of plankton bloom it is. Brownish green blooms often have more zooplankton. The greenish/yellow/blue bloom tend to be more phytoplankton. Some of the plankton tends to turn red at some hours of the day. Green water, as long as it is not excessive, is best for tilapia production, whether or not you are feeding the fish. For tilapia production in ponds, the farmer must manage the level of phytoplankton production in the pond.

3. Interpretation of the Results

The results of the secchi disc readings and the reference colour chart are interpreted as described in (table 10) below.

Table 10. Relationship between Secchi Disc Visibility and Management Requirements for Maintaining Phytoplankton Blooms.

SECCHI DISC READING (cm)	COMMENTS
Less than 20 cm	Pond too turbid. If pond is turbid with phytoplankton, there will be problems with low dissolved oxygen concentrations especially at night. When the turbidity is from suspended solids (eg. clay), productivity will be low.

	Do not add more fertiliser. If there is a foul smell, flush the pond.
20 – 30 cm	Turbidity is good for tilapia production. Do not add more fertiliser if turbidity is less than 25 cm. Levels of fertilisation during production should be to maintain this level with the prescribed level of fertilisation.
30 – 45 cm	If turbidity is from phytoplankton (greenish water), then the pond is in good condition but tilapia growth will improve if more plankton can be produced so continue the weekly applications of fertilizer.
45 – 60 cm	Phytoplankton becoming scarce. The water is getting clear and some aquatic weeds may begin to grow. If you do not have weeds, add more fertiliser to your pond to get a better bloom. If you already see weeds in the pond, they should be removed before fertilizing. If you do not get a bloom then probably check your pH and alkalinity. Also make sure your pond is not leaking and that it is not 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, do not add more fertiliser. Weed them out first.

USAID FISH PROJECT, Training Technical Report, (Boyd, 1998)

5.5. Freshness grading scheme for tilapia

Grade	Extra (Excellent)	A (acceptable)	B (acceptable)	C (unfit)
Skin	Bright, shining	Waxy, slight loss of bloom	Definitely dull, with loss of bloom	Visible lesions possibly; reddish lateral line.
Scales and slime	Scales lying down flat; clear slime	Becoming milky	More turbid and milky , increased slime	Scales raised up, Thick, sticky slime, yellowish color.
Eyes	Convex black pupil, translucent cornea, eye bulging.	Slight clouding of the lens and eye becoming sunken.	Slightly concave, graying pupil, opaque cornea.	Completely sunken, gray pupil, opaque discoloured cornea
Gills	Bright red, mucus translucent	Pink, mucus slightly opaque	Brownish or gray-white, mucus thick and opaque	Bleached, mucus yellowish gray and clotted.
Consistency of flesh	Firm and elastic	Moderately soft and less elastic	More soft, fairly easy to tear flesh	Limp and floppy
Gill and internal odours	Fresh, smell of pond water (natural)	Faint sour odour	Moderate musty or sour odour	Stronger sour or or sulphide smell

Adapted from Connell, 1995 and from Adoga et al. 2010

6. Soy: The Sustainable Alternative

Initial diets for aquaculture species typically contain high levels of fish meal and fish oil, which are flavorful ingredients for aquatic animals. However, supplies of fish meal and oil are insufficient to realize needed growth in aquaculture production during the next 40 years. Global fish meal supplies are approximately 6.8 MMT annually, of which approximately 1.7 MMT, or 25 percent, is used in diets for aquatic animals. If we assume aquaculture grows the least amount predicted (60 million metric tons), and we can restrict fish meal usage to 10 percent of the diet, then aquaculture will demand 6 MMT of fish meal in the next 40 years. Keep in mind, the current global supply is only 6.8 MMT, and this will most likely not increase.

Processed soybeans are the world's largest source of protein for animal feeds and the second largest source of vegetable oil. The use of soybean products in the feed and food industry has increased steadily over the past decades. Specially formulated soy-based feeds are rich in the proteins and nutrients that support healthy and efficient fish growth, while producing less waste. U.S. soybeans increase the affordability and sustainability of the world's supply of healthy, farm-raised seafood and can replace from one-third to one-half of the fishmeal in feeds for many farmed species, thus reducing the pressure on wild fish resources. The U.S. soy growers promote environmentally friendly aquaculture production techniques around the world. Unlike wild resources for fishmeal, the soy industry can scale up to sustain the growth of global aquaculture.

6.1. Using Soybean to Food

High-quality Soybean meal, soy protein concentrates, soybean oil, and other vegetable proteins and oils, can replace from one-third to one-half of the fishmeal in feeds for many farmed species and shellfish to support their growth and healthy development, reducing the need for wild-caught fish for fishmeal.

Soybean meal can serve as the primary protein source in all-plant protein diets for freshwater omnivores, sparing more expensive fishmeal and animal meals for more specialized feeds. Soybean meal cost significantly less than most animal meals, including fish meal. Reducing feed cost is critical to improving efficiency and maintaining sustainability in aquaculture operations. Because the nutrient requirements of farmed fish and shellfish are so complex, each feed ratio is formulated based on the individual species' needs. Most farm-raised fish and shellfish can easily digest soymeal, which helps the fish more efficiently transform ingested protein into body weight.

Soy protein concentrate has been shown to be effective in replacing fishmeal in the fingerling diets in freshwater omnivore diets, allowing production of all-plant protein diets for all life stages of the majority of the cultured freshwater fish species.

6.2. Why Soy-Fed Fish?

Soy-fed fish are growing in popularity as a healthful and delicious meal.

- More than 40% of all seafood consumed globally is raised in farms.
- Aquaculture serves as a "relief valve" for wild-capture fisheries and bridges the 88-million-ton gap between the world's wild supply and consumer demand for healthy seafood.
- Using soy in fish feed is a healthful, sustainable, and environmentally sound way to raise healthy fish for a seafood hungry world.
- Soy-fed fish supply a growing global population with renewable sources of nutritious and affordable varieties of fish and shellfish.

6.3. Soy Fed Fish Species

To reduce depended on wild fish-based food, Feeds with Soy (Containing no fish or animal meals) have been developed to Carps, Catfish, Tilapia other freshwater species. Partial replacement with soybean meal has been developed for marine species.

Trials on soy-based feeds prove that Tilapia F.C.R. 1.2:1. (Reference, Aquaculture Handbook: Fish Farming and Nutrition in Pakistan)

Conclusion: Should soybean meal become widely used in aquatic diets, it will offer more than just a nutritional benefit. Diminishing use of fish meal and increasing use of soybean meal appears to improve the effluent characteristics of aquaculture operations. This will be an increasingly important consideration in aquaculture, as it is in other animal production industries.

6.4. Soybean Meal Specifications

Organizations, companies or individuals participating in a transaction involving soybean meals can follow the National Oilseed Processor Association of U.S.A. (NOPA) standards which clearly aim at providing a minimum number of primary quality characteristics and as such are only a basis for contract specifications (Table 11). The only characteristics defined are moisture, crude protein, fat and crude fiber with a maximum tolerance for an anti-caking agent.

Table 11. Specification for solvent extracted and dehulled soybean meal (SBM)

	Min/Max	Solvent Extracted SBM (%)	Dehulled SBM (%)
Moisture	Max	12	12
Protein	Min	44	47.5 – 49.5
Fat	Min	0.5	0.5
Crude Protein	Max	7	3.3 – 3.5
Anti-caking agent	Max	0.5	0.5

(NOPA, 2011),

Beyond purchasing and possibly storage allocations, these specifications have little impact on normal feed milling operations; neither from a specific quality point of view nor from a formulation perspective. They do not provide a sufficiently detailed overview of the nutritional characteristics required for proper quality management or further use. Meals purchased under NOPA contract specifications will therefore still need additional analysis. In order to provide greater quality assurances and meet the nutritional requirements of the feed compounder or nutritionist, additional recommendations have been added by NOPA (Table 12).

Table 12. Recommended additional specifications for soybean meal.

Total Lysine	> 2.85% (basis 88% dry matter)
Digestible lysine	Equal or > 88% of total lysine
Ash	< 7.5%
Acid insoluble ash (silica)	< 1%
Protein solubility in 0.2% KOH	78 – 85%
Urease activity	0.000 – 0.100 pH unit rise
Trypsin inhibitors	1.75 -2.50 mg / g
Bulk density	57 -64 g /100 cc
Screen analysis (mesh)	95% thru #10, 45% thru # 20, 6% thru #80
Texture	Uniform, free flowing, no lumps, cakes, dust
Color	Light tan to light brown
Odor	Fresh, not musty, sour, ammonia, burned
Contaminants	No urea, ammonia, pesticides, grains, seeds, molds

These are only recommendation that apply in a non-binding manner to all soybean meals.

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