A Guidebook of Tilapia Hatchery Operations for Small-scale Commercial Fish Farmers in Northern Zambia

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Acknowledgements

The information contained in this guidebook was gathered from various published and unpublished sources to help address the subject matter. The works of various authors was consulted to present a fair and reliable documentation of information that is relatively easy to understand by literate small-scale commercial fish farmers in northern Zambia. These sources of information are referenced and duly acknowledged. Whenever possible, tables, figures and certain sections have been directly attributed to specific authors, while other sections have been referenced generally.

The guidebook was developed by Jonas Wiza Ng'ambi, a consultant for WorldFish. Inputs from Sunil Siriwardena, Mary Lundeba, and Steven Cole were provided to develop the guidebook. The guidebook will be used to train indigenous tilapia breeder farmers in northern Zambia, but can be used to train breeders in other parts of Zambia and Africa more generally. The training will be carried out by staff from the Department of Fisheries and WorldFish, together with Peace Corps volunteers working in the region. Financial support to develop the guidebook was provided by Irish Aid Zambia.

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Chapter 1

INTRODUCTION

1.1 Overview of fisheries and aquaculture in Zambia

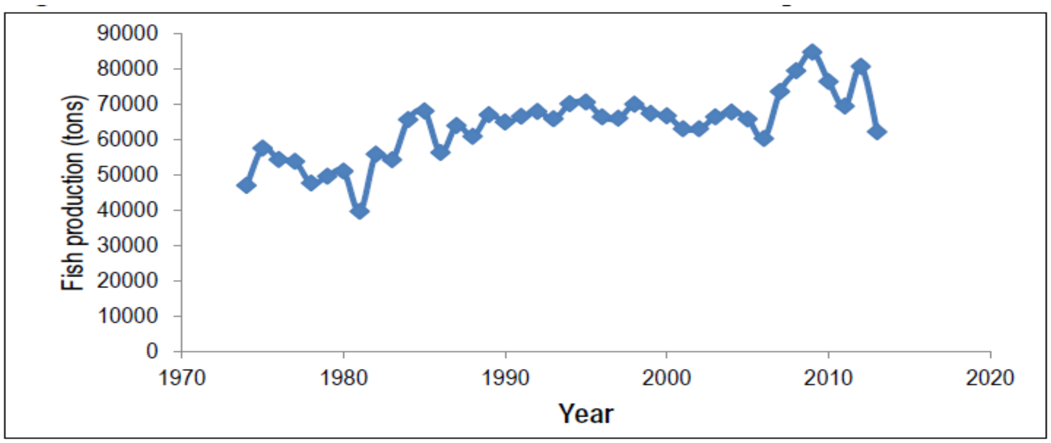
Zambia is endowed with 12 million hectares of water in form of rivers, lakes, and swamps and 8 million hectares of wetlands. This endowment represents a huge fisheries and aquaculture resource that is segmented into three major water basins that include the Congo, Luapula, and the Zambezi catchments (Fig 1.1).

Figure 1-1: Map of Zambia showing major Lakes and rivers (Source: Shula and Mukuka, 2014)

The Congo basin is the smallest and is represented by Lake Tanganyika. The Luapula Basin consists of the Chambeshi River and the Bangweulu Lakes and Swamps Complex, Luapula River, Mweru-wa-Ntipa and Lake Mweru. The Zambezi catchment area is the largest and consists of the Luangwa River, Lukanga swamps, Kafue River, Zambezi, the Middle Zambezi (now dominated by Lake Kariba), and Lower Zambezi. The fisheries sector in Zambia consists of two subsectors namely capture fisheries and aquaculture. The distinctions between the two are explained below.

Capture fisheries involves the harvesting of naturally occurring fish resources in the naturally occurring water bodies such as lakes, rivers, and any impoundments. The major capture fisheries include Lakes Kariba, Mweru–Luapula, Mweru–Wantipa, Lusiwasi, Itezhi Tezhi, and Tanganyika. The major rivers include Kafue, Luangwa, Lukanga, Chambeshi, and Zambezi. Therefore, emphasis is on fisheries management in order to sustain fish production from natural water bodies.

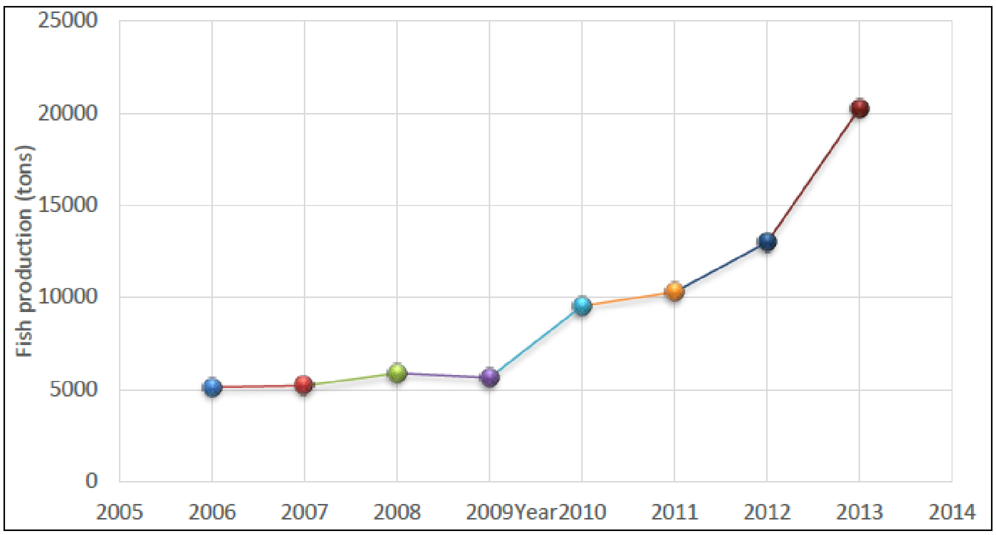
The production from capture fisheries is not likely to increase from the current 75,000 tons on average since they are being over-exploited due to the use of destructive methods coupled with an increasing number of fishers. For instance, there were 7,696 fishers in 1976 against 18,150 fishers in 2013 in the Lake Bangweulu complex alone. This may explain why the fish production from capture fisheries has started to decline since 2010 (Fig 1.2). It is important to mention that the fish catches have been declining in only Kafue and Mweru Wantipa fisheries (Shula & Mukuka, 2015).



Source: (Shula & Mukuka, 2015

Figure 1-2: Trend of Fish Production and Fishers from Capture Fisheries (1974-2013)

Aquaculture refers to the cultivation, propagation or farming of fish, aquatic vegetation, or other living aquatic resources whether from eggs, spawn, spat, or seed, or by rearing fish lawfully taken from the wild or lawfully imported into the country, or by other similar process. In Zambia, the tilapia and the catfish are the main fish types grown through either the cage system or the pond system (See fig 1.5), the systems that have been adapted to the country. The latter system has been rapidly expanding since 2004 especially in Lake Kariba. Its upscaling is also being witnessed in Lakes Mweru, Bangweulu complex, and Tanganyika. While fish diseases, theft, and pollution are well known challenges, the cages have great advantage in that they have a relatively lower investment cost in that they use the already existing water body compared to pond culture. Furthermore, productivity in cages is higher than in ponds (Shula & Mukuka, 2015).



Source: Shula & Mukuka, 2015

Figure 1-3: Trend of Fish Production from Aquaculture (1974-2013)

Zambia's aquaculture fish production has grown significantly in the last two decades. From a total production of only 5,000 tons of fish per annum in 2006, the country now produces about 20,000 tons in 2013 (Fig 1.3). The increase is mainly due to the rapid adoption of cage fish farming which is a high intensive system. Furthermore, the emerging of the private sector in fish seed and feed production has been also a catalyst in the upscaling of fish production in Zambia. Fish demand has also been an attractant to investment in aquaculture.

1.2 **Problems of Aquaculture production in Zambia**

Although several achievements have been noted during the development of Zambian aquaculture, it has not been without constraints or difficulties. The problems range from technical, social-economical to administrative, some of which are listed below:

- Inadequate financial support and incentives for private sector to step into aquaculture
- Inadequate quality fingerlings
- Lack of the right type of fingerlings required in different areas of the country
- Insufficient animal manure
- Lack of affordable fish feed
- Lack of appropriate technology
- Poor rural infrastructure
- Lack of marketing strategy
- Insufficient extension staff
- Inadequate operational funds for research
- Insufficient donor support for research
- Untimely government support after projects

1.3 **Introduction to Tilapia culture**

Tilapias are members of the family Cichlidae that are warmwater fishes native to Africa and the Middle East where more than 100 species are found in the wild.
Tilapia has become the third most important fish in aquaculture after carps and salmonids. Because of their large size, rapid growth (3 to 7 months to grow to harvest size), and palatability, a number of tilapine cichlids are at the focus of major aquaculture efforts, specifically various species of Oreochromis, Sarotherodon, and Tilapia, collectively known colloquially as tilapias. Like other large fish, they are a good source of protein, vitamins, and minerals, including significant amounts omega-3 fatty acids and a popular target for artisanal and commercial fisheries. Originally, the majority of such fisheries were in Africa, but accidental and deliberate introductions of tilapia into freshwater lakes in Asia have led to outdoor aquaculture projects in countries with a tropical climate such as Central Africa, South East Asia and Caribbean. In temperate zone localities, tilapine farming operations require energy to warm the water to the tropical temperatures these fish require. One method involves warming the water using waste heat from factories and power stations.

1.4 Basic Biology of Tilapia

Tilapia is the generic name of a group of cichlids endemic to Africa. The group consists of three aquaculturally important genera; Oreochromis, Sarotherodon and Tilapia. Several characteristics distinguish these three genera, but the most critical relates to reproductive behavior. All tilapia species are nest builders; fertilized eggs are guarded in the nest by a brood parent.

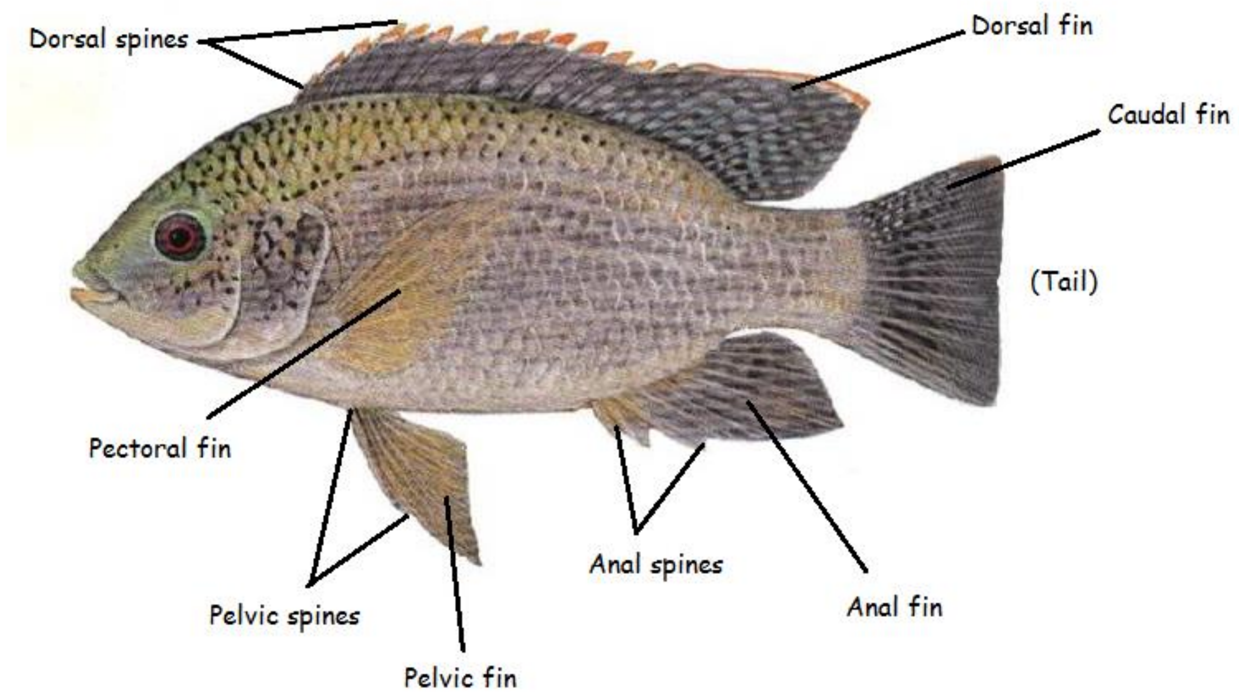


Figure 1-4: External anatomy of tilapia

Species of both Sarotherodon and Oreochromis are mouth brooders; eggs are fertilized in the nest but parents immediately pick up the eggs in their mouths and hold them through incubation and for several days after hatching. In Oreochromis species only females practice mouth brooding, while in Sarotherodon species either the male or both male and female are mouth brooders.

Tilapia have a deep compressed body that can easily be identified by an interrupted lateral line characteristic of the Cichlid family of fishes. They are laterally compressed and deep-bodied with long dorsal fins. The forward portion of the dorsal fin is heavily spined. Spines are also found in the pelvis and anal fins. There are usually wide vertical bars down the sides of fry, fingerlings, and sometimes adults (Fig 1.4).

Tilapia, just like other kinds of fish has a tail consisting of the caudal peduncle and the caudal fin. The fish's fins help it steer through the water and hold it upright in the water. Often a sick fish cannot steer or flops over on its side. Other fins on the body include:

- Pectoral -usually located on the sides of the fish behind the head.
- Pelvic -usually located towards the rear of the body where the hips would be if the fish were a four-legged animal.
- Dorsal-runs along the top of the fish. May be single or double. The second dorsal fin is sometimes called the soft dorsal fin
- Anal-usually located right behind the anal vent (anus) on the rear bottom end of the fish.

1.5 Classification of Tilapia species suitable for culture in Zambia

The classification of various fishes of Zambia has been previously studied (Utsugi and Mazingaliwa, 2002). Tilapias are predominantly freshwater finfishes often some species characterized with nest building and surface or mouth brooding habits. The tilapia group consists of three important genera, *Oreochromis, Sarotherodon* and *Tilapia*. Several characteristics distinguish these three genera, but the most important one relates to reproductive behavior. The taxonomic classification of the Nile tilapia is given below:

Phylum: Chordata
Subphylum: Vertebrata
Class: Osteichthyes
Order: Perciformes
Family: Cichlidae

The three genera under this family to which the most common tilapia species found in Zambia belong, are as follows:

1.5.1 Genus Tilapia (Substrate spawners)

Both parents guard, protect, aerate the breed, and help move the clutch to different nest sites. Fry at first feeding are 4-5 mm and show feeble swimming ability. Fry survival is relatively low.

(a) **Species:** ***Tilapia rendali (Boulenger, 1896)***

- **Common name:** Red breasted bream
- **Common Synonyms:** *Tilapia melanopleura, Tilapia Zilli*
- **Description:** Abdominal and caudal vertebral number 16 and 13–14, respectively. Body, deep, oval, compressed. Colour usually dark olive above, white base below with frequently red pigmentation on check, breast, abdomen and anal fin.
- **Distribution:** All over Zambia
- **Locality of samples:** Mwekera stream, Kitwe district, Lake Kariba, Siavonga, Upper Zambezi river, Mongu district
- **Note:** One of the most important commercial fish in Zambia. Cultured in many places and basically grazing feeder, but feeds on wide range of foods like insects and small fish.

1.5.2 **Genus Sarotherodon** (Paternal/biparental)

Both parents stay close to each other. Eggs and fry brooded in oral cavity up until they are ready for release. Brood may not be collected once released. Fry are between 7- 9 mm at first breeding, well developed fins for swimming. Fry survival is high. (**Note:** No species from this genus used in Zambian aquaculture).

1.5.3 **Genus Oreochromis** (Maternal)

Female solely involved in brood care. After spawning, the female leaves nest to rear her clutch in safety. Fry brooded up until free swimming. There is an extended period of care during which fry seek shelter in buccal cavity for safety. First feeders have well- developed fins for swimming. Fry survival is high.

(a) **Species:** ***Oreochromis niloticus (Linnaeus, 1758)***

- **Common name:** Nile bream, Nile tiapia

- **Description:** Body deep, compressed. Head pointed with straight profile. Eyes red. Distinctively striped truncate caudal fin is characteristic. Pectoral fin long, reaches to anus. Colour usually silvery grey with 8 – 9 thin vertical bars on the body; totally dark grey with bright margin of caudal fin in breeding males.
- **Locality of samples:** Kafue flood plain, Monze district, Siavonga district
- **Note:** Translocated to Zambezi river basin intentionally or unintentionally through aquaculture activities. So many urguments on introduction of Nile bream have been arising in African countries.

(b) **Species:** ***Oreochromis andersonii (Castelnau, 1861)***

- **Common name:** Three spot bream / Kafue bream
- **Description:** Body deep, compressed. Head pointed with straight profile. Body color silvery with 6 to 8 thin vertical bars on body in juveniles; three eye-diametric spots on body in young adult fish, becomes faint in large fish. In mature male, body color becomes dark to black with flush red margins of caudal and dorsal fins; scale borders become clearer by white rims; scales on gill cover distinct.
- **Distribution:** Upper Zambezi system, Kafue system
- **Locality of samples:** Mwekera fish farm, Kitwe district; Kafue flood plain, Monze district
- **Note:** One of most important species for aquaculture and capture fisheries in Zambia. However, translocation of the species is not recommendable from the view of local fish population conservation.

(c) **Species:** ***Oreochromis macrochir (Boulenger. 1912)***

- **Common name:** Greenhead bream, longfin tilapia
- **Description:** Body oval, deep and compressed. Head short with convex profile. Eyes red. Pectoral fin very long, reaches to anal fin origin. Caudal fin shallowly emarginated with orange- yellow margin in male. A green – black eye –

diametric spot on upper corner of gill cover. Light green above, silvery on side and below with 8 – 9 vertical bars on body in young fish. Mature male bears a genital tassel, a sort of egg – dummy; bright green color with black fleck on face and body.

- **Distribution:** Upper Zambezi system, Kafue system, Lake Kariba, Zambia Congo system including Lake Mweru and Lake Bangweulu.
- **Locality of samples:** Mwekera fish farm, Kitwe district; Kafue flood plain, Monze district; Lake Kariba, Siavonga district; Lake Bangweulu, Samfya district.
- **Note:** Male constructs a sand – scrape nest, which is volcano – shaped in Zambezi population; large and circular with characteristic star-like radial grooves towards periphery in Congo population including Lake Mweru. *O. macrochir* brought from Lake Mweru to Mwekera fish farm in 1994, has been bred successively and their offspring still construct star - marked nests using silts on the concrete bottom of the pond.

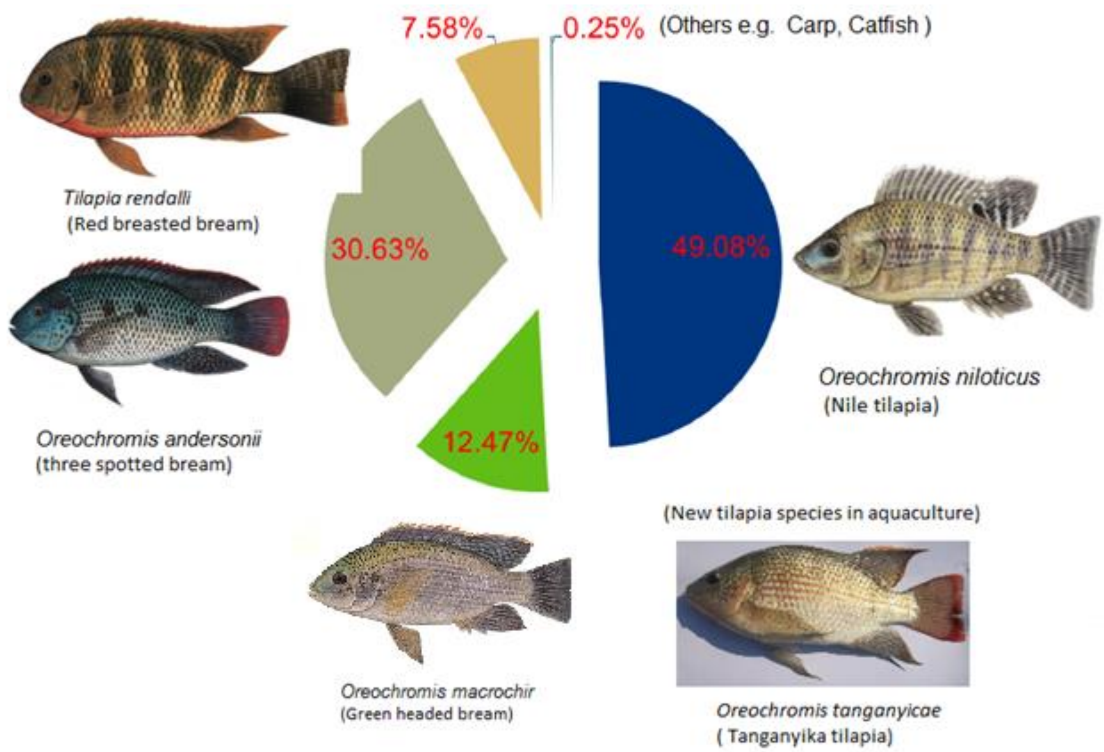


Figure 1-5: Tilapia production in Zambia (Modified from IAPRI, 2014)

1.6 Tilapia production in Zambia

Fish production statistics shows that tilapia are the predominate farmed species in Zambia, with *Oreochromis niloticus* leading at 49.08 %, followed by *Oreochromis* *andersonni* at 30.63%, *Oreochromis macrochir* (12.47%) and *Tilapia rendalli* (7.58%) (Figure 1.4). All other farmed species like carp and catfish constitute only 0.25% of the total aquaculture production (IAPRI, 2014). Recently the department of fisheries has been promoting the breeding of *Oreochromis Tanganyicae* in areas around Lake Tanganyika, in where the species is indigenous.

1.6.1 **Advantage of Tilapia**

The principal practical reasons for farming tilapia are:

- simple reproduction/breeding processes
- rapid growth rate
- good tolerance to high stocking densities and intensive rearing conditions
- resistance to physical handling
- Fast growing
- High demand in local market
- Prefer all kind of supplementary feeds
- Can be profitably cultured in seasonal ponds and small ditches, canals close to the homesteads
- High disease resistance ability
- Can tolerate sub-optimal water quality conditions, e.g., DO, temperature, moderate salinity levels
- Two crops are possible in perennial pond

Tilapia is therefore a robust performer that reduces many of the general risks encountered in fish stock farming. Tilapia has also a very good reputation with consumers, usually available at a reasonable price.

1.6.2 **Major disadvantage**

The major drawback in culture of tilapias is their early sexual maturity, which results in excessive recruitment in ponds. Tilapias reproduce when they are only a few months old, often well below the preferred market size. Uncontrolled spawning in production ponds often causes overpopulation resulting in competition for food, reduced growth, and lower yields of marketable size fish.

1.7 **Sex identification of Tilapia**

Sex identification of tilapia is relatively simple. The **male** has two body openings situated just forward of the anal fins, of which one is the anus. The other is the opening of the urethra, at the end of the genital papilla (an oval-shaped lobe just rearward of the anus), from which milt (sperm) and urine are discharged.

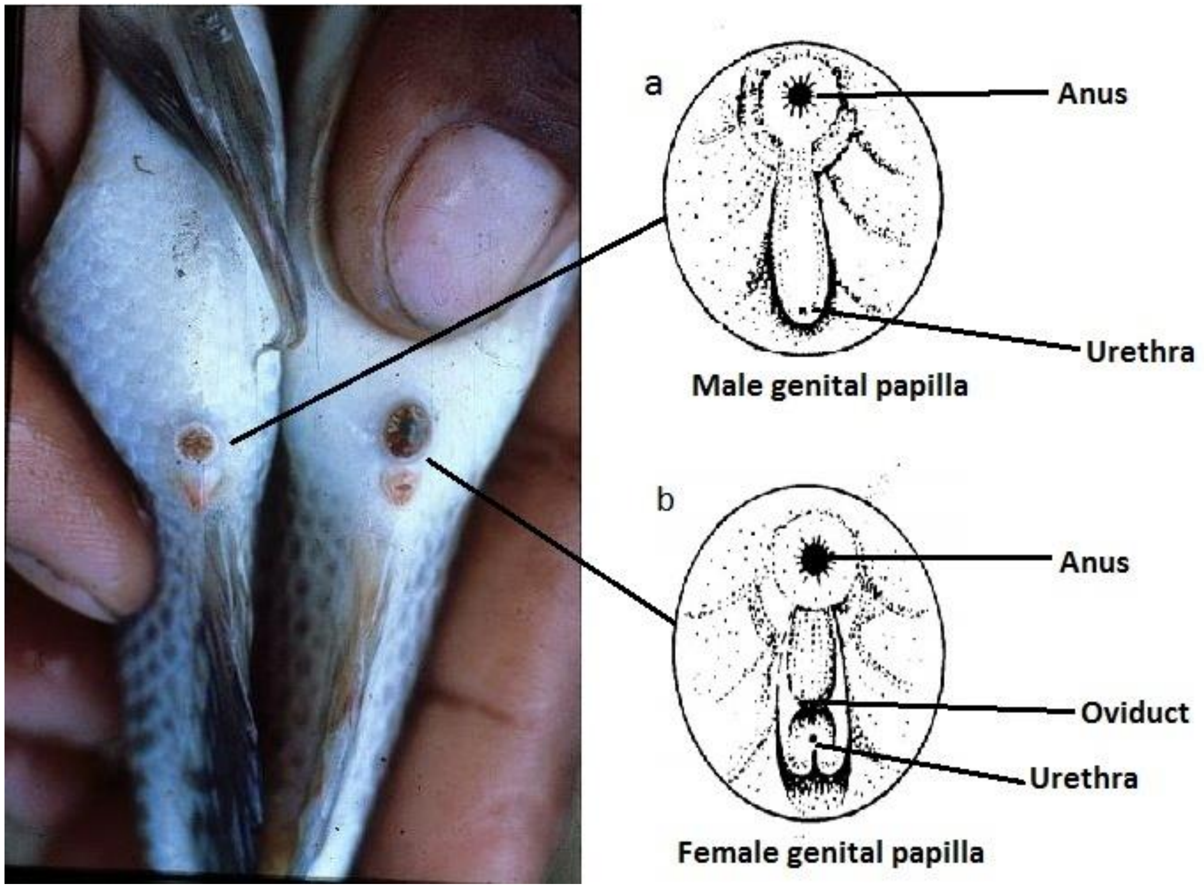


Figure 1-6: Genital papilla of Tilapia fish: a Genital papilla of male *Oreochromis niloticus* having two opening; the urogenital opening, where the milt and urine are excreted and the anus, for the discharge of fecal waste. b. Genital papilla of female *Oreochromis niloticus* having three openings; the anus, the urethra for urine passing and the oviduct, where egg passes through (Adapted from Fish and Allied Aquaculture, Auburn Univ)

The **female** has three body openings, of which one is the anus. The genital papilla of the female has two openings. They are the urethra, which is hardly visible to the naked eye, and the opening of the oviduct (a crescent-shaped slit), from which eggs are released. These features are more visible and identifiable when the fish have grown to 10–20cm in length and 100–150g in weight. Placing a drop of dye (methylene blue or food coloring) on the genital region helps to highlight the genital papilla and its openings. Mature Nile tilapia can also be distinguished by their coloration under the jaw — reddish in males and greyish in females.

1.8 **Reproduction frequency**

Tilapia natural cycle: Upon harvesting, three generations are usually found in the pond. The first generation are the fish stocked, the second are their first offspring and the third the second offspring of the first fish that was stocked (Fig 1.7).

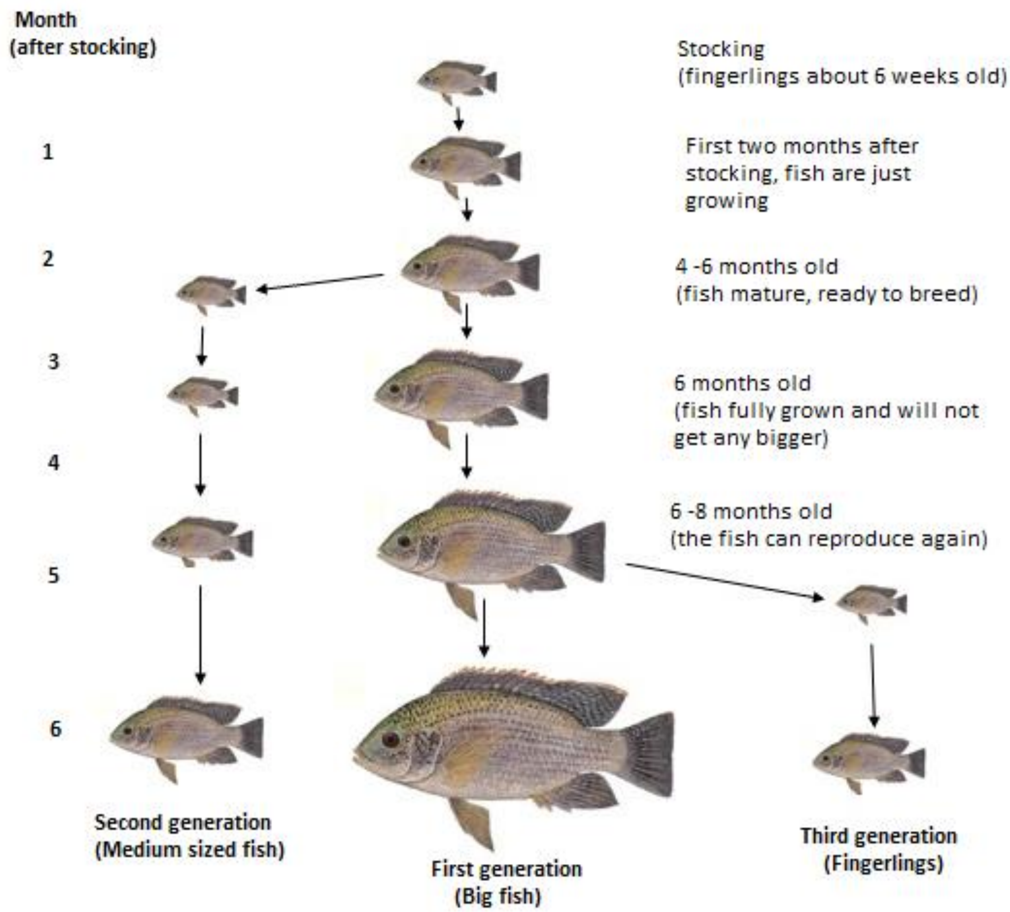


Figure 1-7: Tilapia reproduction frequency: the species can reproduce every 6 – 8 weeks or 4 times in a year (Modified from Gantner, 2002)

The spawning sequence of tilapia is as follows (Fig 1.8);

- Broodstock becomes acclimated to their surroundings 3 to 4 days after stocking.
- Males define and defend territories on the bottom, and form a nest by cleaning a circular area 20 to 30 cm. Wide. In ponds with soft bottoms, the nest excavated 5 to 8 cm deep by digging with the mouth.
- The female is attracted to the nest where the male courts her.
- The female lays her eggs in the nest after which they are fertilized by the male.

- The female picks up the fertilized eggs in her mouth and leaves the nest. The male continues to guard the nest and attract other females for mating. Courtship and mating require less than a day.
- Eggs are incubated for 2 to 5 days in the female's mouth before they hatch. Young fry stays with their mother for an additional 5 to 7 days. They hide in her mouth when danger threatens. The female does not eat while incubating her eggs or caring for the new fry.
- A female guards her young for 5 to 7 days. They hide in her mouth when danger threatens.

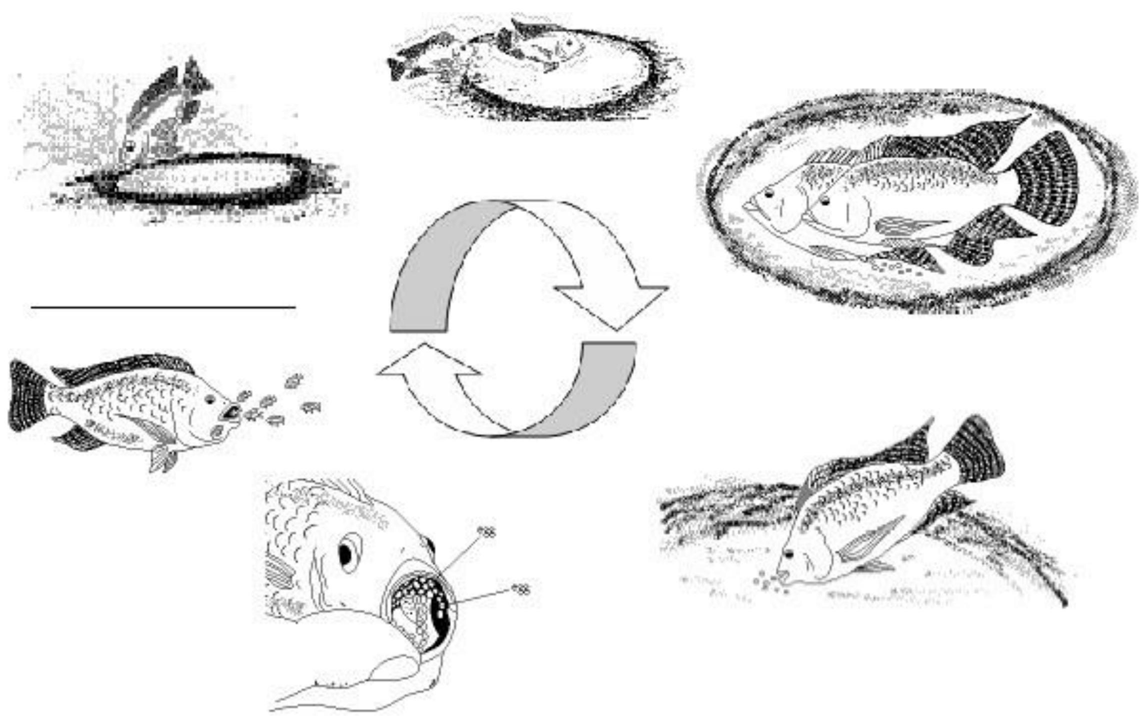


Figure 1-8: Spawning cycle of Tilapia (Adapted from Fish and Allied Aquaculture, Auburn Univ)

Chapter 2

SITE SELECTION

2.1 Importance of selecting a suitable site

The first step or the most important preconstruction activity is to select a correct site as careful site selection is a pre-requisite in pond construction. Improper site selection may lead to:

- difficulties in holding water in the pond,
- high seepage,
- dike erosion,
- low productivity of the pond, resulting low yields and economic loss
- inability to drain water completely, and
- difficulties in harvesting

2.2 Factors to be considered in site selection

Criteria for selection of an appropriate site for pond construction fall into 3 categories. Evaluation of the criteria may require input from the requisite specialists.

- Biological
- Economic
- Physical

2.2.1 Biological criteria

a) **Environmental requirements of cultured species.**

b) **Definition of scale of operation: number and size of ponds:** A clear understanding of the intended pond use, management practices to be applied, and the scale of operation are critical in order to estimate the total land area required for pond construction. The optimum size, depth and number of ponds required are a function of their intended use. The total land area required can be estimated once this information is available.

c) **Source of contaminants:** A biological understanding regarding the use of the pond is required to appreciate whether a substance in a potential water source is a harmful contaminant, a beneficial fertilizer or nutrient, or neutral in its impact.

2.2.2 Socio-economic criteria

a) **Potential danger downstream.** Dam failure and flooding downstream may be a significant danger with larger watershed ponds in danger of receiving heavy runoff. Deterioration of water quality for downstream users of the water is becoming an increasingly important criterion.

b) **Demand for product and availability of marketing channels.** Accessibility and proximity of processing and marketing infrastructure.

c) **Availability of personnel, labor and production inputs.** A commonly under considered criterion.

d) **Security.** Respect for one's neighbor's property is not always observed, especially in the case of a pond with fish that are traditionally considered wild and for the taking! Where possible pond location should take this into consideration.

e) **Economic feasibility and opportunity costs.** Costs and returns and economics of alternative uses of the site

2.2.3 Water supply and water quality

2.2.3.1 Water supply

a) **Water sources.** The most common sources of water used for aquaculture are surface waters (streams, springs, lakes), groundwater (wells, aquifers) and municipal water. Wells and springs are generally preferred for their consistently high quality water (Table 2.1). The quantity and quality of water should be adequate to support production since water supply to the ponds may be seasonal. A good water source will be relatively free of silt, aquatic insects, potential predators, and toxic substances, and it will have high concentration of dissolved oxygen. Warm water species like tilapia can tolerate water with lower dissolved oxygen levels, so tilapia culture is often done in static water, that is, without water flowing through the ponds.

Table 2-1: Comparisons of the advantages and disadvantages of commonly used water sources. Sources are listed by overall rank according to the most desirable characteristics. Reference to contaminates may include pesticides, organic matter, sediments, metals, wild fish, or insects. Reference to dissolved gasses include carbon dioxide, nitrogen, methane, and hydrogen sulfide.

Source	Advantages	Disadvantages
Rainfall	• Inexpensive	• Depends on the amount of rains and seasonal fluctuations
Springs	• Constant temperature • May not require pumps • Few contaminants	• May require pumping • Low oxygen levels • May contain dissolved gases • Inexpensive
Wells	• Constant temperature • Few contaminants	• Require pumping • Low oxygen levels • May contain dissolved gases
Rivers, streams or lakes	• May be readily available • Inexpensive	• May contain contaminants • Excessive nutrients possible
Surface or runoff	• Inexpensive	• May contain contaminants • Susceptible to droughts or floods • Require 5-7 acre watershed per surface acre of water
Ground water	• Inexpensive	• Ponds hard to drain • If wetland, may require permit
Municipal	• High quality	• May contain toxic chlorine or chloramines • Expensive

There is however need to top up water from time to time to compensate the water loss through evaporation. For earthen ponds, the water source should be able to provide at least 1 m^3 of water (1000 liters) per minute for each hectare of ponds that will be built. If the selected site has relatively poor soils (i.e., soils containing too much sand) the source should be able to provide two to three times more water (2-3 m^3 per minute per hectare), however, such sites need adequate water to compensate for water loss through seepage after filling the pond.

b) **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:

- Continuous supply: Water supply is one of the most important factors to be considered while selecting the site as a 24-hour continuous supply is required. Especially water for the hatchery should be adequate, cheap, and free of microorganisms and pollutants.
- Temperature of water should be within the range of 20-35°C though 28-32°C is optimal (comfort zone). Some water quality parameters are presented in Table 2.3.
- Dissolved oxygen (DO) should not be less than 5 mg L^{-1}, however, green water can have DO as low as to 0.8 mg L^{-1} in the morning.
- Water pH should be within the range of 6 – 9 and NH_3 should be <0.1 mg L^{-1}. PH below 5.0 should be avoided.
- As tilapias consume plankton, they can be raised in green waters cheaply. The suitable range of chlorophyll-*a* in the hatchery water is 100-300 mg m^3. Organic manures e.g. chicken manure and chemical fertilizers help to maintain a healthy plankton boom (discussed in Chapter 8).

c) **Quantity**

- Generally pumping capacity for fish ponds depend primarily on the volume of the pond and the flow of water per second (Table 2.2).
- For excavated ponds analysis of water requirements and water availability is relatively simple because they are usually constructed to exclude rainwater runoff, and water supply is controlled.

2.2.3.2 Topography

In general, flat land with a gentle gradient is suitable for pond construction. The steeper the topography, the smaller the pond that may be constructed, the type of pond that may be constructed is also determined by the degree of slope. Excavated ponds are generally constructed on relatively flat land, in a steeper topography ponds are constructed perpendicular to the slope.

Table 2-2: Days required to fill ponds of various sizes and the water flow required

Approximate filling time (days)	Pond volume (m^3)	Required water flow (l/s)
8	400	0.5
	1000	1.5
	2500	3.5
	10000	14.0
4	400	1.0
	1000	3.0
	2500	7.0
	5000	14.0
	10000	28.0
2	400	2.0
	1000	6.0
	2500	14.0
	10000	56.0

Source: FAO, 1998

2.2.3.3 Physical properties of the soil

Land should be comprised of good quality soil, with little or no gravel or rocks either on the surface or mixed in. Farmers may consider importing clay soil for compacting in the fish bottom, sides and core trench to minimize seepage, though this may increase the cost of pond construction. The imported soil should be from a tested site with suitable soil parameters. Soil that will be used to build the dykes must contain at least 20% clay so the finished pond will hold water throughout the growing period. Some soil with higher clay content—preferably between 30 and 40%—should be available nearby. It will be used to pack the core trenches in the dykes. In absence of good soils, farmers should consider using dam liners or concrete during fish ponds construction. However, this intervention significantly increases the costs. Simple soil tests are done as shown in the figures below.

a) Will the soil hold water?

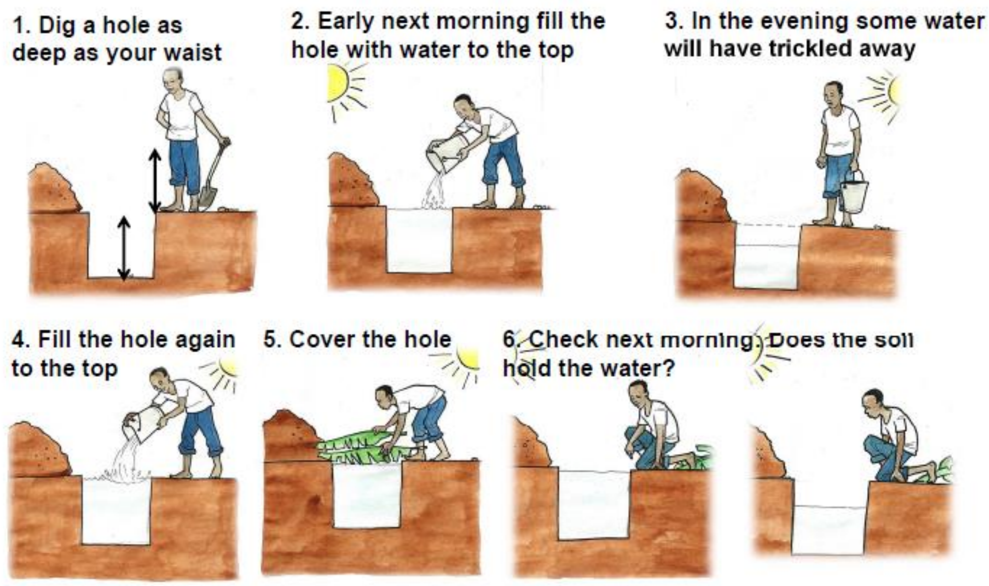


Figure 2.1: Test for the permeability of the soil (Source: FAO, 1981)

b) Will the soil be stable when wet?

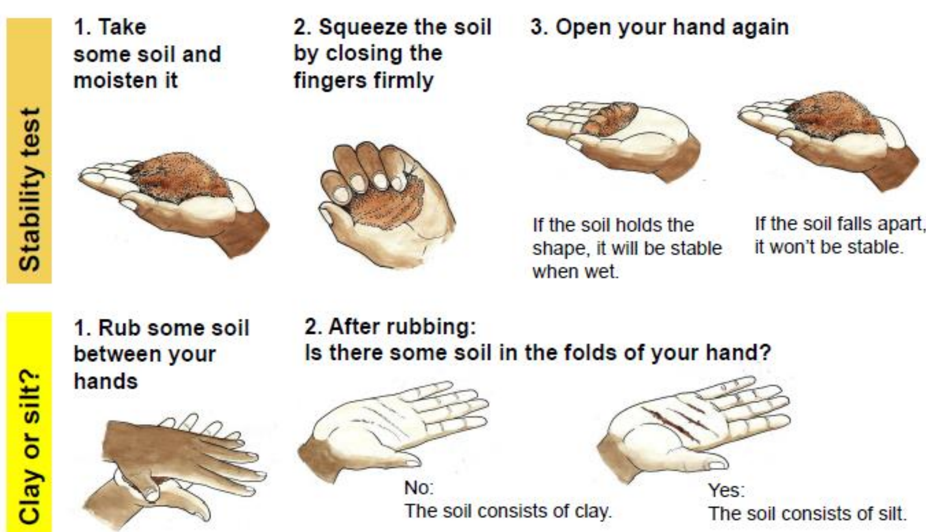


Figure 2.2: Test for stability of the soil (Source: FAO, 1981)

c) Will the soil have adequate clay?

- Take a handful of moist soil and squeeze it into a ball
- Throw the ball into the air about 50 cm and then catch it
- If the ball falls apart, it is poor soil with too much of sand
- If the ball sticks together, it is good soil with enough clay in it

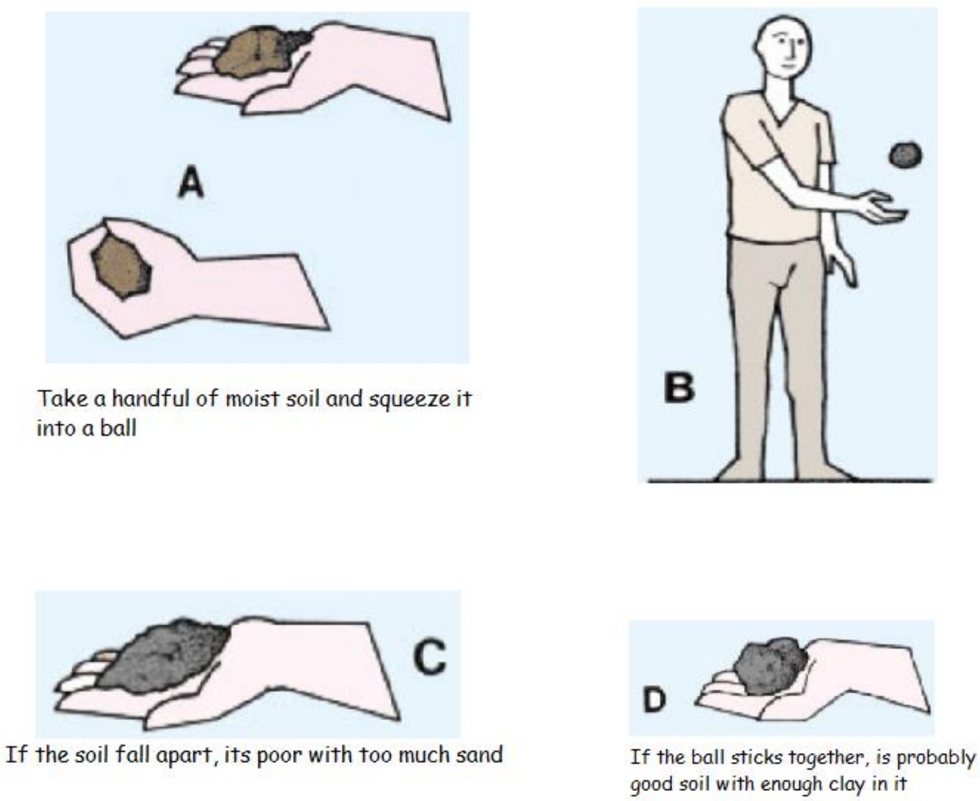


Figure 2.3: Test for texture of the soil (Source: FAO, 2006)

Table 2-3: Relevance of water quality parameters to pond production (Modified from Isyagi et al., 2009)

Parameter	Relevance to Production	Recommended Range	What happens when Consistently below recommended Value	What happens when consistently above recommended value
Dissolved Oxygen **(DO)** (use DO test kit, DO meters)	• Fish breathe in oxygen for their metabolism. • Dissolved oxygen is needed to oxidize potentially toxic metabolic wastes into less toxic forms (e.g. ammonia (NH_3) to nitrite (NO_2^-) and then nitrate (NO_3^-) • Bacteria in ponds that help transform wastes into less toxic products need oxygen for metabolism. • Phytoplankton use oxygen at night during respiration.	From 5 mg/l to saturation	• 0 – 1.5 mg/l can be lethal especially if exposed for long periods • Below 3 mg/l - fish survive, but reduced feed intake higher FCRs, slow growth, stress, and increased susceptibility to disease results. Buildup of toxic wastes because they are not broken down (oxidized)	• Gas bubble trauma when the water is supersaturated to levels of 300% and above.
Temperature (use thermometer)	• Fish are cold blooded animals. Their rate of metabolism is directly influenced by water temperature. • Rate at which wastes in pond are broken down and chemicals dissolve is faster in warmer waters • Affects the solubility of oxygen	26 to 32°C	• Ideally about 26°C to 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. • Organic matter and other wastes are broken down at a slower rate when temperatures are low with high risk of eutrophication.	• Lower solubility of oxygen, stress and death at extreme temperatures.

Parameter	Relevance to Production	Recommended Range	What happens when Consistently below recommended Value	What happens when consistently above recommended value
pH (use Litmus paper, pH meter or pH strips)	• Affects the solubility and chemical forms of various compounds some of which can be toxic.	Optimal range is 6.5-8.5 6.0-9.0 suitable 6.5 to max 9.0	• Below 4, acid death point. • 4 – 6.0. Survive but stressed, slow growth, reduced feed intake, higher FCRs. • Higher proportion of Total Ammonium Nitrogen is in the form of ionized ammonia, which is less toxic for fish. • Low pH indicates high levels of dissolved carbon-dioxide • Susceptible to diseases	• 9 – 11 Stressful, slow growth rate. • Above 11 alkaline death point. All life, including bacteria in pond will die at this point. • Higher pH levels favor higher proportion of Total Ammonium Nitrogen in the form of unionized ammonia in water, which is more toxic for the fish. • Low pH reduced plankton growth in water • Low pH increases hydrogen sulphide toxicity (hydrogen sulphide generates in ponds with spoiled pond bottom)
Alkalinity and Hardness (use Alkalinity test kit, meter or strips)	• In combination, influence the buffering capacity of the pond water. • Hardness is composed mostly of calcium and magnesium, which affect the physiological condition of the fish • Alkalinity also controls the amount and form of carbon-dioxide in water.	Alkalinity > 20 ppm Hardness > 20 ppm Total alkalinity and total hardness above 60 ppm is desirable.	• Extreme fluctuations in pond pH levels during the day which is stressful to the fish. • Fish are under physiological stress • Low levels of primary production which results in lower natural sources of food.	• Water will be well buffered and diurnal fluctuations in pH will be less extreme • Fish will be less stressed Physiologically Young fish will have more natural food available • However, hard water in tilapia hatcheries should be avoided.

(Table 2.3 continued)

Parameter	Relevance to Production	Recommended Range	What happens when Consistently below recommended Value	What happens when consistently above recommended value
Total Ammonia Nitrogen (TAN) (use Ammonia test kits)	• Ammonia by-product of protein breakdown. It occurs in both a toxic form (ammonia) and nontoxic form (ammonium) depending on the pH of the water.	Not more than 0.1 mg/l of the toxic form (ammonia). The proportion of TAN in the form of ammonia tends to be higher as the pH of the water increases above 7	• Fish are happiest when there is no or little ammonia in water.	• The fish succumb more to attacks by trematodes and other parasites. • The fish fail to eliminate ammonia from their blood because there is too much ammonia already in the water. Ammonia is excreted by fish as a byproduct of protein metabolism primarily through their gills. High concentrations of ammonia in water reduce the ability of the gills to do so.

(Table 2.3 continued)

Note: Water transparency measurements using a secchi disk has been explained at appendix 1

Chapter 3

POND DESIGN AND CONSTRUCTION

3.1 **Design considerations for fish ponds**

3.1.1 Water sources used for fish ponds

Water sources can be spring water, seepage water, rainwater run-off, water from bore holes (wells), or water pumped or diverted from a river, lake, or reservoir.

a) **Quantity of water needed**

- Make a decision on the type of fish to be cultured and the size of ponds, so as to determine the amount of water required.
- A general rule is that pond water inflow and outflow should equal the pond volume over the period of a month. If inflow is too low, water quality may suffer from oxygen depletion and/or the accumulation of toxicants. However, if the inflow is too high, large amounts of beneficial algae may be flushed from the pond.
- As a rule of thumb, ponds should fill up in less than a week. For small ponds, e.g., ponds smaller than 200 m^2, 1-inch pipe is recommended. A 400-m^2 pond needs a 2-inch pipe, while a pond larger than 4000 m^2 will require a 4-inch pipe. Delivery capacities of different pipes are given in the table 3.1 below.

Table 3-1: Delivery capacities of pipes of different sizes (1 m^3 is equivalent to 1000 liters)

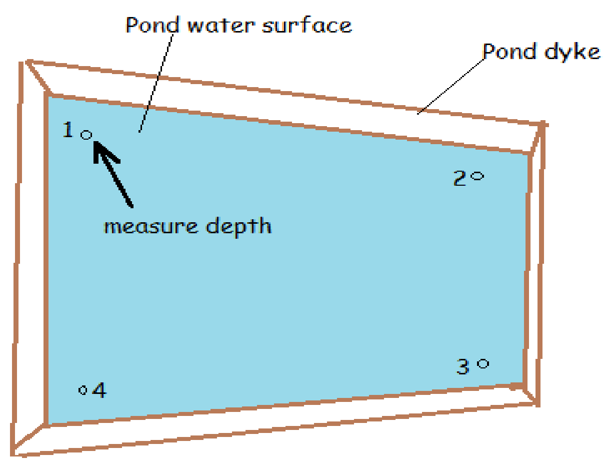
Pipe Diameter	M^3 /hr	M^3/day (24hrs)
1 inch	1.25	30
2 inches	6	144
4 inches	28	672
6 inches	80	1920
8 inches	136	3264

- Ponds lose water through seepage and evaporation. The amount of water lost by evaporation depends on factors such as temperature, wind, vegetation, water surface, and humidity. So get enough water to replace what is lost by evaporation.

Calculation of the volume of water in a pond

First estimate the pond depth. If the pond is small, with a regular shape, and has a bottom with a constant slope from one end to the other, go into the water and measure the depth at four points, 1,2, 3 and 4 in the pond. If the pond is large, estimate the depth at more than four points. To find the average depth, calculate the average of the measurements. You calculate the volume in the pond by multiplying the surface in square meters (m^2) by the average depth in meters (m) to get the volume of the pond in cubic meters (m^3).

Volume = surface area × average depth



Average water depth $= \frac{1+2+3+4}{4}$

Table 3-2: Worked examples of pond water volume calculation

Surface area (m^2)	Average water depth (m)	Water volume (m^3)
235 ×	1.0 =	235
450 ×	1.2 =	540
2500 ×	1.5 =	3750

b) **Water quality requirements**

- The best quality water will be non-acidic and free of silt.
- Good water is also free of insect larvae, predators, unwanted fish species, pesticides and toxins, and excess fertility.
- Water supplied to ponds should be high in dissolved oxygen.

c) **Bringing water to the pond**

1. Gravity flow

- Ensure that the level of the drainage canal is at least 30 cm below the level of the pond bottom and at least 1.5 m below the level of the inlet canal. Canal slopes generally range from 0.25 to 1%, but for large ponds the slope should be about 0.5%.

2. Pumping

- Avoid pumping water if there is a cheaper source. Pumping increases, the cost of operation
- Use the most economical water source.

3. Other

- Plan for a drop of 10 cm from inlet pipe to the pond water level to prevent fish from swimming out of pond into the pipe; better yet, use a screen to prevent fish from moving into the pipe.

3.1.2 Effects of soil types on pond design and construction

a) Range of soil types

- Topsoil is high in organic material and should not be used to construct pond dykes.
- The composition of mineral soils can range from very sandy to very clayey. These extremes are generally not suitable for fish pond construction. Sandy soils are too porous to hold water, while clay is too compact and adsorptive, depriving the water of essential nutrient elements, particularly phosphorus.
- Soils with 20-35% clay are the best for building ponds.

(b) Effects on pond design and construction

- If the site has some soil containing a high percentage of clay (30- 35% or more), use this for filling the core trenches beneath the dykes.

- If your soil has a reasonable percentage of clay (20-30%), you can construct the dykes with 2:1 slopes (2 m horizontally for every 1 m vertically).
- If your soil has a low percentage of clay (20% or less), you should increase the dyke slopes to 3:1 to prevent slumping and erosion of the pond banks.

3.1.3 Pond size, shape, and depth

a) **Size**

- The size of a prospective fish pond should be based on the purpose of the pond.
- If the pond is meant to provide additional food for the family, then it need not be larger than 0.1 ha (1000 m^2).
- Larger ponds produce more fish and are usually more efficient producers of fish per unit of land than ponds less than 1000 m^2.
- A pond of 0.2-0.3 ha (2000-3000 m^2) is easily managed by a small farm family. Such ponds can be maintained with a minimum of effort.

b) **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.

c) **Depth**

- The pond depth is usually in the range 1–2m, and often is a compromise determined by topography, water source and soil. Ideally pond water depth should be 0.8m at the shallow end, and increase gradually to 1.2m at the deep end, with 30–50cm of freeboard.
- Ponds entirely dependent on seasonal rains must be deeper in order to hold water longer into the dry season, for example water depth of 1.0–1.5m. Maintaining the right depth of water helps to regulate temperature, inhibit growth of underwater plants and maintain dissolved oxygen (DO) levels at the pond bottom, which helps the organic decomposition that provides nutrients for the growth of phytoplankton and zooplankton, microscopic organisms that will in turn provide food for the fish.

3.1.4 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 (Fig 3.1).
- 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.

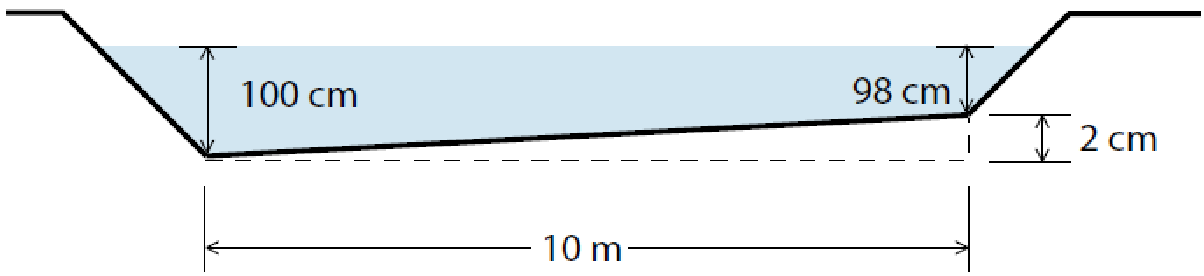


Figure 3-1: A well designed pond slopes slightly from the shallow end to the deep end, with a drop of about 2 cm for every 10 meters of length (Source: Ngugi et al.2007).

3.1.5 Design of the dykes - height, width, and slope

Dykes are also called dikes, banks, walls, levees, embankments and bunds. The dyke is the part of the pond above the natural ground and is for retaining the water. It is important that the dyke walls are sloped to prevent erosion and avoid enlarging of the pond (Fig 3.2).

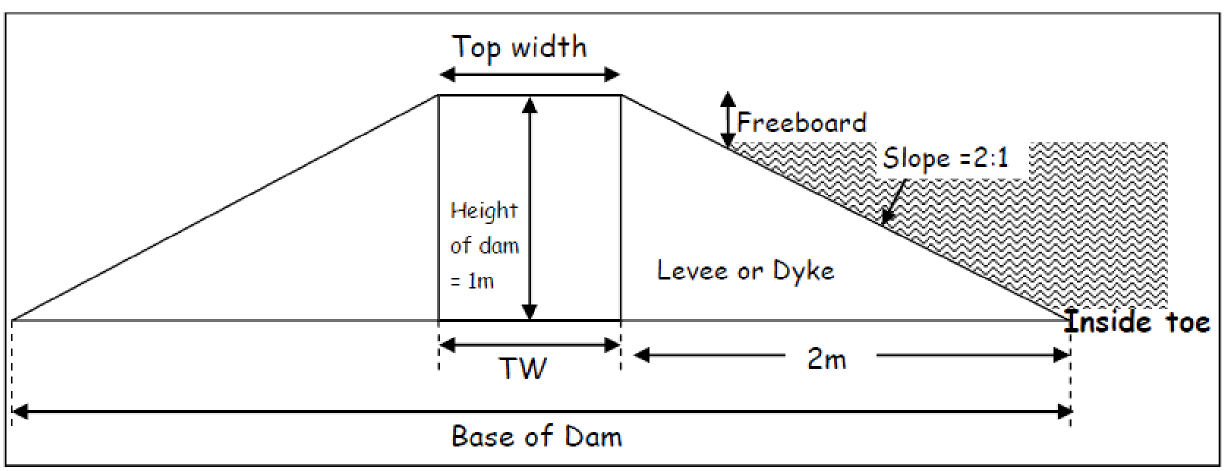


Figure 3-2: Parts of the Pond dyke. In this example the dyke is only 1 m high but it is usually higher at the deep end (Source: Isyagi et al 2009).

3.1.5.1 What are the types of dikes?

The following section on design of pond dykes was adopted without any modification from FAO, 2006.

a) **Types of dikes in a single pond**: It has only the surrounding dike, which is called the perimeter dike.

b) **Types of dikes in multiple ponds:** The dike running around all ponds is the perimeter dike. The dikes that separate two ponds are secondary dikes.

c) **Types of dikes in multiple ponds with nurseries:** The dikes separating nursery ponds are tertiary dikes

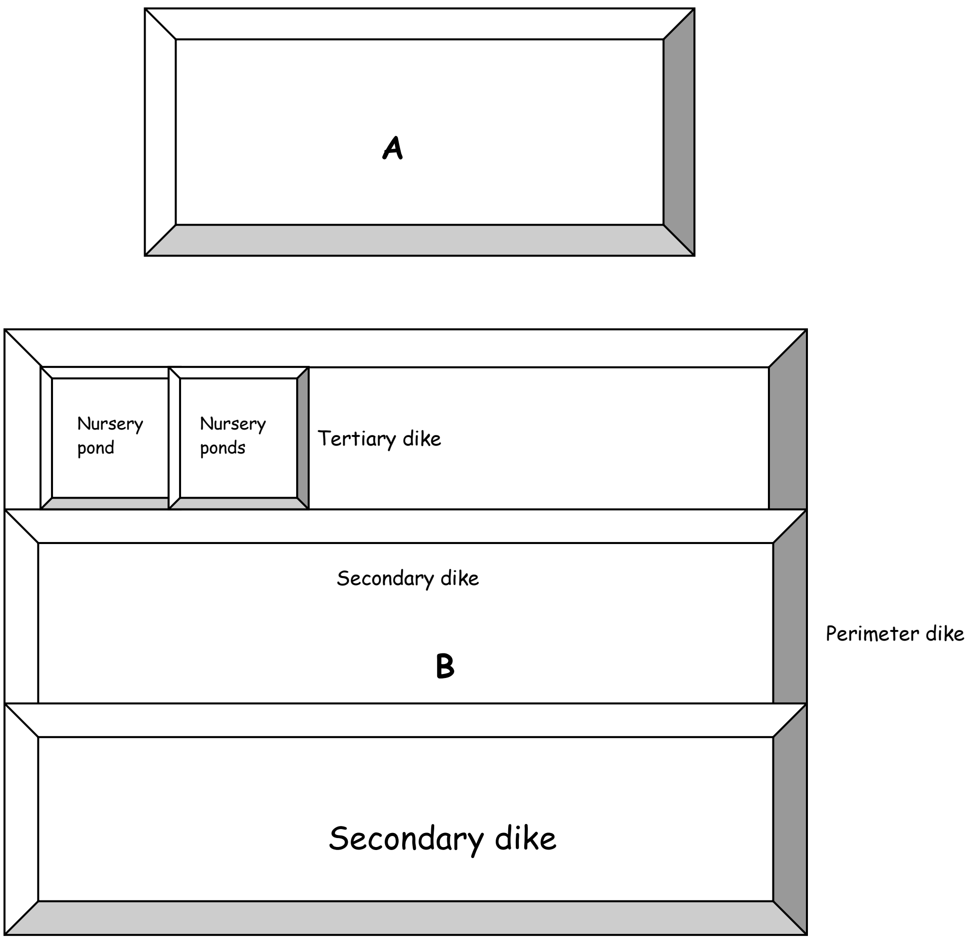


Figure 3-3: Types of dykes in a single pond (a) and multiple ponds with nurseries (b)

- Perimeter dike has to be build strong to resist water pressure.

- It has to be high enough to prevent spillover or to prevent get flooded during heavy rains.
- The secondary dike may not be as strong as perimeter dike as the water pressure is more or less the same on both sides.
- If planned to drain ponds alternatively, then the secondary dikes should be as strong as perimeter dike.
- Perimeter dike and secondary dike should be at the same height to maintain the desired water depth in the pond.
- Secondary dike usually has a dike base and top width less than those of the perimeter dike.
- The perimeter dike and secondary dikes should maintain at least a height of 50 cm above the pond water level. This area of the dike is called free board.
- Tertiary dikes are usually smaller than secondary and tertiary dikes and less in height as nursery ponds usually hold less water depths than main ponds.

3.1.5.2 What is the suitable shape of the dike?

- Construct dikes with trapezoidal cross section with the top width, the side slopes and the height proportionally designed according to the soil material used.

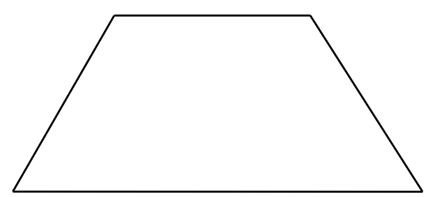


Figure 3-4: Trapezoidal cross section of a dike

3.1.5.3 How to determine the dike dimensions?

- Dike dimensions are dike height, top width or crown, dike base and side slope

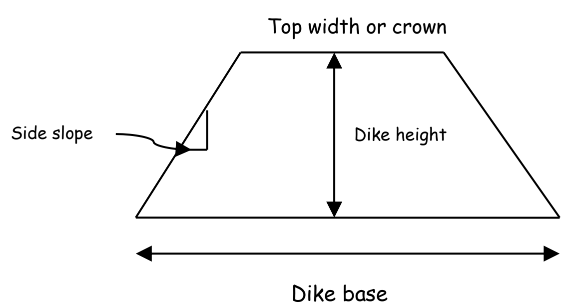


Figure 3-5: Dike dimensions

3.1.5.4 How to determine the dike height?

- Dike height will be determined by the depth of water that you need to retain in the pond, height of the free board of the dike (dike height above the pond water level) and your experience in the flood levels of the area or site.
- Pond depth water and free board should be around 1.0 and 0.5 meter, respectively. Hence, the pond dike height should be at least 1.5 meters.
- If you have experience of frequent flooding in the area, the perimeter dike height of your ponds should be above the flood level to prevent escape fish from your pond during floods.

3.1.5.5 How to select side slope, base and crown width of a dike?

What is side slope?

- The side slope or steepness of the dike is the ratio of the horizontal length to the vertical rise. In other words, how much a side of the dike should move horizontally from the edge of the top width of the dike for each vertical meter of the height of the dike

For example: If a pond has a dike height of 2 meters and top width of 1 meter and a side slope of 1:1, for each meter of the vertical height, the bottom edge of the side should move one meter horizontally from the edge of top width. Therefore, for the total two-meter height of the dike, the side should move two meters away from the edge of the top width.

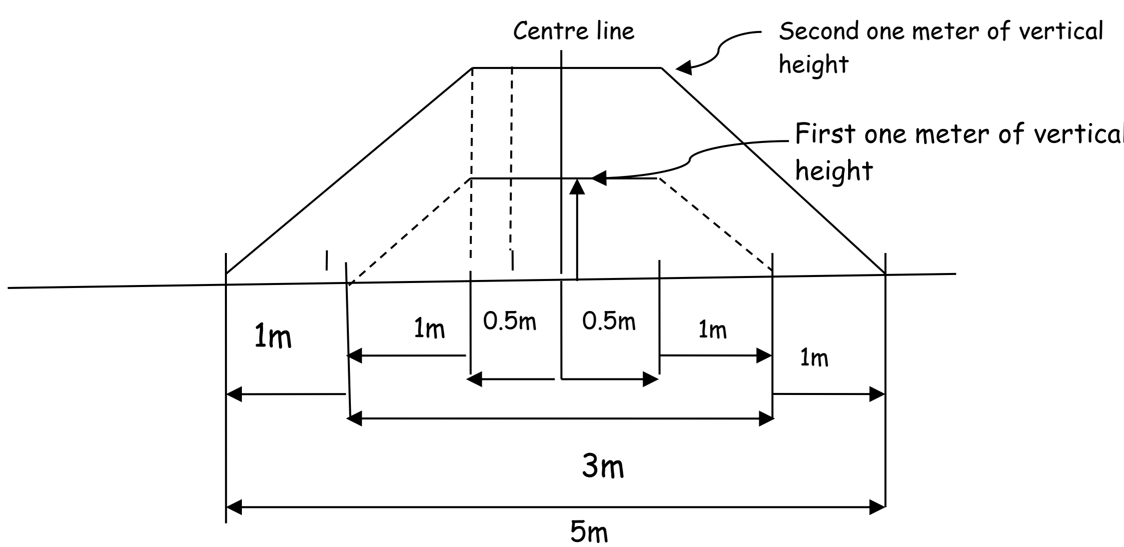


Figure 3-6: Guideline for selecting various dike parameters

3.1.5.6 How to determine the base width of the dike?

- The base width is determined by the side slope of the dike. In above example the base width is five meters.
-

You may use this rule-of-thumb to select the side slope based on soil type and dike heights:

- If the soil contains good clay the side slopes can be 1:1.
- If the soil contains loose soil, silt, silty sand, sandy loam the side slope can be 2:1
- If the soil contains soft clay, clay loam the side slopes can be 1.5:1
- If the soil contains sand or wet clay the side slopes can be 3:1
- Dikes lower than 3 m may have a slope of 1:1. Dikes above 3 m should adopt a 2:1 slope.

3.1.5.7 How to determine the top width or the crown width of the dike?

- The crown width is determined by what equipment you want to move along the dike.
- Crown width should be wide enough for the farmer to walk or push a wheelbarrow along the dike.

You may use the following rule-of-thumb to determine the top width of the dike.

- The minimum top width or crown is 1.0 m for dikes less than 3 m high
- The top width of dikes used as access road is 4.0 m.
- Construct a 0.5-0.6 m wide berm or shoulder on each side of a roadway dike to prevent rolling of soil.

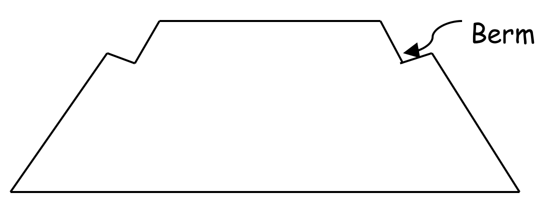


Figure 3-7: Illustration of a berm on a pond dike

3.1.5.8 How to use the trapezoidal equation to determine the dike height, top width, dike base and side slopes?

- It is better to use the following equation to calculate the side slope, crown or the top width, dike base width and dike height. This equation is known as the trapezoidal equation

$$b = T + 2 (Zd)$$

Where,
T = Crown width
Z = Horizontal side of the side slope
d = Height of the dike
b = Base width of the dike

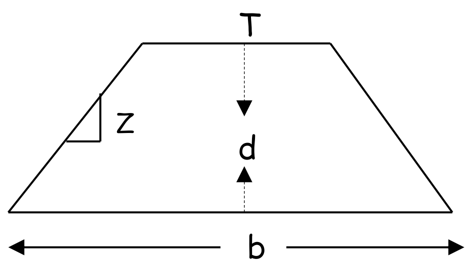


Figure 3-8: Elements of the trapezoidal equation

Example: If you want to know the base width of your dike that you want to construct with a dike height of 1.5m and a crown with of 1.0m. The soil has enough clay to have a side slope of 1:1.

Crown width (T)	= 1.0 m
Side slope	= 1:1
Horizontal side of slope (Z)	= 1
Height of the dike (d)	= 1.5 m

Therefore, the base width (b) = Crown width + 2(horizontal value of side slope x dike height)

$$b = 1.0 + 2(1.0 \times 1.5)$$
$$= 4.0 \text{ m}$$

3.1.5.9 How to calculate the volume of earth that you need to construct your dike?

First calculate the area of the cross section of the dike by using the following equation and using the same figures given in above example.

$A = \{(b + T)/2\} \times d$

Where,

A = Cross section of the dike

b = Base width of the dike

T = Top width

$A = \{(4.0 + 1.0)/2\} \times 1.5 = 3.75\ m^2$

Once the cross-sectional area of the dike is known the required volume of earth to construct the dike can be calculated by multiplying the cross-sectional area by total length of the dike. If the pond has dimensions of 11 x 28m, then the total length of the dikes of the pond is 78m.

Therefore, volume of earth required to construct the perimeter dike

= A x total length of the perimeter dike

$= 3.75 \times 78$

$= 292.5\ m^3$

You need to add the 10 to 20% of the volume of earth as settlement or shrinkage allowance. This additional soil is important to maintain the required dike height as after dike construction with time soil tend to settle and reduce the dike height

If the soil is too sandy or contains lot of organic matter the shrinkage allowance may be as high as 40%. This will increase cost. Therefore, selecting the site with good clay soil is important

If shrinkage allowance = 10% $= 29.25\ m^3$

Therefore, the total volume of earth $= 292.5 + 29.5 = 322\ m^3$

You can calculate the dike dimensions and earth volumes needed to construct the secondary and tertiary dikes using the same methods. Alternatively, you may use this rule of thumb of the relationship between top width, bottom width or base length, height of the dike and side slope

Table 3-3: Relationship among the top width, bottom width and height of dikes with a given side slope

Height	Top width of crown (m)	Dike base (m) at a given side slope		
		1:1 ratio	1.5:1 ratio	2:1 ratio
1.5	1	4	5	7
2	1	5	7	9
3	2	8	11	14
4	3	11	15	19

3.1.6 Position of inlets and outlet pipes

- It is better to position inlet and outlet diagonally (Fig 3.9).
- If a pipe is used as an inlet, it should be projected enough into the pond so that water will fall into the pond at 90^0 directly into the pond and prevent dike erosion by falling along the dike.

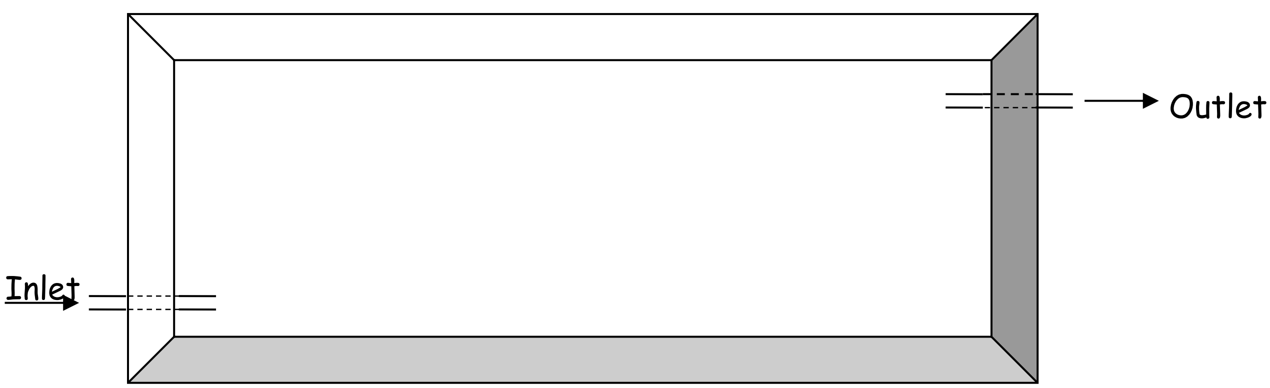


Figure 3-9: Illustration of a pond inlet and outlets

- If earthen canals along the dike crown are used as inlets, it is better to allow the water to fall into the pond along several steps (weir) constructed along the side slope into the pond at the inlet point (Fig 3.10). This will not only prevent erosion of the dike but also oxygenate the supply water.

- Outlet should be placed at a level below the lowest level of pond bottom.
- If peripheral and central bottom ditches or canals are constructed, they should be slope towards the outlet.

Figure 3-10: Illustration of weir to be built at the pond inlet

3.1.7 Harvest Basins

Having a harvest basin set in the pond or between ponds is optional but recommended. Harvest basins make it possible to hold and handle fish alive while draining ponds. They also reduce the amount of labor required during complete pond harvests. A harvest basin can either be set within or outside the pond. **Plate 3.3 & 3.4** shows pictures of a harvest basin set in a pond and outside the pond respectively. Ponds that are to be drained frequently, for example nursery ponds, are much easier to harvest if they have a properly constructed harvest basin.

3.1.8 Pond drainage systems

- Pond drains are normally located at the deep end of the pond with the bottom sloping toward them. Most of the ponds used by small scale farmers do not have drains. In the case of very small ponds, it is of course uneconomical to provide individual drainage facilities.
- Periodic draining and drying of ponds is important because it helps in harvesting fish, eradicating predators, improving the bottom condition of the ponds, and raising production rates.

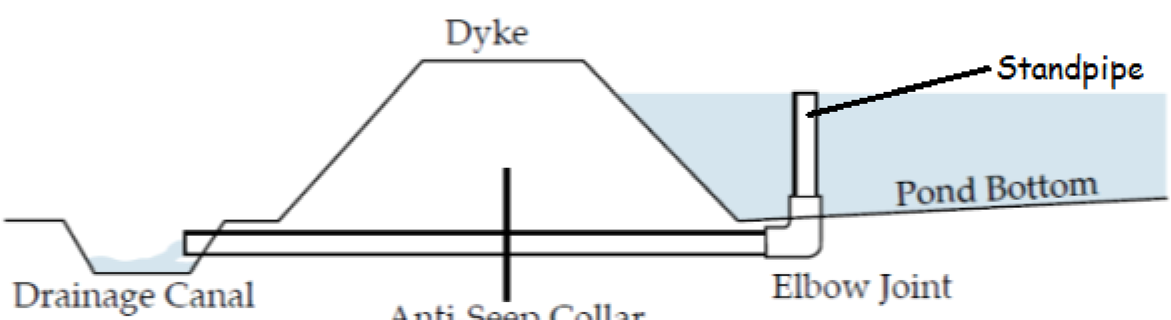


Figure 3-11: A cross section of a pond dyke and drain line with standpipe. The maximum water depth is obtained when the standpipe is in a vertical position; the water depth can be lowered by turning the standpipe down towards the pond bottom (Source: Ngugi et al, 2007).

a) Standpipes

- The simplest drain is a standpipe protruding from the pond bottom (Fig 3.10). The lower end of the standpipe is screwed into an elbow which connects to the main drain. The upper end controls the level of water in the pond.
- When the water level is to be raised or lowered, the angle of the standpipe is changed by rotating the elbow.
- The size of the standpipe depends on the size of the pond, the rate at which drainage is desired, and the volume of water coming into the pond for a flow through system.

b) Monks

The monk is part of the drainage system (Fig 3.12). It is constructed in front of the dyke (inside the pond) and consists of two parallel lateral walls and a back wall. It can be made of brick or concrete. Boards are placed in slots in the lateral walls to retain water at a desired depth.

- The monk controls the level of water in the pond, prevents escape of fish, and permits progressive draining of the pond during harvesting.
- Monks may prove uneconomical and unnecessary in small ponds. In such ponds it is more economical to dig canals through the dykes to fill, drain, or maintain a consistent water inflow and outflow.

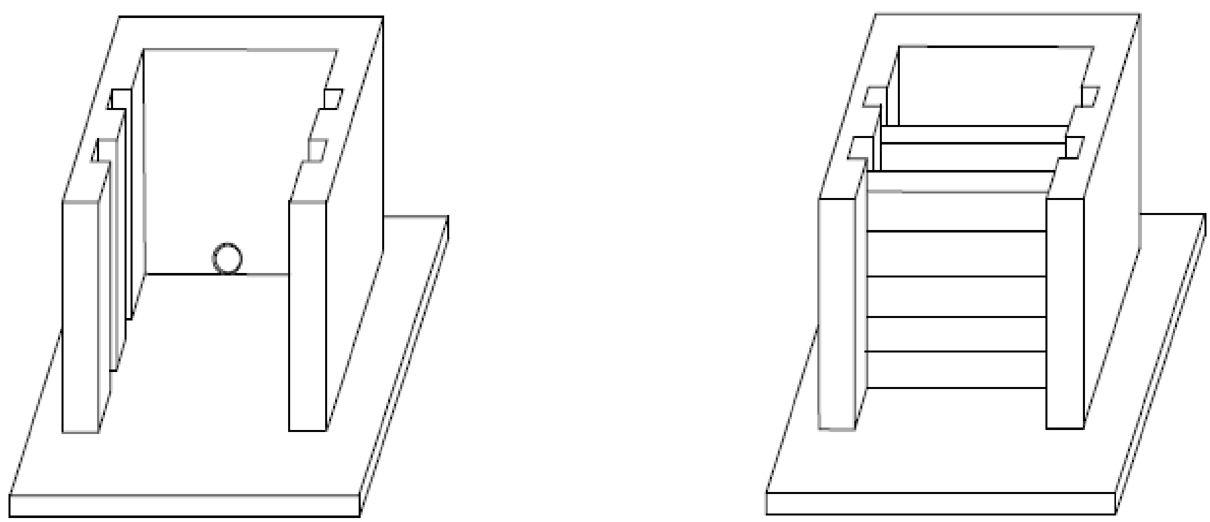


Figure 3-12: A figure of a monk. Boards are inserted on edge into the slots to hold water in the pond. A tight seal is obtained by packing clay into the space between the two sets of boards (Source: Ngugi et al., 2007)

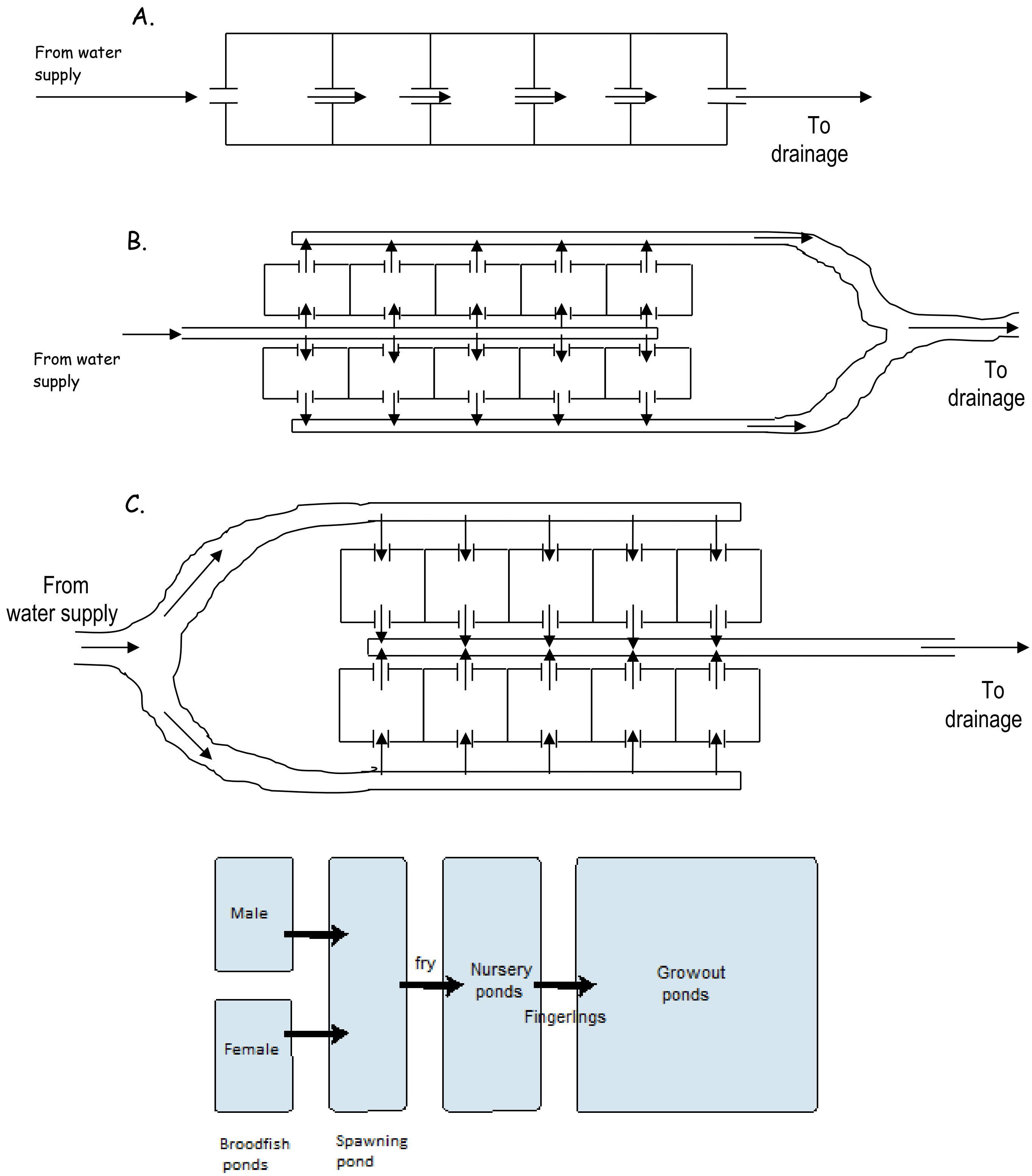


Figure 3-13: A logical pond layout provides for easy flow of water and movement of fish from one rearing phase (pond) to another (Sources: FAO, 1981; Ngugi at al., 2007)

3.1.9 Layout of ponds

- Pond layout can be done either in a series or parallel.
- The advantage of arranging the ponds in a series is it is cost effective when compared to arranging in parallel.
- However, it has the disadvantage of difficulties in maintaining a healthy pond environment as it has a greater risk of spreading disease and contaminations from one pond to the other. Therefore, it is not a good option.

Broodfish ponds, spawning ponds, nursery ponds, and growout ponds are put in sequence and close to each other so that you can move fish from one rearing phase to another easily and quickly. One way of doing this is shown in Figure 2.5. A logical pond layout provides for easy movement of fish from one rearing phase (pond) to another.

3.2 Types of ponds

3.2.1 Dam pond/ Embankment pond

These are also called embankment ponds or barrage ponds. These ponds are made by building an embankment, dam or dyke or similar – ground structures across a water course way and narrow valley. The slope of the land plays a very important role in planning such ponds. A good site is one where a dam can be built across a narrow section of the valley, the sides are gently sloping or steep and there is slow decrease in the elevation along its length to permit a large area to be flooded (see Fig 3.14 below).

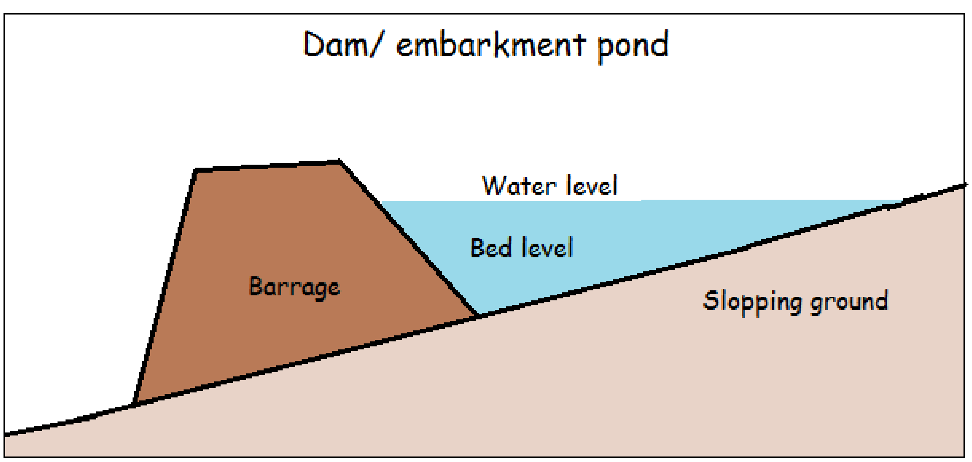


Figure 3-14: Cross section of an embankment pond or dam

3.2.2 Excavated pond

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 (fig 3.15)

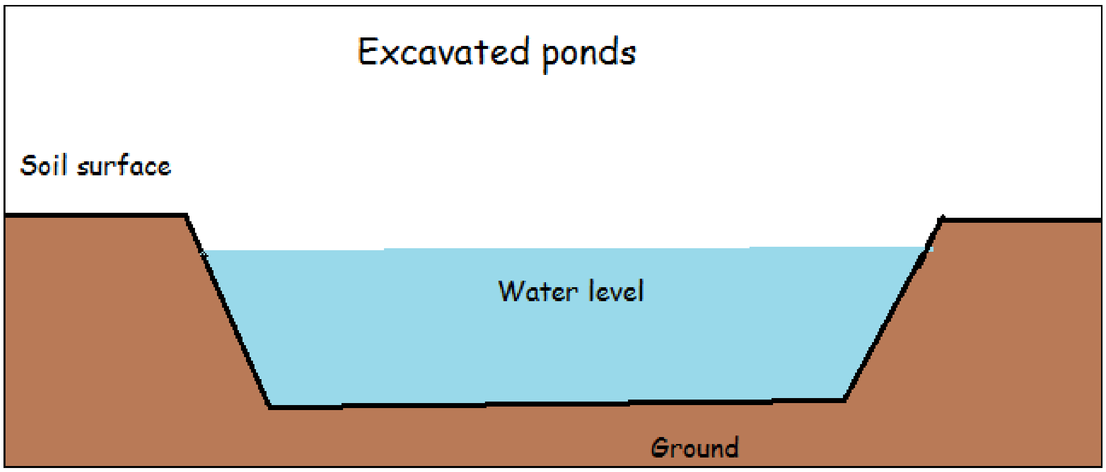


Figure 3-15: Cross section of an excavated pond

3.2.3 Elevated ponds

This type of pond contains requires dykes that are well constructed so they are impermeable. The water supply may need to be pumped depending on the level of the water source. It can be partially drained by gravity. But If the lowest level of pond bottom is elevated at least 25-30 cm than the bottom of the drainage canal, the water can be drained completely through gravity.

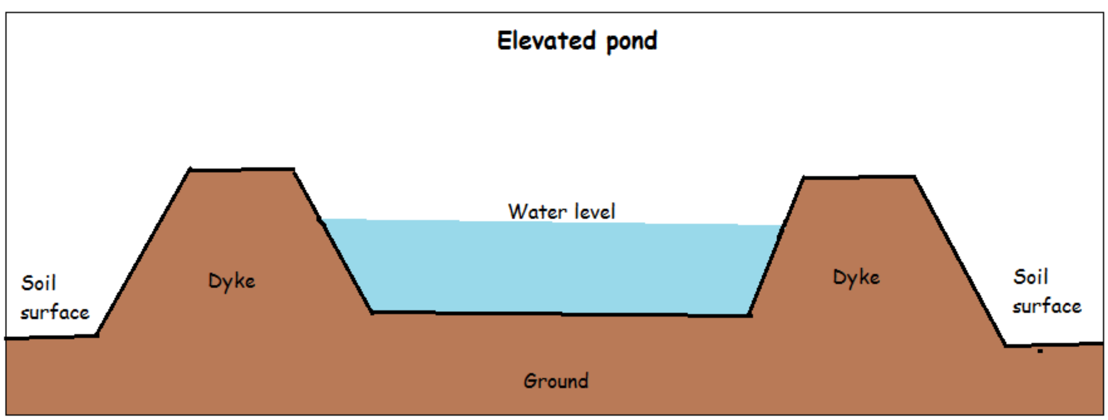


Figure 3-16: Cross section of an elevated pond

3.3.4 **Excavated / Elevated ponds**

The most appropriate type of pond is combination of excavated/ elevated ponds. If the soil has sufficient clay content, the dike can be built from the soil that is removed during pond excavation; thus costs are minimized. It can be partially drained by gravity (Fig 3.17).

This section on pond types has been adopted from Ververvia and Janjua 2015, with some modifications.

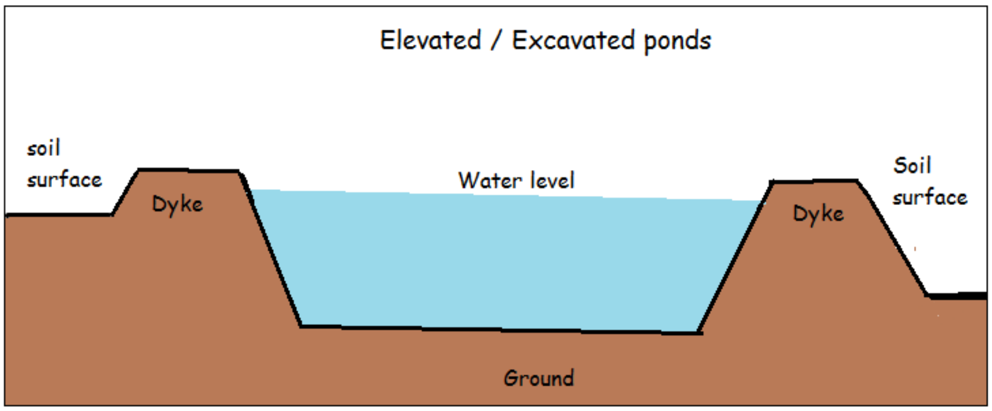


Figure 3-17: Cross section of elevated / excavated pond

3.3 **Pond Construction**

Ponds dug by hand are generally small (100 –300m^2). The tools required for digging include: spade, hoe, mud-scoop spade, fork, wheelbarrow and wooden mullet (ram). The steps in construction are as follows;

- Survey the land
- Clear all vegetation from the site
- Remove the topsoil from the site
- Determine pond, drain pipe, and supply canal elevations
- Peg out the pond, including core trenches, dyke tops, and dyke toes
- Dig core trenches and pack them with good soil
- Excavate the pond area
- Build the dykes
- Install the drainage system
- Install the water supply system

3.3.1 **How to do the actual construction of the pond**

This section has been adapted from FAO 2006. The pond construction process is as follows:

a) **Preparation of the site**

What are the factors should be considered before excavation?

- Pond needs to hold water to a depth of 1.0 meter.
- Potential acid Sulphate layers should not be exposed.
- Should not excavate to a depth so that the pond cannot be drained completely by gravitational flow.

How to prepare the site before construction?

- Clear the trees, scrubs and bushes in the site before excavation.
- Top soil has to be removed and taken away from the pond construction area of the site
- Do not use the top soil to construct your pond dikes as it may contain roots and decaying organic material which are unsuitable for pond dike construction.
- You may store this surface soil in a suitable location, close to the site to use this fertile soil for the following purposes.
  - To cover the top width and inner sides of the dikes above water mark
  - Spread a layer of this soil on top of pond bottom to increase pond fertility
  - To prepare compost piles
- Level the site. If the site is with the suitable slope to receive water into and discharge water from the pond, level the site along the slope.

b) **How to mark the boundaries of the pond and construct the clay core (cut-off trench)?**

- Mark the boundaries of the base of the pond using pegs and string
- If the top soil layer does not have enough clay you need to build a clay core (cut-off trench) to reduce water seepage under the dike.
- To build the clay core, you need to cut a trench along the centre of the dike.

- For small dikes (small ponds) the width of the trench should be 0.5 m and for large dikes (large ponds) 1.0m. The depth of the trench should be 0.5m to 1.0m and for large ponds the depth should reach at least 30 cm into the soil layer with enough clay under the top layer without adequate clay.
- To cut the trench, first mark the center line of the dike base with pegs and string. On each side of the center line clearly mark the width of the trench that you want to cut.
- Dig the trench to a desired depth and fill the trench to the ground level with good quality clay.
- Wet it if necessary (if it is too dry) and compact well the soil in the trench with a concrete tamper or metal tamper
- You need to be careful if you bring clay soil outside the site to test it for acidy or potential acidity

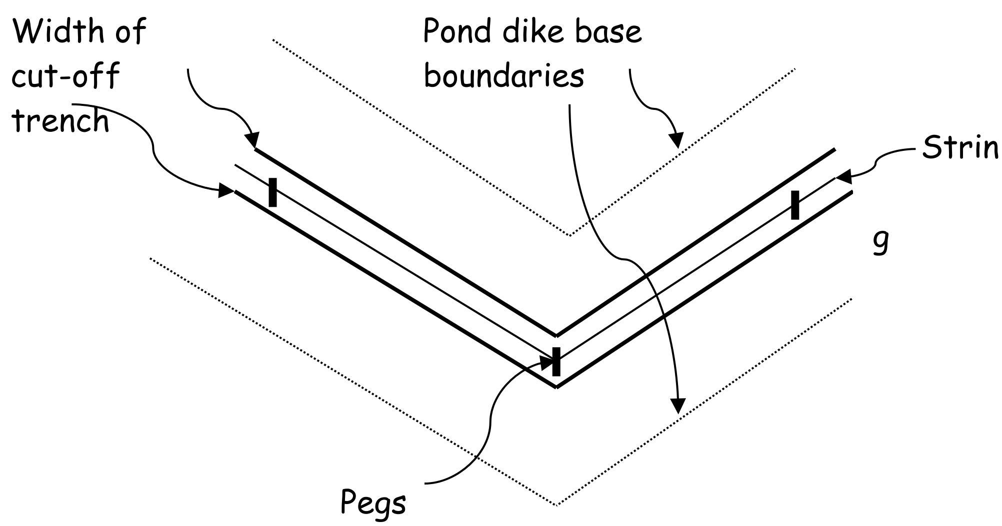


Figure 3-18: Marking boundaries of pond dike

c) **How to excavate the soil?**

- Excavate to the predetermined desired depth (taking the conditions given in factors to be considered before excavation).
- Excavated soil can be used to build the dikes (after removing top soil).
- If the excavated soil is not enough due to the limitations given above, you can push earth from the sides of the pond to supplement the excavated soil to make dikes. Excavated area of the sides of the pond can be used as drainage canals.

- If the site cannot be excavated due to its topography and status of elevation which prevent gravity discharge of water, push earth from the sides to construct the dikes.
- If this pushed soil is not adequate transport soil from a suitable site.
- If soil has to be transported check the soil for its physical and chemical qualities for its suitability for pond construction.

d) **How to pile up soil to construct dikes?**

When you are piling up of soil to make the dike, it is important you maintain the side slope of the dike. In order to maintain the side slope during piling up of soil follow the procedure given below.

- Use pegs and a string as shown below to mark a line along all four sides of the pond 20cm above the bottom parallel to inner and outer boundaries of the pond dike base (Fig 3.19).
- Fill the first layer of soil along all four sides of the pond up to the 20 cm mark and compress and compact the soil using either a concrete, metal or thick wooden tramper (thick wooden board with a large surface area fixed to a vertical pole) or using a vibration plate or a roller.

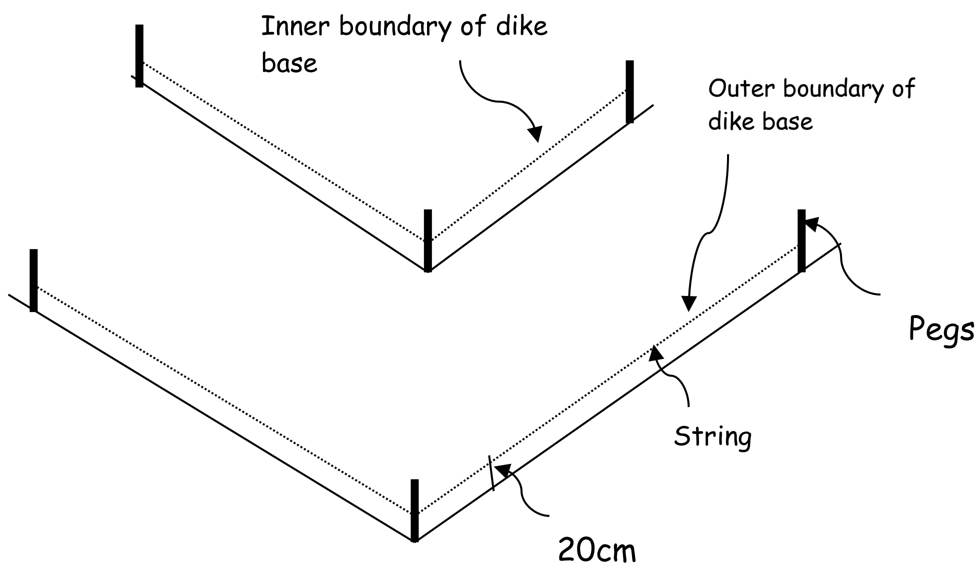


Figure 3-19: Piling up soil during pond construction

- For each dike move the inside boundary and outside boundary of the dike base towards the center line of the dike by a distance equal to 20cm x side slope.
- Then use pegs along this distance to mark the new inner and outer boundaries of the dike base and raise the string to mark 20cm height above and parallel to the new boundaries

For example: If the inside pond side slope and outside pond side slopes are 1.5:1, then the distance is 20 cm x 1.5 = 30cm

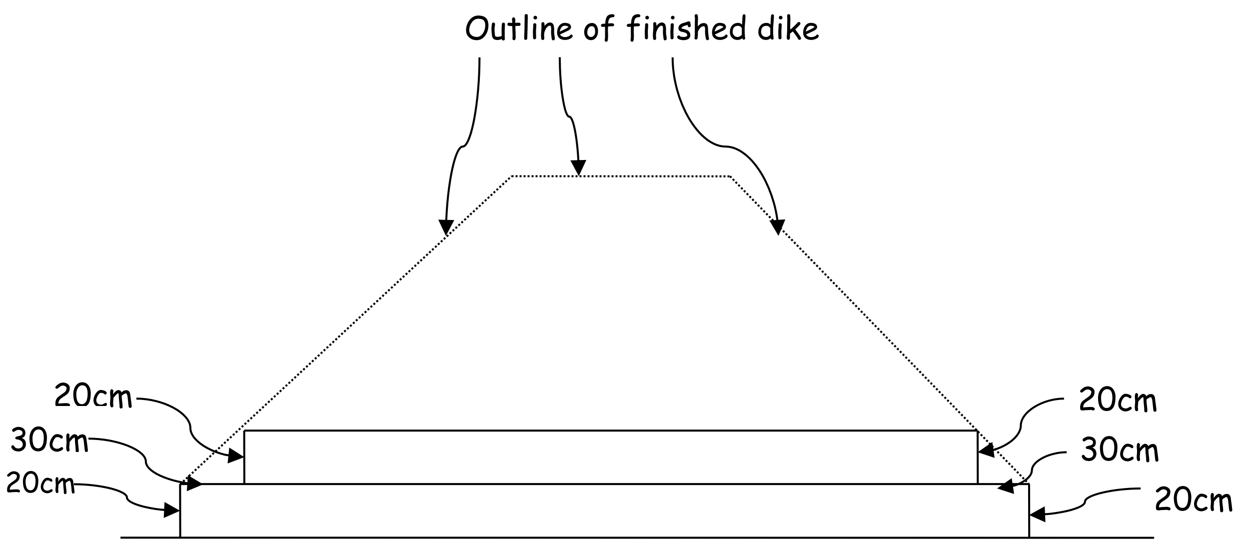


Figure 3-20: Marking the outside and inside slopes of a fish pond

- Fill the second layer of soil along all four sides of the pond up to the new 20 cm mark and compress and compact the soil using either a concrete, metal or thick wooden tramper (thick wooden board with a large surface area fixed to a vertical pole) or using a vibration plate or a roller.
- For each dike, move the inside and outside dike base boundaries towards the dike centre line by the same distance as previously (30cm) and raise the string another 20cm along and parallel to the boundaries
- Fill the third layer of soil along all four sides of the pond up to the new 20 cm mark and compress and compact the soil using either a concrete, metal or thick wooden tramper (thick wooden board with a large surface area fixed to a vertical pole) or using a vibration plate or a roller.

- Repeat these steps until you reach the level of the top of the dikes. If the last soil layer is less than 20cm thick, adjust the level of the string with the level of the top of the dike, instead of 20 cm height.
- Once you repeat this steps the sides of the dikes will look like staircases
- In order to obtain a smooth side slope follow the following steps

  - On the top of each dike, set out the planned dike top width, measuring half of its value on either side of the centre line and mark the limits with pegs and a string
  - Starting from the top of the dike, obliquely cut the end of each soil layer on the sides of the dikes following a slope that joins the limits of the dike top width to the bottom limit of the layers, until reaching the dike base
  - Remove all the cut soil, pegs and strings

- It is better to pile up soil 10%-20% more than the required dike height at the final stage, i.e., when piling up the final layer. This 10% -20% additional soil layer is called shrinkage allowance and it is for settlement or for shrinkage of dike height with time after construction.

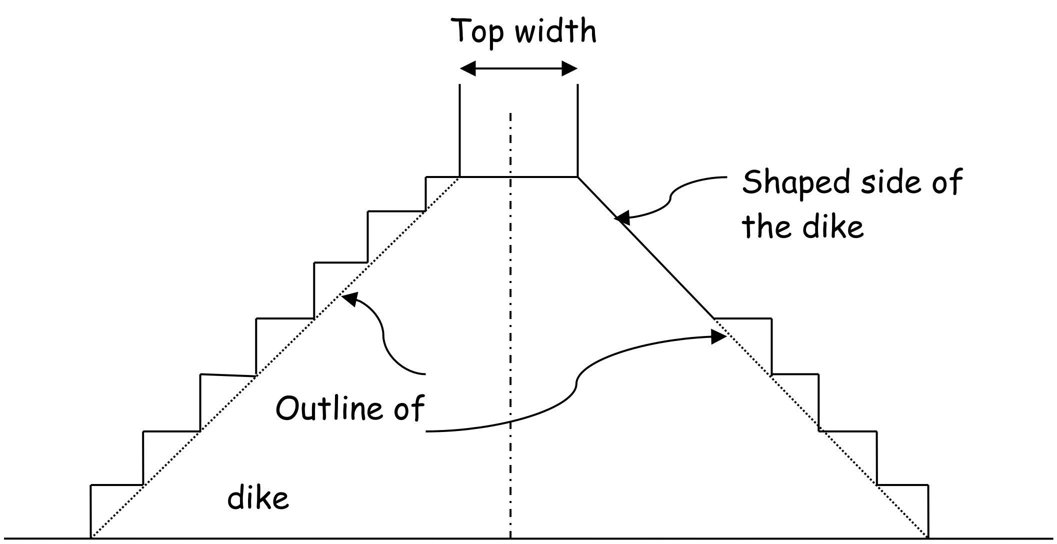


Figure 3-21: Illustration of the slope cutting process on a pond dike

e) **How to maintain a uniform dike height along entire dike length?**

- It is very important to have a uniform dike height when constructing the dike. You can use the following simple technique to ensure the uniformity of dike height along the dike length.
- Get a 50 m long transparent plastic tube/hose. Fill the hose with water. Hold one end of the hose at one end of the dike and the other end at the next 40 m away.
- If the water levels at both ends are the same, the dike is level. Repeat this process along the whole length of the dike

f) **How to stabilise the dike slopes?**

- After levelling the pond, plant creeping grasses on the dikes to prevent erosion. Plant bananas at the outside slope of the perimeter dike to serve as wind breakers.
- Do not plant trees along the dikes because the roots will cause leakage and seepage.

3.3.2 Hand Construction of Ponds (example)

Fish ponds are dug either mechanically using heavy equipment, or by hand labor (manually). Choice of construction methods depends on site characteristics, economic factors and desired pond size. Heavy equipment is used for large, commercial ponds, whereas manual labor is usually used for small, family ponds. A practical example of hand construction of ponds adapted from Nandlal & Pickering, 2004, is as follows:

1. **Setting and pegging the pond**

a) First, prepare a sketch plan of the pond area (see Fig 3.22).

b) Clear the entire area of the fishpond of all grasses, trees, stumps. These could be burned or removed from the site. It is important to dig a channel or drain to allow water to drain away from the construction site.

c) To outline the dimensions of the pond, first mark the outside edge of the dyke using wooden or bamboo stakes. For example, for a pond that will have approximately 24m x 14m of water surface area, mark out a boundary measuring 30m x 20m. This will allow for a **dyke** around the pond that will be about 3m thick at ground level. For bigger ponds, use the dyke-width dimension depends on the side slope and dike height as earlier seen. The corners of this rectangle can be marked with pegs, and a string can be run between the pegs.

d) In order to get rid of roots, remove about 10–20cm of topsoil from throughout the 30m x 20m marked area. It is important that there should not be any roots or dead grass in the dyke for water to leak through later. Note that the topsoil removed needs to be set aside, to be put back later on the top and outer sides of the pond dyke.

e) Next, mark out a smaller rectangle of 24 x 14m inside the bigger (30 x 20m) rectangle. This will show where the *inside* of the dykes will be at ground level. This 24 x 14m rectangle is the area of ground that is going to be dug. The earth that is dug out will be used to make the tops of the dykes. The bottom of the dyke in the shallow end of the pond will begin from about another 1.5m inside this smaller rectangle. The bottom of the bank in the deepest part of the pond will be about 2m from the lower end of this smaller rectangle.

f) Then mark a third rectangle in the centre of the pond, measuring about 21m x 11m. This is called the **central area,** and represents the flat bottom of the pond.

2. **The digging process**

a) The central 21m x 11m area is dug out first, and the soil is used to build the dyke of the pond. The workers should be organized in a row with shovels and digging forks. The digging begins at the shallow end of the pond, at the string marking the central area.

b) The pond is dug to about 20cm deep at the shallow end, increasing gradually in depth towards the other end. At the deepest part, at the string marking the central area the depth should be about 30cm.

c) As the soil is dug out, it should be placed in the space marked out for the dyke, between the 24m x 14m rectangle and the 30m x 20m rectangle.

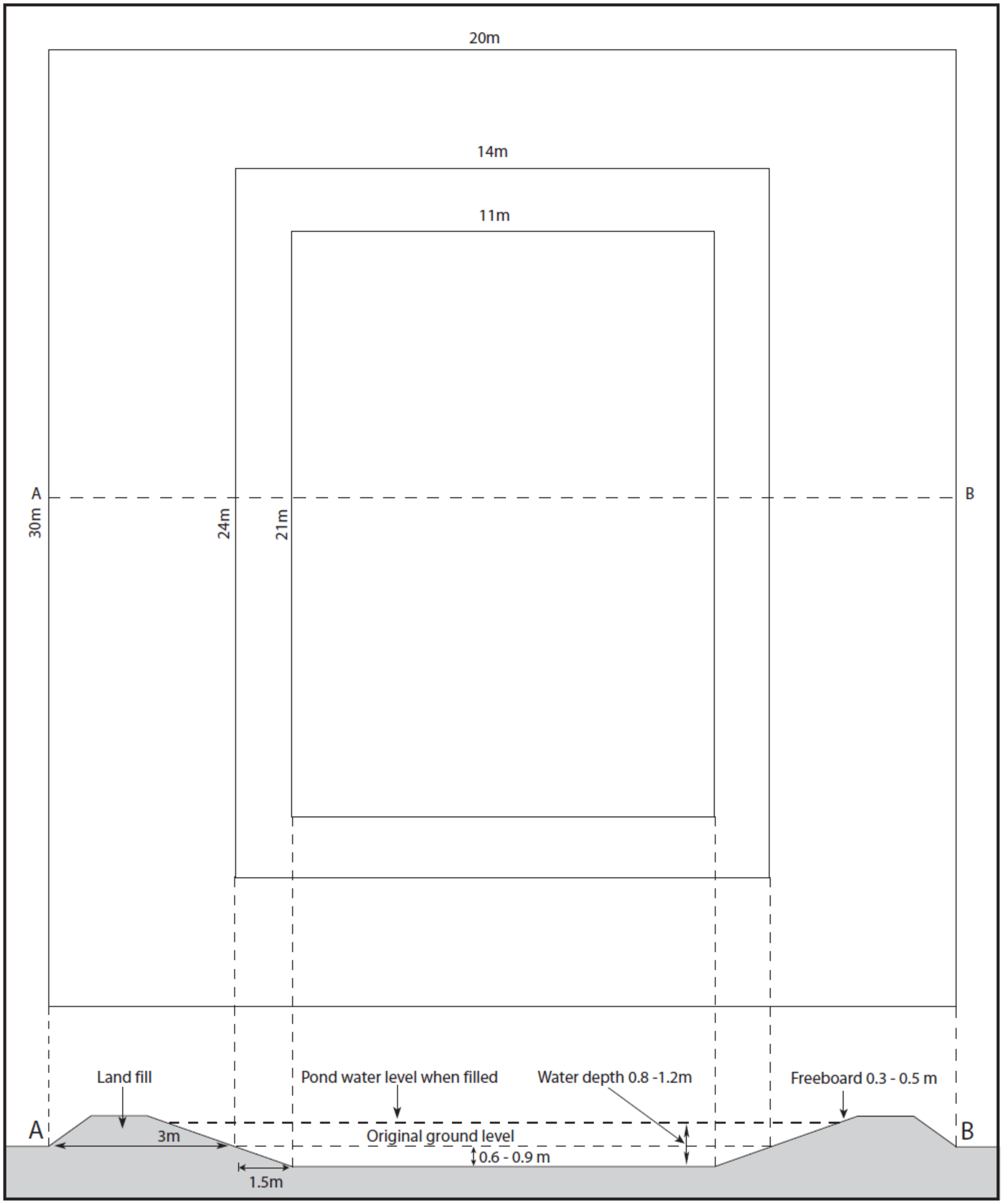


Figure 3-22: Ground plan for a hand-dug pond (top) and cross-section of pond along A-B (bottom) (Source: Nandlal & Pickering, 2004)

It is recommended that the soil be placed nearest to the digging area so that the dyke will become higher and wider towards the deeper end. Whenever the loose soil placed on the dyke reaches about 30cm (knee height), it should be packed down tightly. This can be done by compacting the soil with a heavy length of tree trunk. It is very important to ensure that the slope of the pond bottom be made as regular as possible.

d) Once the first 20–30cm layer of soil from the central part has been dug out, the whole process can be repeated to take out another layer. As before, begin the process by digging out 20cm deep at the shallow end and 30cm deep at the other end. As before, the soil removed is placed on the dyke area and packed down tightly. Then, for a third and last time, another layer of soil is dug out of the central area and packed down tightly on the dyke.

e) When the digging is finished in the central area, there will be a hole 21m x 11m with straight sides. The dyke can be then shaped by digging the soil away from the edges of the central area to form a slope up to the 24m x 14m string.

f) This soil can be placed on top of the dyke and packed down tightly with the slope continued smoothly up to the top. The inside of the dyke should slope more gently than the outside (except where two ponds are built side by side). Fig 3.23 shows what the dyke should look like when finished. The top of the dyke should be about 1.5m wide, and flat all the way around the pond.

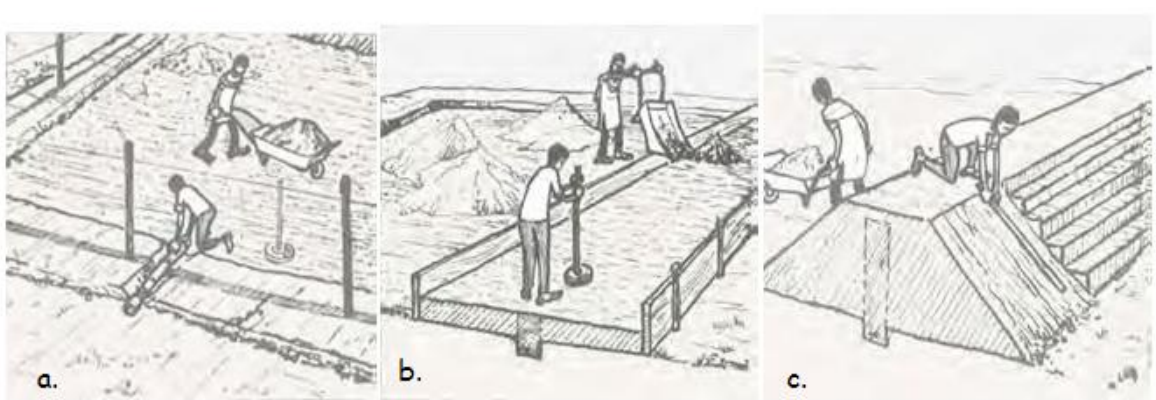


Figure 3-23: Dike construction process (Source: ACF manual)

g) The topsoil removed at the beginning should now be placed on the top and outer sides of the dyke. The bottom of the pond should be about 1.3m below the top of the dyke at the shallow end, and about 1.7m below the top of the dyke at the deep end. The bottom of the pond should be fairly smooth and regular. All loose soil and other trash from the bottom of the pond should be removed.

h) Additional earth should be placed on top of the dyke as settlement or shrinkage allowance. This additional soil is important to maintain the required dike height as after dike construction with time soil tend to settle and reduce the dike height
   - For good clay soil shrinkage allowance can be 10-20%
   - For sandy or soil with organic matter the shrinkage allowance may be as high as 40%.
   - This will increase costs. Therefore, selecting the site with good clay soil is important

3. **Ponds side by side**

When marking out ponds to be built side by side, leave an extra 1.5–2m between the two big rectangles (30m x 20m markers) to allow for the slopes of the dykes inside the adjoining ponds

4. **Installing the water inlet**

A water inlet is required to fill the pond with water. This inlet should be placed at the point nearest to the water source. Most often this will be at or near the shallow end of the pond. An inlet pipe should be 25–50mm in diameter, and long enough to reach across the top of the dyke from one side to the other. Once the position of the inlet is decided, dig a ditch across the dyke. This should be dug to a level to allow water to flow from the channel or pipe that brings the water from the water source and into the pond a little above the water level on the inside of the dyke. The inlet pipe can be placed in the ditch in the dyke, and the dyke rebuilt over it. Alternatively, if an open channel is used to allow water into the pond, erosion of dyke soil can be prevented by using roofing iron or hard plastic to line the bottom of the channel.

5. **Installing the water outlet**

The water outlet is made at the bottom of the dyke at the deepest end of the pond (Fig. 3.12). The outlet is usually made from PVC pipe and should be at least 100mm in diameter. Since the dyke at the deep end will be wider than at the shallow end, and the outlet pipe is installed at the bottom of the dyke, the widest part, several meters of outlet pipe will be needed. It may be possible to join pieces of pipe together to make the required length. The inlet and outlet of each pond should be positioned diagonally opposite.

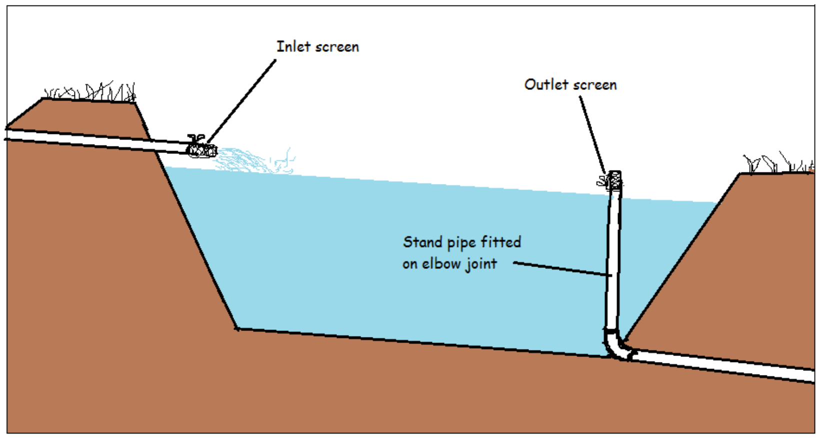


Figure 3-24: Pond inlet and outlet with screens

A gap or ditch is dug through the dyke where the outlet is to be located. It should reach from the deepest part on the inside of the pond through the dyke to a lower level outside of the pond, to allow water to drain from the pond. If the outlet is below ground level on the outside of the pond, it will be necessary to dig a drain to take the water away from the outlet. The outlet pipe is placed in the gap in the dyke and the dyke is rebuilt over it.

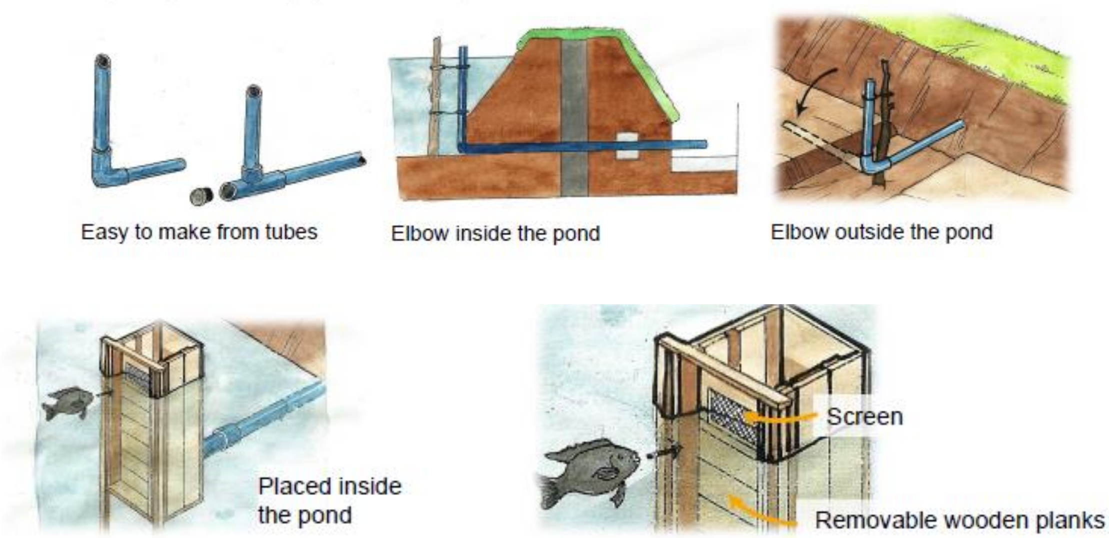


Figure 3-25: Simple elbow outlet and more sophisticated monks for bigger ponds (Source: FiBL, 2011)

6. **Screening inlet and outlets**

Care must be taken to place screens on the inlet, the outlet pipe and overflow pipe to prevent fish from escaping as well as stop other fish from entering the pond (Fig 3.14 & 3.15).

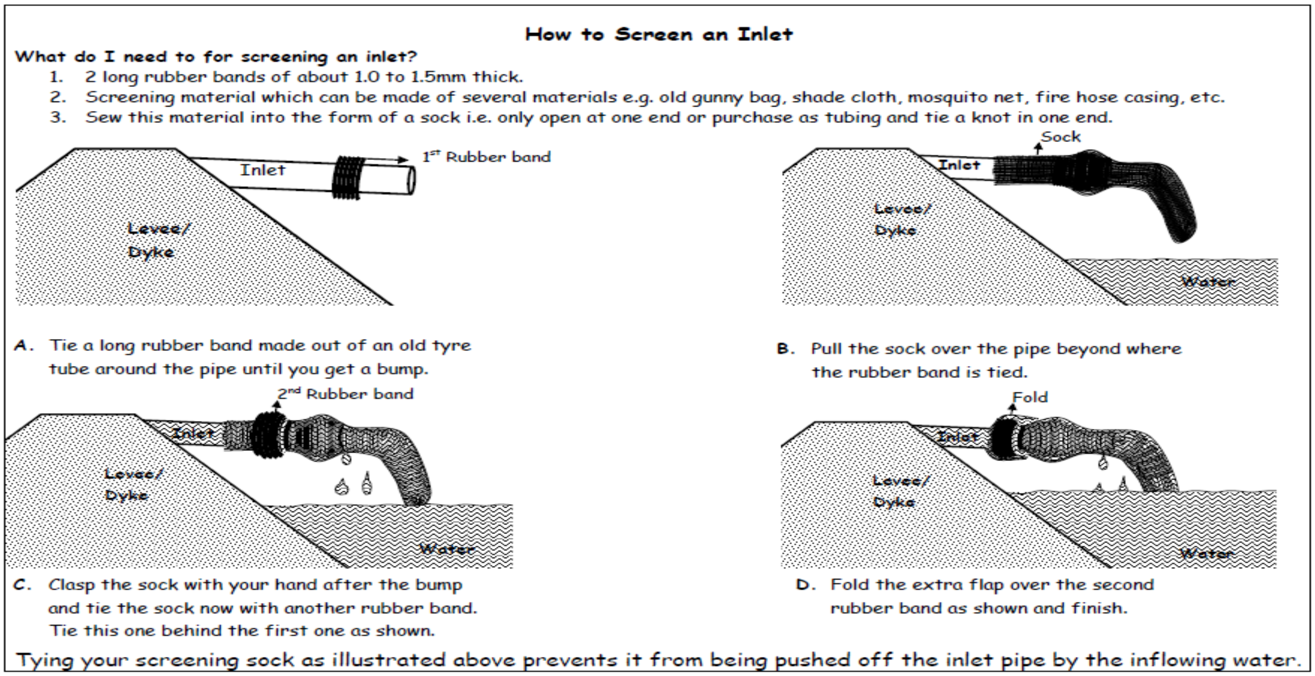


Figure 3-26: How to Screen the Inlet Pipe (Source: Isyagi et al., 2009)

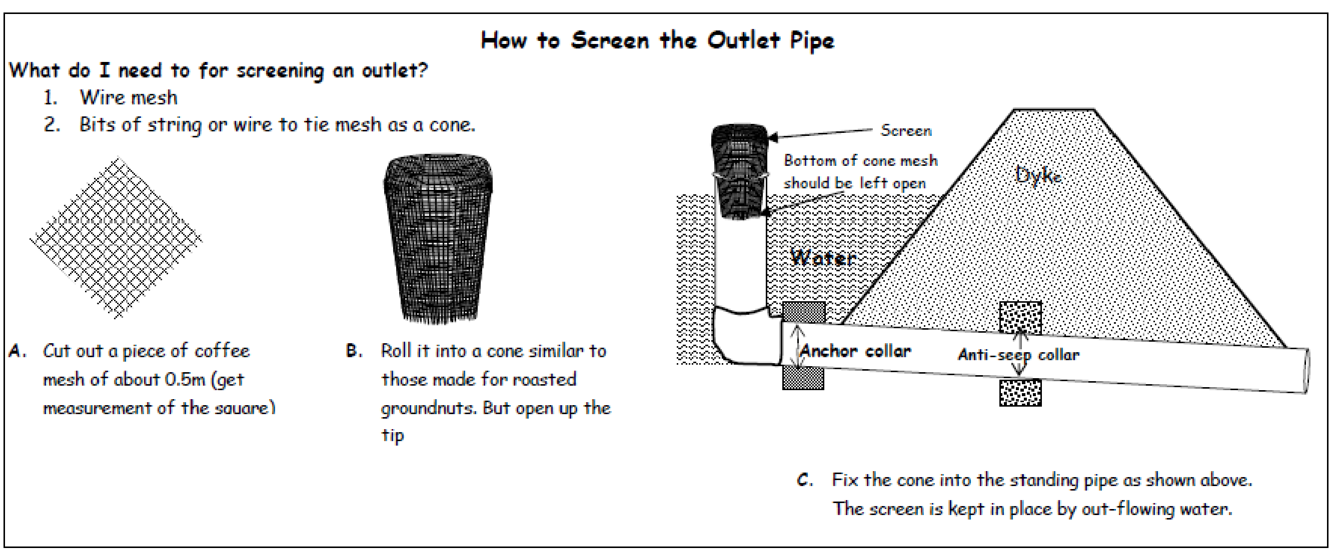


Figure 3-27: How to Screen the Outlet Pipe (Source: Isyagi et al., 2009)

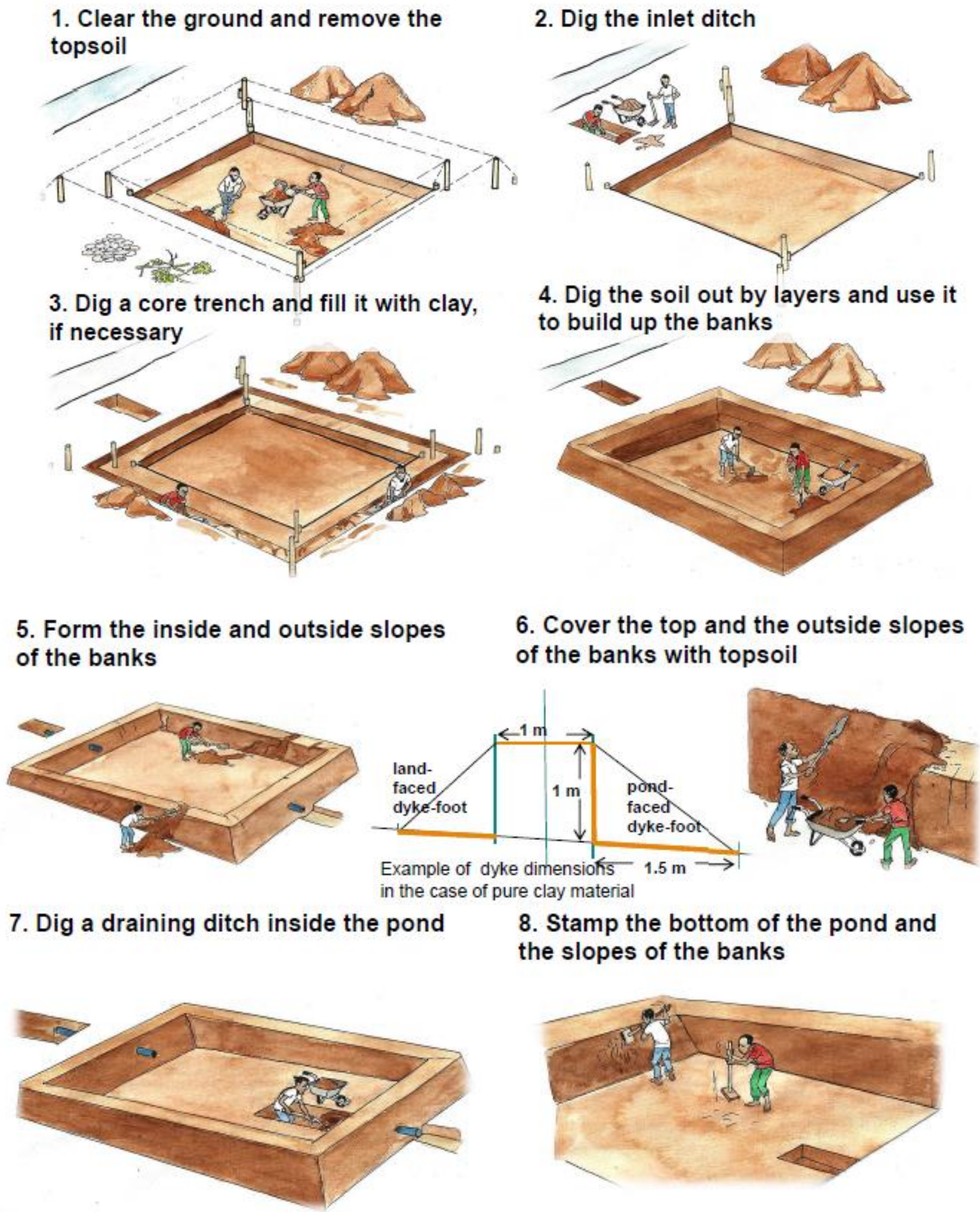


Figure 3-28: Illustration of the pond construction process (Source: FiBL, 2011)

Plate 3-2: Pegged out fish pond and core trench digging. The core will be packed with soil containing not less than 30% clay before dyke construction begins (Source: Ngugi et al.2007).

Plate 3-1: Pond construction typically involves excavating the inner area and using that soil to build the embankments (Source: Ngugi et al.2007)

Plate 3-4: A Harvest Basin Set Within the Pond (Source: Isyagi et al., 2009).

Plate 3-3: A Harvest Basin Set Outside a Pond (Isyagi et al., 2009)

Chapter 4

CONSIDERATIONS FOR TILAPIA HATCHERY OPERATIONS

A hatchery is a facility for breeding fish to produce fry and fingerlings for grow-out. The goal of the hatchery is to produce a consistent quantity and quality of fingerlings for various types of tilapia grow-out operations. The fingerlings can be produced in suitably designed ponds, or net enclosures (called "hapa") in ponds, or tanks (made of concrete, plastic, fibre glass, metal, glass, wood). These different systems require different levels of inputs and management. The choice of system depends on the circumstances of the area and the number of fingerlings that will be required.

4.1 Importance of Small-scale Hatcheries

Small-scale hatcheries are an attractive development activity since they present relatively low risk to farmers and can return their investment quickly for the following reasons:

- Small size results in low construction cost
- Small size is easy to manage at family scale
- They do not always require sophisticated equipment (pumps, aerators, electricity etc.)
- The range of species that can be produced are not restricted by hatchery size
- They can be located almost anywhere that has a suitable supply of water
- They can be located close to the farmers that will purchase the fry

4.2 Site selection for a hatchery

Several factors have to be considered while establishing a successful tilapia hatchery. In principle, the following factors should be considered;

- Access to a suitable water source
- Local demand for tilapia seed and potential profit from the hatchery should be kept in mind while selecting a particular location for the hatchery.
- The site should be accessible so that seed, broodfish and other hatchery materials can be transported to and from the hatchery in a reasonably short time and at low cost.

- Distance from grow-out farmers is also important, although fry can be packed in plastic bags with oxygen and transported long distances (up to 20 hours drive or 40 hours shipping including air cargo and road) throughout the world. However, long journeys can exhaust fry and affect their survival.
- Usually hatcheries and nurseries tend to be located in clusters. This follows a marketing trend in which some areas might have a good name already for particular products. Therefore, that location may be preferred over a more removed/ independent one.
- While in clusters, there is a risk of competition, therefore it should be considered while selecting the site.
- Climate/weather should be kept in mind while establishing the hatchery. A site vulnerable to extreme weather cycles or natural disasters such as floods, storm/wind, etc. should be avoided.
- It is always good to place a farm / hatchery in a location promoted or facilitated by the Government.

4.3 Basic facilities for a fish hatchery

- Ponds or tanks for holding and rearing an adequate number of broodstock fish
- Spawning pond, tanks, or hapas
- Nursery pond, tanks, or hapas
- Holding tanks with hapas for recovery from handling stress prior to distribution of Fingerlings
- Water supply system and storage tank (for an indoor incubation system)
- Air (aeration) system (where applicable)
- Pumps (for recirculatory egg incubation system)
- Electricity supply and/or generator (for indoor incubation system)
- Basins, buckets, containers
- Seine nets, scoop nets, grading basket
- A good scale for weighing fry and fingerlings
- Accessories for packing of fry and fingerlings

4.4 Types of ponds at the hatchery

The number and sizes of ponds depend on the target production and the sizes given in this section are only a guide to a small-scale hatchery.

- **Nursery ponds**: These are the smallest and shallowest of ponds for fish culture. These ponds should be no larger than 40 x 40 m and should be 1 –

1.5 m deep. Smaller ponds can be used if only small quantities of fry are produced (i.e. from natural or semi-natural spawning techniques). Two or more nursery ponds are desirable at the hatchery.

- **Broodstock ponds**: These ponds can be the same size of the reservoir (200-300 m^2) and should be approximately 1.5 – 2.0 m deep. If they are too shallow, the broodstock growth will be poor and the ponds will tend to dry up completely in the dry season. Ideally the hatchery should have two ponds, since male and female brood stock need to be separated during the breeding cycle, but if broodstock can be obtained from outside the farm, maintenance of broodstock may not always be necessary.
- **Fry to fingerling rearing ponds**. Whereas fry may be raised in small and shallow ponds (1.0- 1.5), fingerlings need larger sized (800 – 2000 m^2) and slightly deeper (1.5 – 2 m) ponds. If the ponds are seasonal, only one crop of fingerlings will be possible, whereas at least four crops can be produced in perennial ponds.
- **Sex reversal ponds:** These are transitory ponds used for sex reversal of fry before they grow into fingerlings. The ponds may be 500 – 1000 m^2 and 1.0 – 1.5 m deep. As soon as the objective is achieved the fry are moved to fingerling rearing ponds.
- **Holding ponds:** A holding or marketing pond, which is small but quite deep, is used to keep fish caught from a stocking pond for sale at short notice when the demand and price are high. These ponds can be 500-1000m^2 ha in size with a water level of 1.5 – 2.0 m.
- **Stocking or growout pond:** A ***stocking pond*** is much larger, often 2000-10,000 m^2. It should be 1.2 – 2.0 m deep. This pond might be perennial or seasonal. Big ponds require less time in labour (fertilising, feeding, etc), but are more difficult to harvest, take longer to prepare and fill with water and provide less control over wild fish species invasion. Small ponds are more costly to excavate (per unit area), but control of predators is easier and they are of advantage if selling fish regularly in small amounts
- **Quarantine pond:** Fish brought in from outside are first placed in a small (200 m^2) but perennial (1.5 m deep) ***quarantine pond*** for a time to verify that they are not infected. You can also use this pond to treat diseased fish from other ponds.
- **Reservoir pond:** This is used to store inlet water before use in the hatchery and nursery. Inlet water sometimes has a high level of suspended solids, which it is desirable to settle out. In situations where water supply is not continuous, a reservoir will allow hatchery operation to continue

without interruption. A small-scale hatchery should ideally have a reservoir of 40 x 40 m (1600 m^2) with a depth of about 1.5 m. The deeper the reservoir pond the better since water clarity improves with increasing depth, but excavation cost increases. The reservoir can be used as a broodstock pond in small operations.

4.5 Fingerling production systems

Hatchery operators in may choose either of the following methods depending on their capacity and level of production. The different systems for producing fingerlings are outlined below.

4.5.1 The Pond Method

The open pond method is the simplest and most common way to produce tilapia fingerlings. In this method, a pond is used for both spawning and rearing of broodstock. The brooders are stocked into ponds and allowed to spawn naturally at controlled conditions. The minimum pond size should not be below 200m^2.

Advantages of the open pond method are as follows:

- Pond management is very simple
- The pond serves as a spawning and rearing facility at the same time, therefore, fingerlings produced are larger compared to those produced from other methods
- No supplemental feeding is required if high manuring rates are used.

Disadvantages:

- The number of fingerlings produced per square meter is less compared with the other methods like hapas and tanks.
- The fingerlings produced are not of the same size. They need to be graded after harvesting.
- If fry and fingerlings are not regularly harvested, there is a possibility for over populating leading to stunting and inbreeding

4.5.2 The Hapa method

A "hapa" is a net enclosure which is like an inverted mosquito net with four top corners that are usually tied to bamboo stakes in a pond (Plate 4.10). The netting material is made of fine meshed polyethylene and seams are sewn with nylon thread and double stitched to prevent splitting.

The advantages of the hapa method are as follows:

- Fry and fingerling production on a per square meter basis is high
- Fry and fingerling are more uniform in size and age
- Broodstock are easily handled as they are confined in a relatively small area.
- Fry and broodstock are well protected from predators

Disadvantages of the hapa method

- The hapa requires high and intense management as compared with the other methods
- The brood fish in hapas may be easy targets for poachers
- If inserted in a lake, hapas may be destroyed or blown away during stormy weather
- The feeding of brooders and fry is a must in a hapa and this raises production cost

4.5.3 **The tank Method**

Hatchery operators can also produce fingerlings using concrete tanks (Plate 4.2). When this method is used operators should make provisions for dissolve oxygen (DO) supply to tanks through air blowers operated by compressors or pumps so that good water quality parameters are maintained. The tank method is advantageous when the hatchery is used for producing sex reversed all male fingerlings because effluents are easily managed and treated.

Advantages of the tank method are as follows:

- Fry and fingerling production per square meter is high
- Fry and fingerling are more uniform in size and age
- Brood stock are easily handled because they are reared in relatively smaller area compared to open pond method
- Fry and broodstock are well protected from predators

Disadvantages of the tank method

- Tanks require high and intense management as compared with the other methods
- The brood fish in tanks may be easy targets for poachers
- Tanks have high initial capital costs and these may increase production costs.

- The feeding of brooders and fry is a must in a tank and this raises production costs.

4.6 **Artificial incubation of eggs in recirculatory systems**

To boost broodstock productivity, the time between two successive spawnings may be considerably shortened by removing the fertilized eggs from a female's mouth. Once the clutch of eggs is removed, the female assumes that the eggs are lost and quickly returns to reproductive mode. This is similar to removing eggs from a chicken to encourage it to lay more eggs. The eggs removed from the females are incubated and hatched in down- or upwelling jars or trays with clean flowing water (Plates 4.3. 4.4 & 4.5) under controlled conditions that ensure high survival of eggs and fry making mass production of uniform seed possible. Hatching jars should be provided with frequent replacements of water or slow flow-through and also receive aeration to maintain an appropriate dissolved oxygen level. The intensity and costs of this operation depends on the level of investment.

Advantages

- High hatching rates and survival rates
- Helps prevent cannibalism and prepares females for further spawning
- Mass production of uniform seed possible
- Mass production of male tilapia can be done efficiently
- Various incubation systems possible, including cheaper ones

Disadvantages

- Startup costs may be higher than the natural method
- May require electricity to run pumps and aerators which may not be possible in some rural areas
- May require water from a borehole to run efficiently which may not be readily available in some rural areas
- May need commercially compounded feeds to yield expected returns

4.7 **Counting tilapia fry**

There are four commonly used techniques for counting fish fry, which are described below;

- **Individual count technique: Using** a small hand net or plastic spoon, proceed to count fry one by one as they are passed from one container to another. This technique is precise and useful for enumerating small groups of fish, but is too tedious and time consuming for counting lots bigger than several hundred or thousand fish.

- **By volume:** Counting fry can be done by volume. Small plastic cups can be used for measuring fry by volume: Total fry = no. fry in 1 cup x total no. cups. The following is the procedure;
  - It is better to count the fish in more than 1 cup and use the average number as number of fry per cup
  - If the number of fish in sample 1 and 2 is very different, then this will indicate that there has been error in counting.
  - Be careful that the sample is representative of fish from the whole batch by confining and mixing the fish before taking samples. Large and small fry will tend to separate out.
  - The more even size the fish are the more accurate will be the estimate of fry numbers.

Figure 4-1: Estimating fry numbers by gravimetric and water displacement method (Source: Meyer & Meyer, 2007)

- **Gravimetric technique:** Determine the average weight of a known number of fry without water. Then the rest of the fry are weighed in groups to estimate their numbers (Fig 4.1). The fry are weighed in a previously weighed container, such as a plastic strainer, and then counted one by one to estimate their average weight. For this technique it is indispensable to have a precision balance and fry of uniform size.
- **Water displacement technique:** Fry are transferred to a container (beaker or graduated cylinder) with a measured volume of water. The fry are then

counted and their number is related to the increase in the volume observed in the container. Additional fry numbers are estimated by the water they displace in the container. Again it is important to use this method with fry of uniform size.

- **Visual comparison of fry population:** Several identical plastic trays or bowls are required for this technique. Each bowl is prepared with an equal amount of clean water. It is recommended to use bowls made of white, yellow or clear colored plastic. Fry are counted one by one into the first bowl. Then fry are added to additional bowls until the populations appear equal through visual comparison. It is best to observe the bowls from directly above. After a little practice and experience, this method provides a simple and quick way to enumerate large numbers of fry with sufficient precision (± 5%) for most farms.

Figure 4-2: Estimating fry numbers by visual comparison of populations. After individually counting fry into a plastic dish with water, a second identical dish is prepared and fry added until the populations appear equal, as seen from above (Source: Meyer & Meyer, 2007).

Plate 4-1: Breeding and nursery hapas (blue) and B-net rearing hapas (black) installed in rows with enough space to enable water circulation (Source: Gift manual, 2004).

Plate 4-3: Low cost tilapia breeding and fry rearing tanks (Source: www.fishconsult.org)

Plate 4-2: Typical modern monosex tilapia seed production hatchery system in Thailand (Source: Hussain, 2004)

Plate 4-4: Small scale hatcheries made from local materials (Source: www.fishcounsult.org)

Chapter 5

TILAPIA BREEDING MANAGEMENT

5.1 Broodfish source, requirement and selection

Ideally, hatcheries should have their own broodstock culture ponds so that they have a ready supply of broodfish for spawning. Broodstock ponds also allow the hatchery to ensure that the nutrition of the fish is adequate and the fish are of good quality.

Obtaining quality broodstock requires sound knowledge on managing and selecting breeders that are unrelated (not close relatives). It is imperative to keep records of the breeders to manage the stocks. These records need to be collected for each generation, and include, for example, numbers, sex, holding facility, growth rate, survival, fecundity and deformities.

The key to good broodstock management is obtaining and maintaining good quality broodstock. The hatchery should obtain parent stocks of known origin, usually from research stations of Fisheries Departments. They should have good performance — that is, good growth rate, desired color and body shape, lowest feed conversion ratio, disease resistant etc.

Broodstock are a valuable asset, and they need to be protected through management practices that prevent loss of quality. A government hatchery should maintain standard reference strains at all times. The effective population size (Ne) of the breeders should be between 400 and 1000.

To maintain the quality of broodstock, the operator should:

- prevent any deliberate or accidental introduction of inferior tilapia types into the breeding system
- eliminate from the breeding system any fish that have questionable characteristics, for example slow growth, deformities such as curved backbones, signs of disease or parasites, blindness, or unusually large and hardened belly
- ensure parentage is known; for example, introduce breeders from known sources

- ensure no fish remain in the pond from the previous breeding cycle before starting the next cycle
- keep stock lines in secure and separate holding facilities
- reduce inbreeding (breeding between closely related fish) by maintaining a large population of breeders and ensuring that a large proportion of them get a chance to breed
- replace broodstock fish every 18–24 months, if possible
- when replacing aging broodstock, choose offspring originating from as many parents as possible for breeding
- maintain a systematic record of stocks

5.2 **Avoiding mating of relatives (Inbreeding)**

The main strategy for the hatchery operator to reduce inbreeding is to maintain a large population of broodstock fish, and ensure that a large proportion of them get a chance to breed and contribute to the next generation. If possible, more broodstock should be used than just the minimum necessary to meet fingerling production targets, so that as many broodstock as possible will get a chance to breed.

At least a few fry from all of these broodstock should be retained and grown out for use as the next generation of broodstock, before the previous generation gets too old and is discarded. This requires a lot of small ponds, tanks or hapa, and good record keeping, to know the identity of parent fish. This activity is usually carried out by a hatchery specialist, normally at the Department of Fisheries.

5.3 **Rearing, conditioning and holding of broodfish**

Conditioning is a short period of rest and recuperation. Fingerlings intended for use as broodstock should be grown out at low stock density (1–2 fish per m^2) in ponds. They take 4–6 months to reach breeding size of 150–300g. Fish kept for broodstock should not be used for more than 1.5–2 years.

Ponds can be fertilized to encourage natural food production (plankton). The following fertilizers are being widely used to maintain the plankton bloom (green water):

- NPK (16-20-0) – 175 kg (per ha per week),
- Urea (46-0-0) + tri super phosphate (0-46-0) - 61 kg + 40-70 kg (per ha per week)

- Fresh chicken manure - 1,875 kg (per ha per week)
- Chicken manure + 46-0-0 (urea) - 1,100 kg + 26 kg (per ha per week)
- Fresh pig manure - 5,000 kg (per ha per week)
- Cow/buffalo manure - 6000 kg (per ha per week)

Supplementary feed (for example, a commercial pellet feed or a grower mash with around 30% crude protein content) should be given in the morning and afternoon at a daily ration equal to 3–5% of total fish body weight until they reach breeding size. Fish feeding and pond fertilization are discussed in Chapter 8.

Female breeders should be placed separately from male fish. Both males and females are conditioned for spawning for at least 10–12 days, feeding a lesser amount of supplementary feed (2–3% of body weight daily). The female fish should be examined, and only those in "ready to spawn" breeding condition should be introduced to male fish for spawning. There are five categories of breeding condition: ready to spawn (RS), swollen (S), not ready to spawn (NRS), had spawned (HS) and immature. A detailed description of how to recognize each category of breeding condition is provided in Table 5.1.

Table 5-1: Description of breeding-condition categories for female tilapia fish

Category	**Days to spawning**	**Description**	**Timing of fry collection (days)**
Ready to spawn (RS)	3 to 7	Pink to red and protruding genital papilla Fully opened genital pore Distended abdomen	10 – 14
Swollen (S)	5 to 10	Pink to yellow genital papilla Slightly opened genital pore Slightly distended abdomen	12 – 16
Not ready to spawn (NRS)	21 to 30	White to clear and flat	Further conditioning
Had spawned (HS)	15 to 30	Red genital papilla Shrunken or compressed Abdomen	Further conditioning
Immature	Unpredictable	Papilla very small No sign of maturity	Further rearing

Choose males of similar size to females. If males are significantly larger (30–40% of female size), clip the upper lip (see next section on mouth-clipping). The reason for (1) holding female fish separately from males, (2) conditioning them by proper feeding, and (3) choosing only those readiest to spawn for introduction to males, is to achieve synchronicity of spawning. "Synchronicity of spawning" means large numbers of fish spawning at about the same time. These three steps are the secret to producing large batches of similar sized fingerlings for grow-out.

5.4 **Mouth clipping of males**

Male tilapia can be aggressive in their mating behavior, and can pursue and nip at female fish. In a pond environment stocked at low density the female fish are able to escape this type of harassment, but in the confined space of hapa nets or tanks they become exhausted or suffer scale damage that forms sores, leading to their death. For hapa or tank hatchery methods, mouth-clipping of male fish with sharp scissors to remove the pre-maxilla bone of the upper lip (Fig 5.1) is one method to reduce their ability to inflict damage.

The wound can be disinfected (for example, with a 10% solution of Betadine) to avoid infection. The recommended method for reducing harassment of female fish is to mate female fish with similar-sized males, in particular avoiding use of males that are very much larger than the females.

Figure 5-1: Mouth clipping of male Nile Tilapia that are much larger than the female breeders to reduce their aggressive behavior (Source; Gift manual)

5.5 Broodstock collection and maintenance

For seed production, the broodstock will be collected from the regional research stations, who are maintaining outbred and improved stocks of Tilapia for brood stock development, fingerlings (20 – 30 g in weight) could be collected and stocked at the rate of 3-4 fish/m^2 in the small and medium type brood stock rearing earthen ponds ranging from 1000 – 1500 m^2 with the depth of 1.0 to 1.5 m. During all the phases of growing period of brood stocks, the fish should be fed with formulated or commercial feeds having at least 30% crude protein @ 3-10% body weight. During 1st and 2nd week of rearing the fish can be fed @ 10%, during 3rd and 4th week @ 5% and during 5th and 6^{th} week onwards @ 3% body weight. If formulated feeds are not available alternatively a mixture of 60% rice bran and 40% mustard oil cake can be given at 5 -10 % biomass 2 times a day. Feeding of brood fish during low temperature and rainy days should be avoided to minimize the loss of resources.

5.6 Estimating the number of required broodstock

Normally hatchery operators who want to establish large hatcheries and expand further, should start from 20,000 – 30,000 fry as a founder stock and keep them continuously in well-managed tanks or hapas in ponds. Total number of broodstock requirement can also be calculated based on the production target assuming an average 500 eggs can be collected from a female per month (this depends on the weight of the female. 250-300 g female can produce on average 1000 eggs), and eggs have about 30% overall survival until being ready to be sold. If a hatchery has a target of producing / supplying 1 million fry per month, the number of mature broodfish required would be:

No. of mature females required = 1,000,000/ (500 × 0.30) = 6,667 females

No. of mature males (1:1 sex ratio) = 6,667 males

Total number of mature broodfish = 6,667 Females + 6,667 Males = 13,333

Assuming 75% survival during nursing, 90% during second nursing, 90% during maturation and 95% during handling, the number of broodfish fry required would be:

No. of broodstock fry required = 13,333/ (0.75*0.9*0.90*0.95) = 23,102

The final number of brood stock fry to be obtained would be 25,000 considering the transport and handling losses.

5.7 **Common method of broodstock, fry rearing and maturation**

As broodstock fish are the key element of the hatchery, their quality and management are directly associated with quality and quantity of seed production, which ultimately determine the success or failure of the hatchery. Table 5.2 shows the normal procedures of broodstock rearing and maturation:

Table 5-2: Summary of stocking density and feeding throughout various life stages of Tilapia

Month	Stage	Stocking (no/m^2)	System	Feeds and feeding
0-2	1st nursing	1,000	Hapa	Maize meal & fish meal/soybean meal (3:1), 5 times daily, ad libitum
2-4	2nd nursing	200	Hapa	Maize meal & fish meal /soybean meal (3:1), 3 times daily, ad libitum
4-6	Maturation	1	Pond	Floating pellets (~30% CP*), twice daily, ad libitum

(Source: Bhujel, 20011) *Crude protein

5.8 **Breeding or spawning**

- Tilapia can be bred in ditches, rice fields, ponds, hapas/cages or tanks depending upon the available facilities and the scale of operation. Males and females are stocked in the same breeding unit. Stocking density varies with facilities. The recommended male to female ratio for breeding or spawning is 1:3.
- As tank system is very expensive to construct and in pond system there is greater chance of entering wild fish. Use of hapa-in-pond system is preferred as it makes handling of fish easier and helps maintain purity of broodstock. It is the best choice in terms of cost and flexibility. Instead of constructing many small ponds, it is a lot cheaper to have hapas in a large pond. Normally sizes of hapas used are 40 m^2 (8 m x 5 m), 60 m^2 (12 m x 5 m) up to 120 m^2 (24 m x 5 m). Hapas can be made using nets available in the country or can be obtained from abroad.

5.8.1 Tilapia seed production in ponds

(a) Pond selection and preparation

- One or two ponds having an area of 400 – 800 m^2 with inside slope about 1:3 and average water depth of 1.0-meter need to be selected for the purpose of natural spawning.
- All the predatory fish and animals are to be completely eradicated by dewatering and drying of ponds before stocking of fish. If this is not possible, then ponds need to be poisoned by using rotenone @ 10 – 12 kg/ha.

How drying helps the pond bottom?

- Remove the waste and mineralize the organic waste that accumulated during previous culture (if the pond being used before for fish culture).
- Removal of organic waste will prevent production of hydrogen sulphide.
- Kill most of the unwanted predators and competitors that entered into the pond during the previous culture.

- Ponds should be limed (600 kg of $Ca(OH)_2$ per hectare is recommended for old ponds and new ponds with a neutral pH).
- Seven days after liming, manuring and fertilization of each pond should be made respectively with cattle dung @ 800 – 1000 kg/ha and Urea plus T.S.P (25 + 25 kg/ha).

How liming the pond bottom helps to improve pond condition?

- To correct the soil pH.
- Lime helps to increase the alkalinity of pond water and thereby prevent unacceptable pH fluctuations in the pond. If pond water pH fluctuates more than 0.5 within a day, it will be harmful, particularly to fry and fingerling
- To neutralize the acid layer in pond bottom and dike surface, if by chance exposed the potential acid sulphate soil layers.
- Liming increases the availability of nutrients by assisting in the release of nutrients from the soils and thereby favoring the growth of natural food (plankton) in the pond
- Lime act as a disinfectant. The toxic and caustic action of liming can kill bacteria, fish parasites and their intermediate hosts.
- Liming improves soil conditions and promote the bacterial breakdown of waste materials.

(b) Stocking of brood fish

- Sexually matured breeders weighing 80 to 100 g each should be stocked @ 2-3 fish/m^2 with a sex ratio of 1 male to 3 females.

(c) Feeding

- Supplementary feeds with a mixture of 60% rice bran and 40% mustard oil cake or 75% rice barn or 25% fish meal can be given at 3-5% biomass 2 times a day.

(d) Collection of early fry

- Three to four weeks after stocking of brood stock, when early fry are found schooling near the shore of spawning ponds, the available fry should be collected regularly in the early morning with a fine-mesh seine net and transferred to holding hapas set in the ponds prior to stocking in the nursery ponds

5.8.2 **Tilapia seed production in hapas**

A commercial mixed sex seed production system in fine meshed hapas (net cages) can be operated easily for large-scale production of tilapia seed for aquaculture where monosex tilapia culture is not preferred. The marginal or small-scale farmers with one or two earthen ponds having an area of 1500 – 2000 m^2 each can follow a simple and efficient method.

(a) Setting of breeding hapas

- A series of breeding hapas having the size of 2 m x 1 m to 12 m x 3 m with depths of 1.5 m can be set in the pond(s) by fixing them to bamboo poles by nylon thread. At least 0.25 m of top side of the hapas should above the waterline. The hapas can be covered with fine meshed nets or kept uncovered.

(b) Stocking of broodfish

- Sexually matured breeders weighing 80 to 100 g each should be stocked @ 2-3 fish/m^2 with a sex ratio of 1 male to 3 females.
- The breeders need to be fed with supplementary feed consisting of 60% rice bran and 40% mustard oil cake or 75% rice barn or 25% fish meal. The feeds can be given at 3-5% biomass 2 times a day.
- About 10 – 15 days after stocking of breeders, schooling of tiny fry will be visible in each hapa.

5.8.3 **Traditional method of fry collection**

- Tilapias show a high degree of parental care to their eggs and fry. Females of the mouth brooding tilapia incubate eggs in their mouths until the young can swim independently (swim-ups). These free swimming fry can be collected from the edges of the pond, hapa or tanks at an interval of 7-21 days using long scoop nets.
- This system is cheap and easy, but net fry production per unit area of space is very low because it is not possible to collect all the fry from the system. Therefore, it is often called the "partial harvesting method". Survival is also low due to predation and adverse environmental conditions. Furthermore, fry vary in size and age; therefore, if sex-reversal technique is to follow, partial harvesting does not yield good results.
- If harvesting is done more frequently e.g. 2 times a day (morning and evening), a more uniform age and size of the fry could be obtained.
- Grading of fry is therefore important in partial harvesting which can be done using various sizes of mesh.
- Fry harvested from ponds / tanks may result in a poor quality during sex-reversal because fry are of different age, although they seem to be similar in size, which respond differently to the hormone feed.

5.8.4 **Improved method: Egg robbing and artificial incubation**

- For a larger scale hatchery, fertilized eggs or yolk-sac larvae should be collected from the mouths of brooding females once every 5-7 days.
- The fish should be gathered to a corner of the breeding hapa. Then two hand nets (large mesh and small) can be used in conjunction for scooping up the broodfish. Eggs can be dislodged by putting a fore finger in the mouth of brooding females and shaking to release eggs or yolk-sac fry which are collected in the small mesh net. They are then transferred for artificial incubation in various types of plastic bowls with sufficient water to remain submerged.
- During harvesting, eggs or yolk-sac larvae are separated by stage (these are arbitrary stages based on the developmental extent which is observed, Stage I – just fertilized with no spots, Stage II – with eye spots, Stage III – darker in color and with small tail and protruding eyes, Stage IV – with longer tail and head, Stage V – swim up fry).
- They are transferred to the hatchery and washed with clean tap water, passed through a fine net, weighed, and then placed into down-welling or upwelling incubators (Fig 5.2, Plate 5.3)

- Water flow rate is adjusted in such a way that all the eggs are gently churned /agitated.
- Stage IV and V fry can be directly transferred to the tray system for larval rearing.

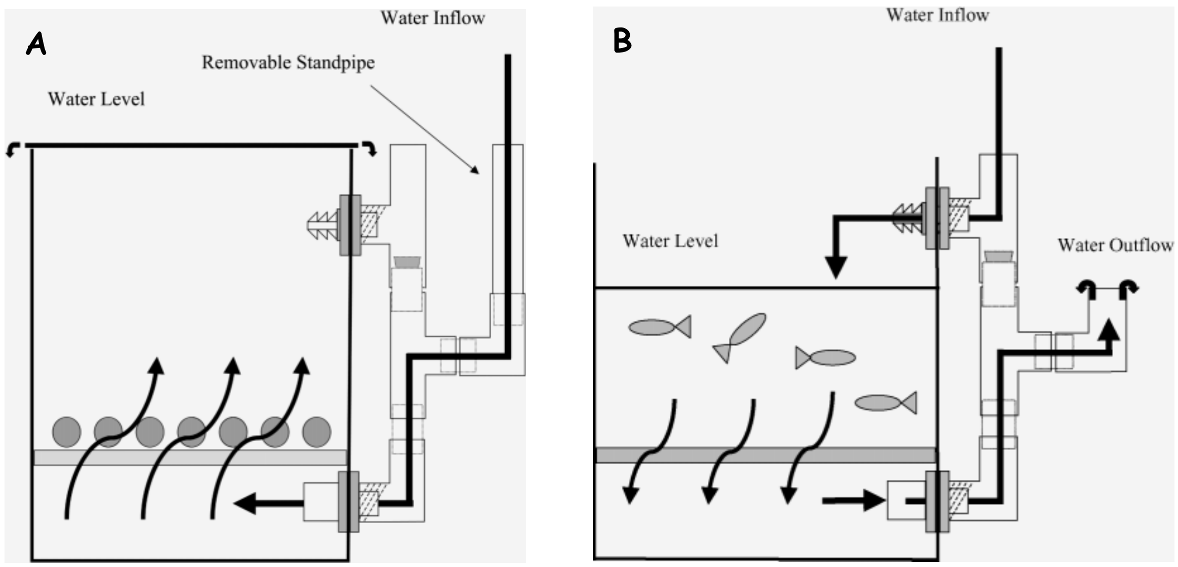


Figure 5-2: Schematic of the isolation incubator functioning as an upwelling (a) and downwelling (b) incubation units (adapted from Heindel et al., 2005)

5.9 Sex Reversal Technique for the Production of Monosex Fish Fry

Sex reversal is a technique of changing of sexes from one sex to another in fish by administering synthetic steroid hormones before and/or during the period of sexual differentiation. In this technique, the first feeding fry are treated with male hormones or androgens (ie. 17α-methyl testosterone), which develops testes and male sexual characteristics at maturity and on the other hand, treatment with female hormones or oestrogens (17β- oestradiol) produces individuals with ovaries and female characteristics in fish.

5.9.1 Advantages of all male seed production through sex-reversal

- Technique is simple and economic.
- It does not need sophisticated laboratory and equipment.
- A technician or an experienced farmer can run monosex seed production hatchery and nursery systems.
- Overall input costs are not very high.
- Reliability of 98 – 100% male seed production
- Ensures high production and high net profit.

5.9.2 **Sex-reversal and early nursing**

- Early nursing of fry can be carried out in hapas, ponds, canals, tanks etc.
- Early nursing is usually done for about a month. If the fry are sex-reversed, this period can be divided into two phases; 21-day hormone treatment phase followed by 10-30 day nursing. Feeding young fry with a male hormone (17α-methyltestosterone) produces phenotypically all-male fry (not genetically). It stops breeding in grow-out systems and male fish grow about 20% faster than females.
- For sex-reversal, 60 mg 17α-methyl-testosterone (MT) is mixed with 1 kg of fish meal (or high protein fry booster mass containing 50% crude protein) together with 10-20 g of vitamin C. As the hormone is insoluble in water, ethyl-alcohol is used to dissolve it. Normally a stock solution of 5 g of hormone in 10-L ethyl-alcohol is prepared and stored in a refrigerator. The stock solution can be stored for 6 months.
- Feed is mixed by adding 120 ml of stock solution and another 120 ml of fresh alcohol per kg of feed using a mixer. The alcohol is then evaporated by spreading the mixed feed under shade for about an hour. Feed should not be dried under intense sunlight because the hormone will degenerate. After drying, the feed should be packed in a plastic bag or kept in a container with a tight lid and stored in a room at a low temperature (approx. 10°C).
- Fry stocked at a density of 5,600 m^2 in a hapa are fed with the MT mixed feed at 14, 30, 50 and 84 g per day for the days 1-5, 6-10, 11-15 and 16-21, respectively. Feed is divided into equal portions and the fry are fed 5 times a day.
- Size of the hapas during the 21 days of hormone treatment for sex-reversal depends on the scale of production. The smallest hapa can be 5 m^2, medium 10 m^2 and largest 20 m^2
- If the fry are not going to be sex-reversed, then they can be fed on a mixture of untreated rice bran and fish meal (2:1) in the same routine.
- Grading of fry is very important after the initial development stages to minimize mortality caused by cannibalism and social dominance, as tilapia fry are aggressive in nature. The first grading is done one month after hatching, followed by second grading event a week later (or a day before sale). Fry are grouped into 3-4 categories such as small, medium, big and very big, depending upon the size.

Grading mechanism for fish fry

Grading fry by size is achieved by sieving fish through netting, plastic mesh or parallel bars. Several sizes of graders will be necessary depending on the size of fish that will be graded.

Table 5-3: Grading mechanism for fry (Source: FAO 2006)

Opening size between vertical bars (mm)	Weight of escaping fish	
	Range (g)	Mean (g)
9	1.8 – 2.8	2.0
12	6.6- 8.8	7.1
15	13 - 15	14.3
19	22- 32	29.8
26-28	Above 100	

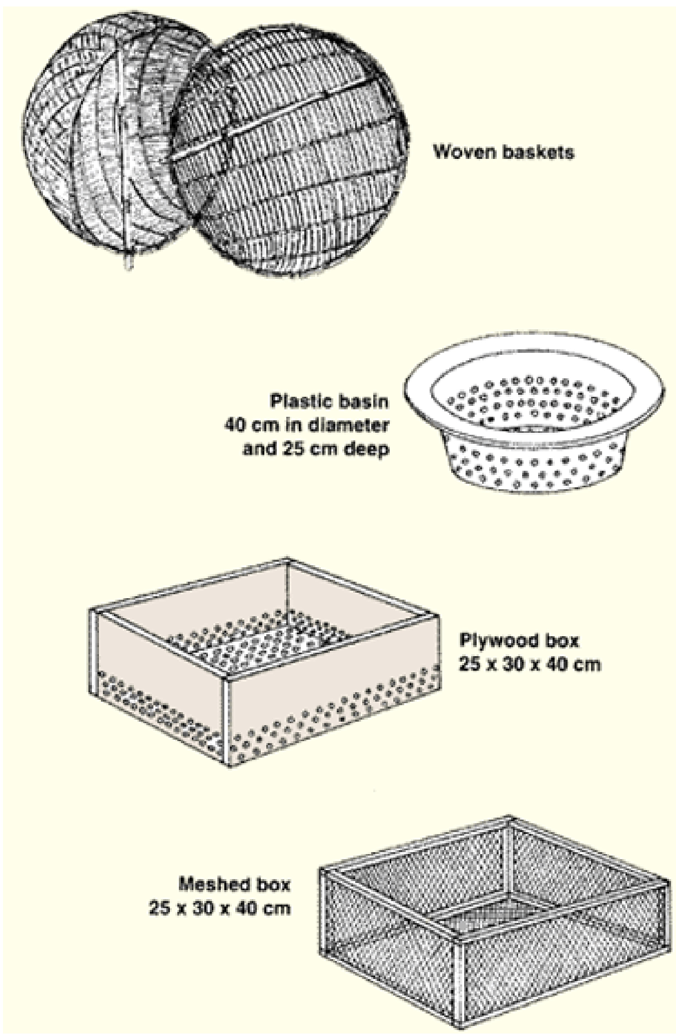


Figure 5-3: Equipment used for grading fish fry (Source: FAO 2006)

- During nursing (10-30 days), fry should be kept at a density of 1,000 – 2,000 fry m^2 in the hapa. The size of the hapa can be 20 - 120 m^2 depending upon the scale of production.
- Fry are then fed on a mixture of maize / rice bran and fish meal (2:1) 4-5 times a day at about 25-50 g m^2 per day.

5.10 **Nursing of fry to fingerlings**

Fry smaller than 1 inch are susceptible to predation by carnivorous fish and birds. Smaller fish are also less tolerant to poor water quality, which is a common feature of ponds with organic manures. Factors such as these increase mortality rates, particularly in the first month of growth. Therefore, if they are nursed for at least a month before stocking them into the grow-out ponds, their survival can be increased considerably. Following are the steps for normal fry nursing method:

- Small individual ponds, or hapas in a pond, reservoir or lake, are ideal for nursing (Plate 5.2). The system should be well protected from birds and other predatory fish or animals.
- Smaller ponds (50-500 m^2) should be well prepared, and should be drained and dried completely at least for a week. Ponds should be limed at a rate of 500-600 kg per ha and filled with predator free water.
- A week before fry stocking, ponds should be fertilized with urea and TSP to develop a green color. Afterwards uneaten feed and their excreta will maintain the green color. Overly green water is also undesirable during nursing. Therefore, organic manures are not recommended.
- Stocking density depends on fry/fingerling stage (weight). Some guidelines based on successful farms: per m^2 ; 0.2 g – 750; 0.5 g – 450; 1 g – 255; 2g – 145; 5g – 63; 10g – 35; 20g – 20; 50g - 10
- Fry are fed with floating pellets or with a mixture of rice bran and fish meal (2:1), 2-4 times a day at about 5-10% of biomass or to satiation.
- Nursing period is normally about one month. During this period fry attain at least 1 g size which is a suitable size to stock into the grow-out pond.
- It is necessary to manage the timing of fry purchase with the period of nursing, fry harvest, preparation of the grow-out pond and fry stocking. It is recommended that new fry should be obtained one to two weeks prior to the harvest of the grow-out pond. After harvesting it takes at least two weeks to prepare (draining, drying, liming, filling and fertilizing) a pond, during which fry can be nursed in other smaller ponds or hapas.

A summary of fry and fingerling rearing methods is given below (Fig 5.4 and 5.6). First box illustrates larve to fry and to fingerling rearing system in same pond/s. Second box illustrates a separate ponds/hapas for nursery phase.

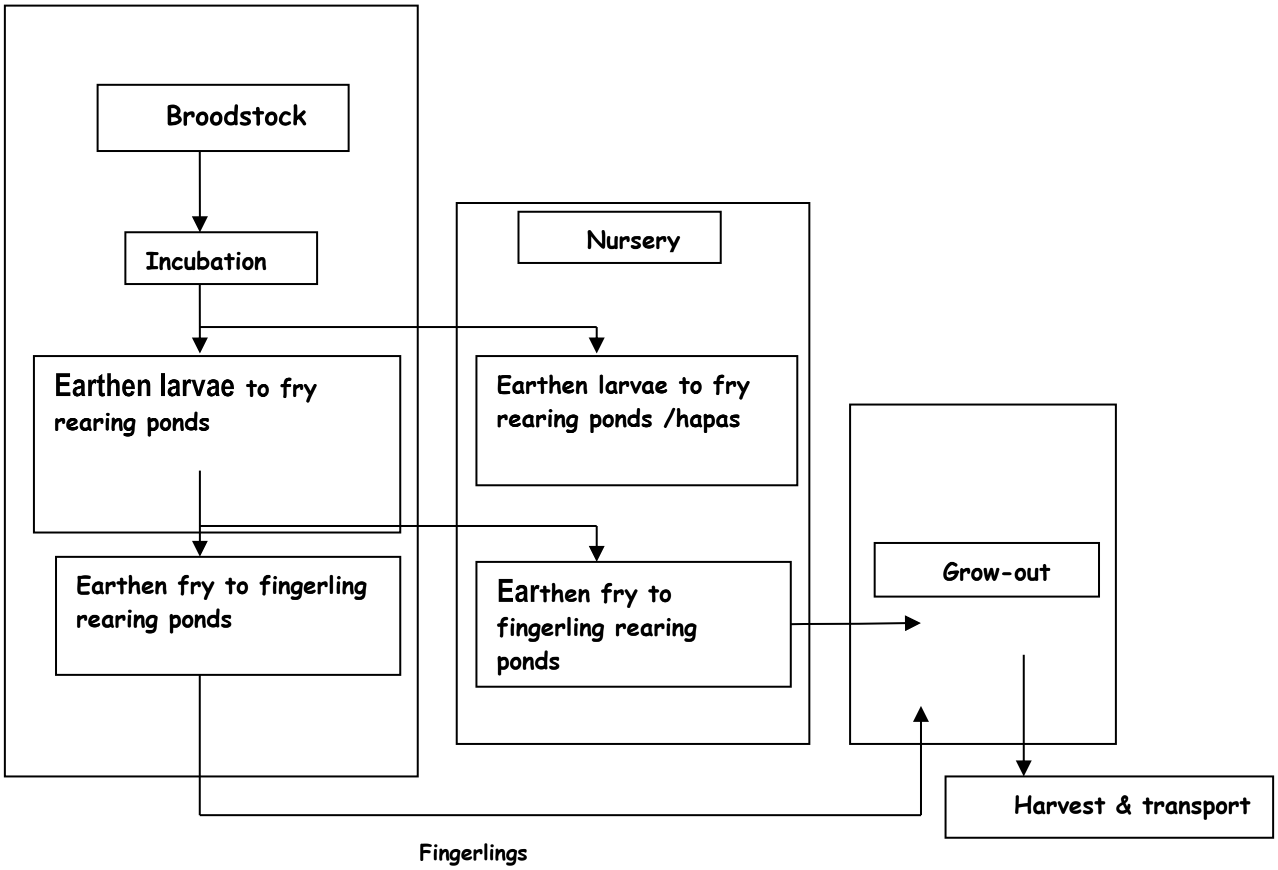


Figure 5-4: Rearing methods for fry and fingerlings

5.10.1 **Advanced nursing**

The level of seed demand is unpredictable for different seasons. It also differs year to year for the same season. Tilapia culture is mostly dependent on rainfall, which is the main source of water to fill the ponds. It is common to have large numbers of unsold fry during the dry season. Similarly, fry can also be kept at high densities during the cold season, and sold early in the next warm season at higher prices.

Why advanced nursing?

- to hold fry during low fry demand
- to keep stock of fry for the high demand season
- to minimize feed and feeding cost

- to grow fry to a bigger size, this means more protection from predators
- to have high potential growth (compensatory growth)
- to fetch higher prices from bigger fry

Methods:

a) **Stunting** – Intentional storing of fish at high densities with minimum feeding to keep fish alive is stunting. This can be done at any time of the year.

- Hapas or cages in ponds are used for stunting.
- About 2,000 fry m^2 can be stocked in the hapa or cage and fed with a mixture of fish meal and rice bran (1:2).
- Feeding rate is maintained at 3, 2, and 1% biomass day-1 for the first, second and third month, respectively.

Figure 5-5: A female red tilapia incubating eggs in her buccal cavity (Source: Meyer & Meyer, 2007)

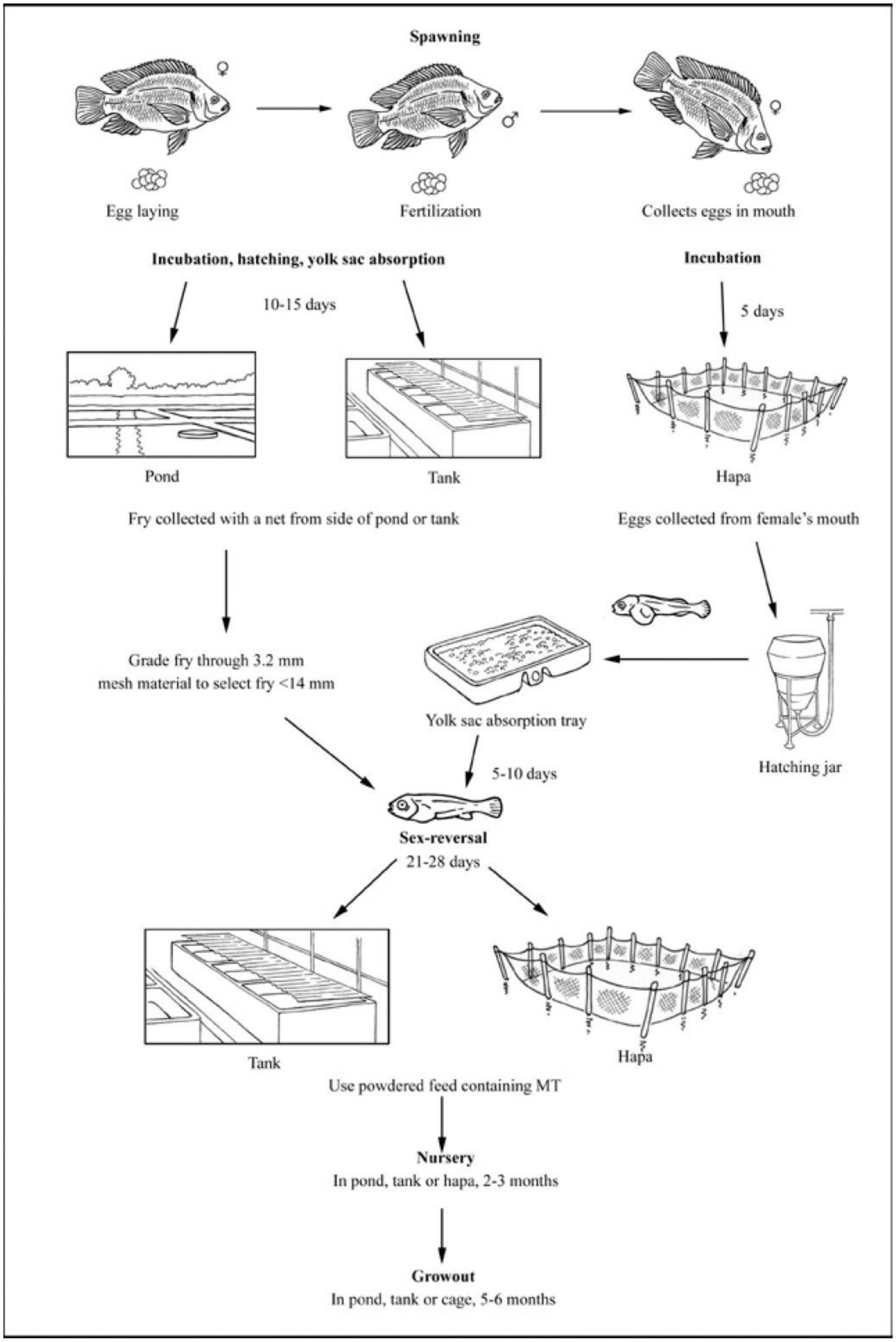


Figure 5-6: Production cycle of *Oreochromis niloticus* (Source: www.fao.org)

Plate 5-2:Plastic vowels placed in a bamboo frame for separating the collected fertilized eggs having different colours (based on different age groups).

Plate 5-1: Hapas for rearing fry and fingerlings

(a) eggs placed in down welling plastic jug for incubation until hatching; (b) yolk-sac fry placed in plastic trays for larval rearing until becoming swim-up or yolk-sac absorption (Bhujel, 2011)

Plate 5-3: A series of round bottom plastic jars and flat trays for incubating the fertilized eggs/hatched fry with yolk sac.

Chapter 6

FISH HANDLING AND TRANSPORTATION

The way and manner live fish are transported is a very important aspect of fish culture. In most cases, fry and fingerlings must be transported from hatchery to pond for stocking. Brood fish are sometimes transported into the hatchery to spawn. Spawning is the act of depositing eggs and producing young fish. It may even be necessary to transport live harvested fish to the market for sale. A fish farmer must be very familiar with the principles, techniques and practices of fish transportation so as to minimize fish death resulting from transportation. The ultimate aim of transportation is to provide healthy live fish at the destination.

6.1 Considerations in fish transport

Fish transport must be done carefully in order to successfully take them to their destination. A poorly organized effort may easily result in death of fish. The following factors directly influence fish transport:

6.1.1 Tolerance to transport

Tolerance of fish to transport is related to their ability to resist or adapt to stressful conditions. Their resistance also changes as they pass through various life stages. Larvae (newly hatched fish which are still too young to feed on feeds supplements) are very delicate, just as brood fish which are ready to lay eggs.

6.1.2 Presence of food in the intestine

Fish survive transport better if they have no food in their intestines. For this reason they could be starved for 1 or 2 full days prior to the time they will be transported. Brood stock are often conditioned for transport to spawning facilities by crowding them up in a seine net and releasing them. This procedure can be done for 2 consecutive days before moving them from their pond to hatchery for spawning. The fish stop eating and this helps them adapt to the stress of artificial spawning. Fish can also be harvested and held in net enclosures or tanks for 24 to 48 hours with clean, preferably gently running water. The fish pass food out of their intestines and will be in good condition for transport. If fish have disease or parasites they can also be treated easily in tanks prior to transport

6.1.3 **Age and size of fish**

A lower weight of small fish can be transported per unit volume of water than large fish. Fish can be broadly classified into four main groups according to what life cycle stage they are in.

- Newly hatched fish are called larvae or sac fry. *Oreochromis niloticus* larvae depend on yolk for 6-12 days after hatching up to first feeding fry
- Post larvae do not have a yoke sac and are commonly called fry. Fry weigh less than 1g.
- A 3 to 4 weeks old fish weighing more than 1g may be called a fingerling juveniles (5-8 weeks) may weigh 3 -5g.
- Sexually matured fish are often called brood stock.

Table 6-1: Guide on fish age group/size and transport rule

Quantities of different fish that can be transported in sealed plastic bags (18 inch ×32 inch) with about 7.6 liters of water and pure oxygen				
Fish size	**Duration of transport (Hours)**			
	1	**12**	**24**	**48**
Newly hatched larvae (grams/L)	120	80	40	10
1/4 inch (0.64 cm) Fry (grams/L)	60	50	40	20
1 inch (2.54 cm) Fingerlings (grams/L)	120	100	75	40
2 inch (5.08 cm) Fingerlings (grams/L)	120	105	90	40
3 inch (7.62 cm) Fingerlings (grams/L)	120	105	90	40
Larger Fish (grams/L)	480	180	120	60

Source; Bolorunduro, 2001

Table 6.1 provides a **A rule - of – thumb** guide to determine how many fish of a given age group may be transported. These figures are based on transporting fish in sealed plastic bags containing oxygen and about 8 liters of clean water at approximately 18^{o}C. These numbers are only a rough guide and may not work under all conditions for all kinds of fish. Tanks or containers must be used to transport fish if plastics bags are not available. Quantities of different sized fish that can be transported in sealed plastic bags (18 inch x 32 inch) with approximately 17.6 liters of water and pure oxygen are shown below. Table 6.2 gives recommendations for transporting different sized fish in tanks with diffused oxygen at approximately 18ºC.

Table 6-2: The weight of fish in grams per liter of water transported in tanks with diffused oxygen (Source: Bolorunduro, 2001)

Fish size (g/l)	**Duration of transport (Hours)**			
	1	**6**	**12**	**24**
Larvae and Fry	NR	NR	NR	NR
1 inch Fingerling	120	60	30	30
2 inch Fingerling	240	180	120	120
3 inch Fingerling	360	240	120	120
8 inch Fingerling	360	360	240	180
Larger Fish	480	480	360	240

NR = Not Recommended

6.2 **Transportation by open system**

The open system consists of water filled containers in which the basic requirements for survival are supplied continuously from outside sources. The simplest of these are small tanks, plastic containers, cans, buckets, bowls, boxes, calabashes, clay pots, trucks, vans, etc. (Fig 6.1). The procedure is as follows;

- Almost fill containers with clean water and transfer fish at rate not more than the following. (for open transportation less than 5 hours distance)
  Tilapia fingerlings - 200-230 fish/ 50 liter container of water
  Adult Tilapia - 100-150 fish/ 50 liter container of water
- Cover water top with leaves to shade fish from sunlight and heat and to reduce splashing or net to prevent jumping out.
- Agitate water at intervals to help the supply of oxygen.
- As much as possible be fast and avoid delay in transit.
- Allow fish to swim out freely from the container during stocking.

Open transportation method is suitable for movement of fish within the farm, for short distances and for periods not longer than 2 hour except for catfishes which can endure 5 hours. For longer distances, air or oxygen should be supplied constantly or intermittently. Transportation tanks, vans or trucks with facilities for air/oxygen supply can be used. Ice block can be used to lower the temperature for longer hours of journey. The advantage of this method is that it is simple, economical and requires no special skill for adoption. It is however risky. Fingerlings can die through water splashing in the container. Open method is also limited by time and distance.

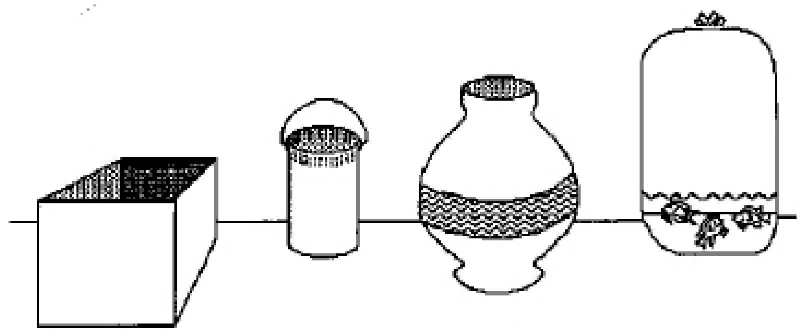


Figure 6-1: Various containers are used to transport fish

6.3 **Transportation by closed system**

The closed system makes use of sealed containers in which all the basic requirements for fish survival are self-contained. It is by far the most ideal method for live fish transport. The suitable container is oxygenated polyethylene (plastic) bags or tanks. They are best used for long distance transportation of fingerlings of Tilapia, Carp and other weak species of fish. Plastic bags should not be used to transport brooder/adult fish or post fingerling with sharp spines, as this will result in bursting of the container. It is essential to maintain adequate oxygen in the water while transporting fish using this method. The technique recommended for oxygenating water during fish transport is the use of pure bottled oxygen. It may be bubbled continuously into an unsealed container during transport, or injected into a plastic bag containing water and fish which is then sealed air-tight for transport.

When plastic bags are used, oxygen is added after water and fish. One-fourth of the bag usually contains water and fish and three fourths contains oxygen. After adding oxygen the bag is sealed shut with a twisted rubber band, string or other material. As a precaution against leakage, the first plastic bag should be placed inside a second bag whenever possible. The sealed double bag of fish is then placed in a box or other container for added protection and loaded onto a vehicle for transport. If properly packaged and insulated from heat, these containers can transport fish for 24 to 48 hours without water exchange. Oxygenated Bags should be placed horizontally while transportation to allow greater water surface area to dissolve oxygen in water. Vertically placed oxygenated bags are not recommended.

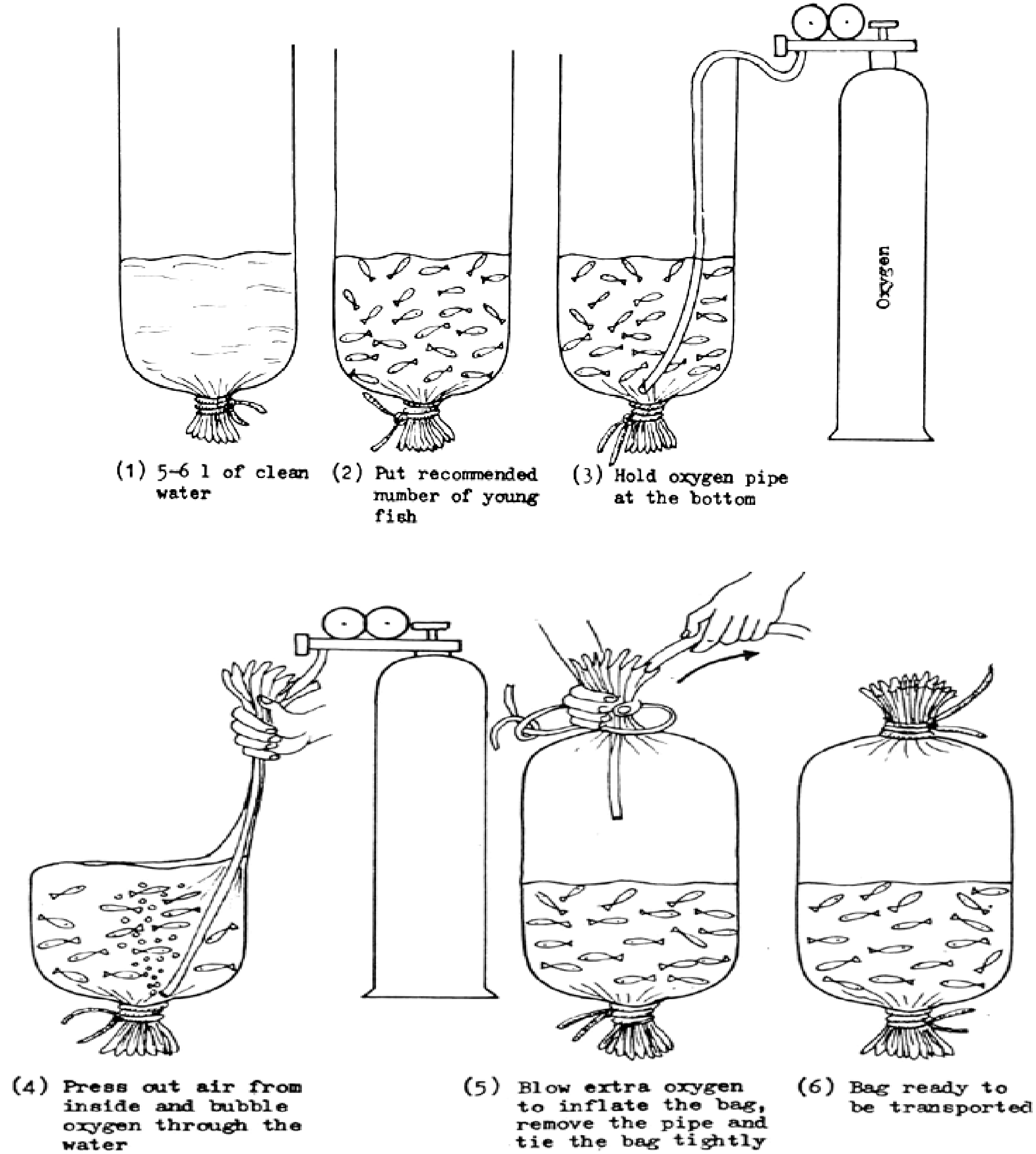


Figure 6-2: Procedure of filling the bag with water, stocking with the fish, displacing the air, introducing oxygen and closing the upper end (Woynarowich and Horváth, 1980)

6.4 **Changing water during transport**

During hot weather or long trips, fish may rise to the surface and start gasping for air. This means oxygen in the water has been depleted and water should be changed.

The following precautions should be exercised when adding water to a container of fish or when transferring fish into fresh receiving water. The new water should be clean, not muddy and should be free of chemical pollutants. Water from clean, clear-running springs or streams is best. Poorly aerated water from wells, or reservoirs should be avoided because of low dissolved.

New water should be the same temperature as the original water. To change water, empty half of the old water from the transport container and then refill with new water of the same temperature. The farmers can know this by using a simple mercury thermometer or feeling the water directly. Plastic bags can be squeezed around the neck and filled to allow water but not fish to escape. Siphon tubes are used to remove dirt and fish waste from the bottom of the transport container. Do not add water quickly into the container as this may injure fish. It should be added carefully and after 10 minutes change all of the water. It is advisable that the temperature of new water should not differ from that of the transport water by more than 3 degrees centigrade. If it does, replace only one fourth of the old water initially and wait 10 minutes, then replace one fourth of the water again and wait 10 minutes before completely changing the water.

6.5 **Aerating Transport Water**

Aeration is the process for adding pure oxygen or air into water for the purpose of increasing the dissolved oxygen content. Transport water can be aerated by agitation or air can be pumped into it during emergencies when water exchange is impossible and fish are clearly under stress. Agitation is the process of increasing the amount of oxygen in water by stirring, pouring, shaking or some other mechanical means. Agitation can be done in several ways. A small quantity of the old water can be removed and poured repeatedly from a height of 30 - 50 cm through a screen, or porous cloth back into the transport container. A person can also stick his hand into the water submerged up to the knuckles with fingers spread, and briskly wave back and forth. Electrical devices are also used for agitation.

Pumping air into the transport water can be done continuously from the start of travel or as an emergency measure. The finest air bubbles possible should be pumped into the water. Oxygen diffuses faster through fine bubbles. Large bubbles forcefully pumped into the water may injure fish. Equipment which can be used includes bicycle tire pumps, battery operated aerators from aquarium shops, air filled inner tubes with air being squeezed through a regulated nozzle and any other locally built device.

Agitation can be done simultaneously with aeration. However, these are only temporary measures and will not keep the fish alive very long. They may be tried until the water can be exchanged. Do not bubble your breath through the water. It contains carbon dioxide, not oxygen. You will only hasten the death of your fish by doing this.

6.6 Temperature of transport water

Warm-water fish species (tropical fish) are suitably transported in water temperatures ranging from 18 to 28 ºC. The ideal temperature is 21 to 25 ºC. Warm water holds less oxygen than cold water. Respiratory requirements of fish are also greater at higher temperatures. Thus fewer fish can be transported per unit volume of warm water. The **golden rule** of fish transport is to always maintain sufficient oxygen in the transport water.

This can be done in the following ways:

- Keep transport containers cool. They should always be kept shaded and out of direct sunlight. As water warms, it holds less oxygen, so prevent rapid warming of the transport containers.
- Ice may be packed around containers on long trips (Fig 6.3). **Do not** add ice directly to the water containing the fish. Be careful to prevent water from dropping below 18ºC when using ice.
- A wet cloth may also be wrapped around containers to reduce temperature by evaporative cooling if ice is not available.

6.7 Acclimatize or condition fry/fingerlings before packing

Fry need to be prepared for transport before they are packed. The main problems during fish transportation are shortage of oxygen, high ammonia production from excreta, high temperatures (in hot seasons or areas), and the stress due to handling. In order to avoid these problems, the following steps are helpful:

- Fry harvest should be done at least 6 hours, or a night, before sale.
- Fry are harvested from the hapas/cages or ponds using scoop nets.
- Fry/fingerlings are graded and kept in separate hapas based on their size.

- After grading, fry are counted and transferred to containers / tanks filled with the water from conditioning tanks. They should be transported to the packing tanks as soon as possible.
- Fry are kept at high density in hapas in packing tanks supplied with clear water using sprinklers.
- It is essential to condition the fry/fingerlings by starving overnight so that they empty their stomach and intestines. This reduces the production of excreta in plastic bags / transporting containers. This avoids mortality during long transportation periods.

Selection of good quality fry for transportation

Selecting good quality fry for transportation is a must. Following are some visual and behavioral checks you can perform to select good quality fry and fingerlings for stocking

- Vigorous and actively swimming fry/fingerlings
- Uniform in size
- Normal body shape and no deformities
- Normal body color and soft to touch
- No signs of any patches, spots or lesions
- No scale damages or loss of scales
- Fins not damaged, no fin rots, intact and clean
- Gills deep red in color without any signs of hemorrhages, spots or cysts
- Quick response to external stimuli such as tapping and touching

Avoid fry and fingerlings for stocking if you see any of the following:

- Lethargic, abnormal swimming behavior
- Darker or abnormal body color, rough to touch, excessive mucus secretion
- Great variance in size and abnormal body shape or deformed body
- Appearance of discolored patches, spots, cysts, lesions
- Broken or damaged fin tips
- Loss of scales or scale damages
- Discolored gills from deep red, broken gills, appearance of hemorrhagic spots, cysts
- *No or week response to external stimuli*

6.8 Packing Un-Purged Fish

It is unwise to pack fish that have been caught from ponds or tanks where they have recently fed to satiation. This is because they have a gut full of food that will be expelled in the packing water, thus polluting it. Tilapia are especially difficult in this respect due to their long gut length and their continuous eating habits. Tilapia caught and packed directly after capture will quickly foul the water. Only short journeys for unpurged fish are possible without oxygen or in some way purging the fish prior to packing. One solution is to hold them in a portable plastic pool, at the pond-side in the shade, with clean water, for some hours after netting them to attempt to purge them of most of the gut contents. Use of one or more portable air-blowers can assist in keeping this holding water well oxygenated. If purging is not possible, the maximum packing density recommended tilapia is no more than 6-10 adult fish per 100-liter drum for travel that is not more than 4-6 hours. Aeration will be essential.

6.9 Stocking Procedures

- Temperatures of the transport water and water where the fish are to be stocked must be equalized before stocking the fish. This normally requires 15 to 30 minutes. A temperature difference of no greater than 3 degrees centigrade is tolerable.
- Plastic bags should be floated on the water surface for 15-30 minutes where the fish are to be released while the water exchange and acclimatization procedure is done.
- Fish are then allowed to swim out of the bags into their new surroundings
- Fish transported in containers which cannot be set into the new water may be transferred with a soft net, or dipped out with a scoop or bucket. **Do not** pour fish from any height into their new environment (Fig 6.5). They will be weak after transport and can easily be injured by rough handling at this stage. Allow them to swim slowly into the water

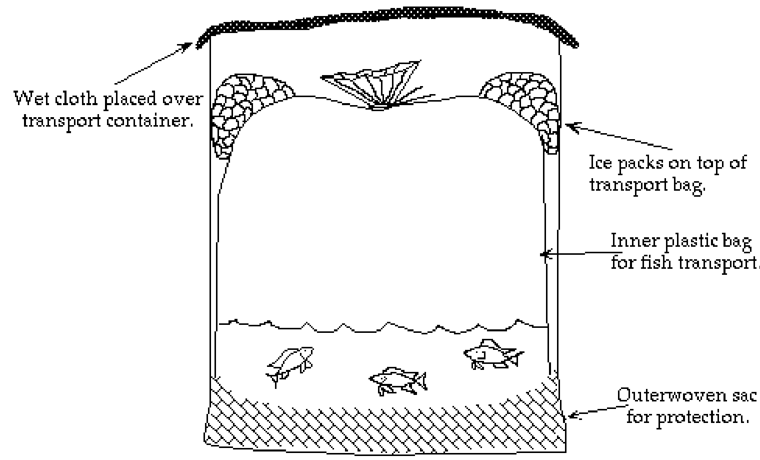


Figure 6-3: Fish transportation bags with ice for cooling

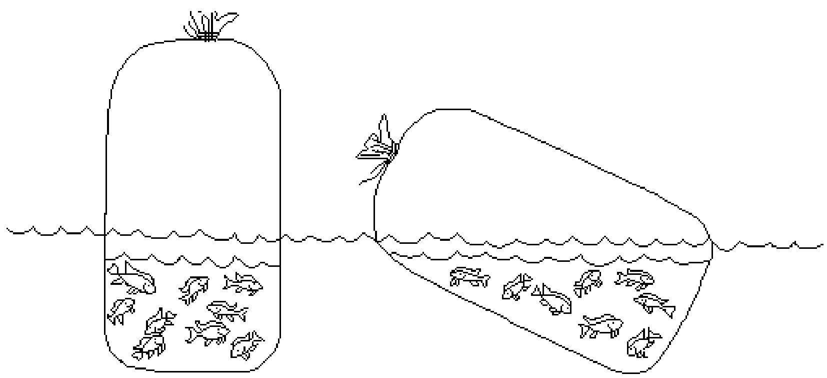


Figure 6-4: Floating the Bag of Fish before stocking

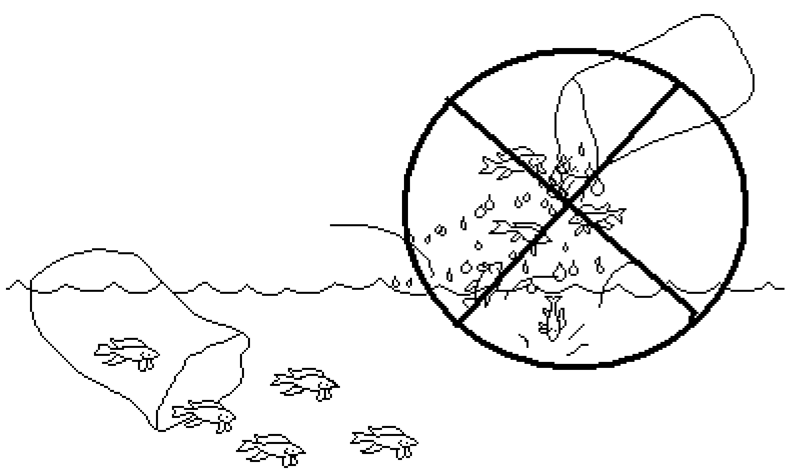


Figure 6-5: Releasing of fingerling during stocking

Chapter 7

TILAPIA GROW- OUT CULTURE

Tilapia culture ranges from small scale subsistence to a large scale commercial farming. Pond usage is the most popular culture system followed by cages. Tilapia is also grown in tanks and raceways but it is cost intensive and unsuitable for small scale farmers. The work involved in 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 (see Fig 7.1). To have a good yield of fish the farmer must know about the steps that need to be taken through each pond cycle and the interactions among them:

- Repair and maintenance (preparation of the pond)
- Application of lime and fertilizer
- Filling the pond
- Additional fertilization
- Stocking of fingerlings
- Feeding
- Daily maintenance
- Sampling (of fish to determine feeding rate)
- Harvesting
- Purging
- Marketing
- Record keeping

7.1 Pond preparation

There are four important steps in pond preparation:

7.1.1 Draining and drying

Ponds should be drained and dried for at least two weeks. Drying helps oxidize and breakdown chemicals and their residues in the mud, and eradicates all wild fish, remaining fish from the last harvest, insects and other predators from the pond. If complete draining and drying is not possible or very costly, it is recommended to use one of the commonly used piscicides e.g. rotenone, tea seed cake or Potassium cyanide on the remaining water in the pond.

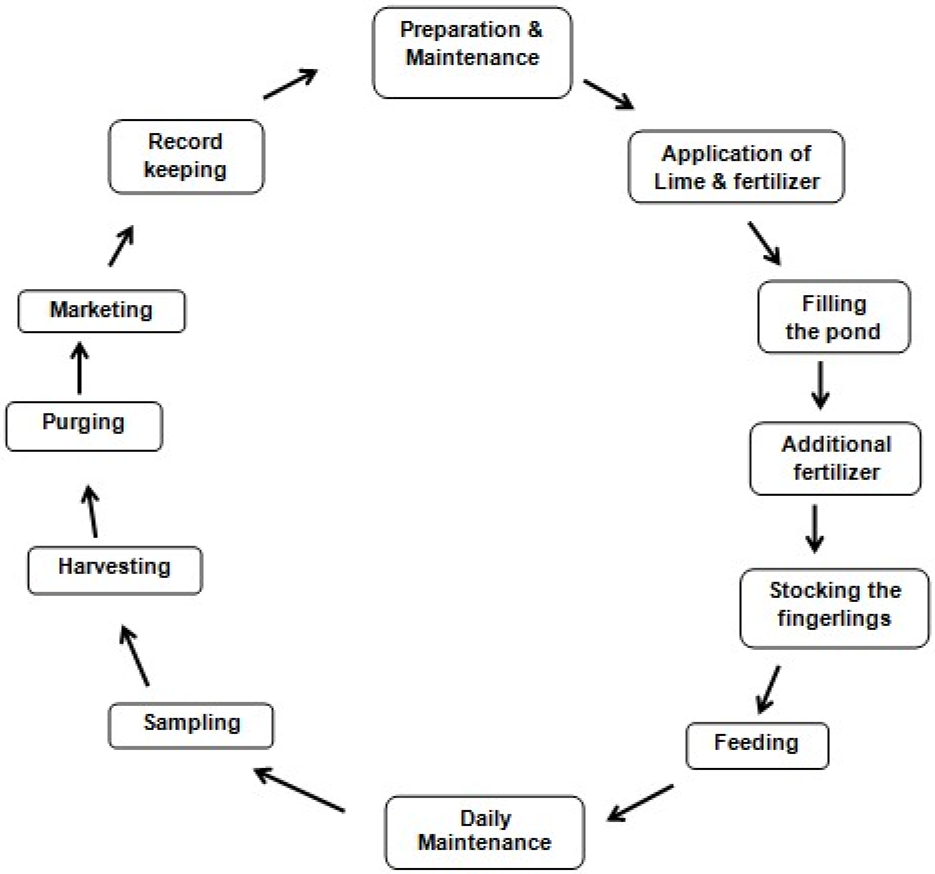


Figure 7-1: The pond cycle (modified from Nandlal and Pickering, 2004)

7.1.2 **Liming**

- Always choose agricultural limestone ($CaCO_3$) for application in your fishpond. If agricultural limestone is not available in your area, please consult your fisheries officer or extension agent about the possible use of other liming materials, e.g., quick lime or slaked lime.
- Apply the amount of agricultural limestone shown in Table 7.1, depending on either the total alkalinity of the pond water or the pH of the soil.
- If unsure of the alkalinity or soil pH of your pond, start by using the lowest recommended amount from this table, i.e., apply 1,000 kg of limestone per hectare of pond surface area until pH or alkalinity can be determined.

- Distribute the powder evenly around the pond bottom and on the slopes of the dykes. This can be done using a shovel. Always wear gloves when working with any kind of lime.
- If necessary, you can also apply lime by spreading it over the water surface after filling the pond.

Table 7-1: Types of lime to be used for disinfecting fish ponds (adopted from FAO, 2006)

Basic chemical	Common name	Toxicity for fish	Application rates	Preferred with
Calcium carbonate $CaCO_3$	• Limestone (90-95 % $CaCO_3$) • Dolomite • Basic slug etc	Low	2000 kg/ha	• Water pH above 4.5 • Fish are present
Calcium hydroxide $Ca(OH)_2$	• Hydrated lime, caustic lime, slaked lime	Medium	1400 kg/ha	• Water pH below 4.5 • No fish present • For pest control
Calcium Oxide CaO	• Quicklime, unslaked lime, or burned lime	High	1100 kg/ha	• Drained pond • For pest control

7.1.3 **Initial fertilizing and pond filling:**

Once no pests remain in the pond, and lime to counteract any acidity in pond soil has been applied, fertilizers can be broadcast over the pond bottom. Chicken manure can be broadcast over the pond bottom at the rate of 1000–2000kg/ha. Inorganic fertilizer can also be applied in combination with the chicken manure as discussed in chapter 8. The fertilizer encourages the growth of plankton that will provide natural food for the tilapia.

The pond can be filled to about 30–50cm depth initially, so that it can be easily warmed by the sun during the day, allowing good growth of plankton. Fertilizer can be submerged at the middle of the pond (fixed to a pole) or at the inlet water for slow release. Seechi disc readings can be used to determine the plankton blooming levels to control application of fertilizer (Appendix 1). The fertilizer rates may be increased or reduced depending on how well the plankton grows. The plankton should be maintained (by addition of more fertilizer) throughout the grow-out period. Types and amounts of fertilizer are discussed in more detail in Chapter 8.

7.2 Stocking fingerlings into grow-out ponds

- For all-male (monosex) culture of tilapia for the market, stock fish of 20-40 g size in properly prepared ponds at a density of 1-2 fish per m^2.
- If only mixed-sex tilapias are available to you, stock them as you would all-male fingerlings (stocking density depends on the size of fish you stock, One to two-inch size-2/m^2; 3-4-inch size-1/m^2), but stock catfish fingerlings along with them. For every 1000 tilapia fingerlings stocked you should stock 50-100 catfish fingerlings (5-10% by number). At the time of stocking, the tilapia fingerlings should be four times bigger than the catfish fingerlings so that they cannot be eaten by the catfish. Later the catfish will help control the tilapia population by consuming small tilapia that begin to appear when the tilapia you originally stocked reach spawning age (about 3 months).
- If you plan to rear tilapia fry to fingerling size, either for further stocking or for hand sexing, stock 1-3 g fish in properly prepared nursery ponds at 10 fish per m^2.

7.2.1 Best time to Stock Pond

The best time of day to stock the pond depends on the water quality (notably oxygen levels, temperature and pH) and not particularly on the hour of the day. It is recommended that the pond be stocked when the pond's water quality is at its best. The dissolved oxygen levels should preferably be not less than 5 mg/L (5 ppm), water temperature not less than 25 $^{\circ}C$, and pH levels between 7 and 7.5 at stocking. Stocking of small fish fry should be carried out under favourable conditions for them

- Avoid stocking under too cold or too hot conditions
- Avoid stocking soon after heavy rain
- Avoid cloudy days

The other consideration one must take into account is one's work schedule. When stocking the pond, one must have the time to be present to monitor the fish during and a couple of hours after the stocking process. Therefore, it is preferable to stock during the day, and not at night.

7.2.2 **Intervals between Stockings**

At times it may not be possible to get all the fish required to stock the pond at once. In the event that this happens, do not stock fish more than two weeks apart because by then there will literally be two entirely different populations. Fighting and subsequently stress and lower survival rates may ensue. Also, remember that the lot stocked first will be growing in the mean-time and it is important to have uniform sizes stocked into the pond.

7.2.3 **How to Stock**

Stocking should be done in a manner that minimizes stress to the fish. Stress results in mortalities and disease outbreaks. Therefore, do not pour the fish straight into the ponds. Acclimatize the fish first over 15 to 30 minutes and gently release the fish into pond (Fig 7.2). This helps them adapt to the differences in water quality between the transport container and the pond without shocking the fish. When fish are shocked by the sudden changes in water quality, they become stressed or die. Temperature, oxygen, mineral content and pH are the key parameters for which acclimation needs be done for fish fingerlings. Allow 15 minutes for every degree change in temperature and for every unit change in pH.

Figure 7-2: Plastic fish transportation bags should be floated in the pond long enough to equalize water temperatures prior to releasing the fish (source: Ngugi, 2007)

a) **Guidelines for stocking fish from bags**

The following are the recommended steps to follow when stocking fish into ponds from bags.

- DO NOT open any of the bags before they get to the pond. This is because once a bag is opened, all the oxygen in the bag will leave into the atmosphere. The **fish only have about 5 to 10 minutes before they run out of oxygen after a bag has been opened**.
- Set the bags right next to the pond (keep bags in basket or box to support the bag) or just in the pond. You are going to add water to the bag, so it may be too heavy to move after that. If you have the equipment, check the water quality parameters of the pond before opening the bags and the water quality within the bags as well as during the course of acclimation, especially for temperature and oxygen.
- Open one bag at a time. Begin with the bag that is least inflated. If you have no tools for checking water quality, use your fingers to detect for any obvious temperature differences between the pond water and water in the bag.
- Add water from the pond into the bag. While doing this, you can allow the other un-opened bags to float on the pond. This will allow the other bags to adjust to the pond temperature. Cover these bags to shade and prevent excessive sunlight.

NOTE: Floating the un-opened bags on ponds alone is insufficient to acclimate the fish properly. This is because bags used for packing fish for grow-out ponds are large and the bag often contains much more fish unlike those used to pack ornamental fish for stocking aquaria.

- Add small amounts of water from the pond into the bag over 10 to 20 minutes to allow the temperature and water quality (e.g., pH) of the transported water to slowly become similar to that of the pond water.

- The total amount of water added should be double or triple the amount already in the bag.

- Then lower the bag in the pond and tip it so that the fish can swim out on their own. Observe how they swim out.

NOTE: Pouring fish from a bag or throwing them into the pond can be stressful. It is best to let them swim out of a bag or out of a net by themselves. In some countries, lakes are indeed stocked by dropping the fish from airplanes, but survival is not reported.

b) **Guidelines for stocking from transport tanks/ containers**
Drive down as close as possible to the pond.

- Check the water quality in the pond and in the tank.
- With a bucket, remove about a third of the water in the tank. Then add pond water. Repeat this process 2 times giving time for the parameters to gradually re-adjust as mentioned above.
- Scoop out a few fish at a time into a bucket with adequate water using a scoop net.
- Gently lower bucket in water and let fish swim out on their own. Transportation of fingerlings is discussed in detail in the fish handling and transportation chapter.

7.3 Feed management

Tilapias vary in their feeding habit. Apart from phytoplankton, most tilapias eat zooplankton, detritus, aquatic plants, insects and even small fish fry. Commercial pellet, waste food and almost any other type of feed given, with perhaps the exception of meat, is also eagerly devoured. Very little investment is, therefore, required in their nutrition if they are cultured in green water ponds. Production costs will increase with increasing stocking density. Feed will only be required if stocking density exceeds 2 fish per m^2. If fish are stocked at higher densities, then the type of feed will be determined by fish price. If the price of tilapia is very low, then it will not be economic to feed large amounts of commercial floating pellets. Only cheap feed inputs will be cost effective in such a situation. Such feeds might include: waste food from restaurants, brewery wastes and schools, maize meal, rice bran and broken rice - if available very cheap bread or wafer and brushed up animal feed. The types of supplemental feeds being used by farmers are too numerous to mention. Feeding is discussed in Chapter 8.

7.4 Daily Management

Because tilapia tolerates low levels of dissolved oxygen, in semi-intensive culture they generally do not require large quantities of water to be flowed through the pond. However, water must be available to replace water lost through seepage and evaporation and also, when necessary to flush out any heavy phytoplankton "bloom". The management of pond water quality is important. Water temperature, dissolved oxygen, pH, salinity, and amount of plankton must all be managed using a secchi disk (Appendix 1) to provide the best possible environment for growth and general well-being of the fish. For semi-intensive operations, at least occasional checks should be made of water temperature, dissolved oxygen and acidity (pH), to ensure that values remain in the range known to be good for tilapia growth (see Table 2.1).

a) Fertilizer

The purpose of adding fertilizer to tilapia grow-out ponds is to encourage growth of natural food organisms (plankton) in the pond. More natural food means faster fish growth, and less supplementary feed will need to be added.
Fertilization provides phytoplankton with more nutrients, which leads to more phytoplankton growth. Zooplankton (animals, like tiny shrimps and water insects) will feed on phytoplankton, so will also flourish if fertilizer is added. Tilapia feed on both phytoplankton and zooplankton, as well as any supplementary feed added to the pond. The importance of pond fertilization is that it is a cheap way to provide food for the fish, for the following reasons fertilization is discussed in detail in a chapter 8).

b) Water quality monitoring

- It is essential to monitor the water quality parameters regularly to assess the pond environment.
- Maintenance of water quality in optimum levels is prerequisite for a good health for any cultured aquatic organism.
- Water quality indicates the status of health of fish, health of plankton bloom and condition of the pond bottom.

The condition of the ponds and the behavior of fish should be observed twice daily, morning and afternoon. Water color, water smell, and fish activities including surfacing behavior should be noted. If the fish gasp for air at the water surface in early morning (behavior called "piping") and continue to surface after sunrise, the DO content is too low and fresh water should be added into the pond. Fish that are surfacing to eat food will swim forwards, and this is a good sign. Fish surfacing to gulp air tend to move slowly backwards as they gulp, and this is a bad sign. Water turbidity or transparency can be measured by a Secchi disc (Appendix I).

c) **Sampling**

Sampling of the fish should be done once every 3 weeks (or at least once per month) to find out how much fish have grown, so that the amount of supplementary food can be increased to keep pace with their growth. To calculate the Daily Feed Ration (DFR), which is the amount of feed to be given to the fish in the pond each day, the total number of fish stocked into the pond at the beginning needs to be known and the Average Body Weight of the fish (ABW) needs to be estimated.
A variety of methods can be used to catch a sample of fish for weighing: for example, cast net, seine net etc. It is important to use a method that does not disturb the pond bottom excessively. It is better to sample in the cool of the morning or evening. The fish should be weighed as soon as they are caught, then released again. Measuring the weight of 30–50 fish from the pond should be adequate.

7.5 Fish harvest

When fish are removed from the pond and not returned, they have been harvested. Fish are normally harvested for the following reasons:

- Sale and/or consumption.
- transfer to other ponds
- mortalities are also regarded as "harvest", in the pond record because they are fish removed. They should be noted as mortality.
- as much as possible, harvest based on your marketing plan. The pond should finally be harvested before it gets to its carrying capacity.

7.5.1 How to Harvest Ponds

Ponds may be harvested with a seine net or by draining. Draining the pond marks the end of a production cycle because all the water from the pond will have been removed. When a pond is to be harvested completely, it is better to pass a seine two or three times before completely draining it in order to reduce the number of fish in the pond. This may be done on the same day or over a period of time. It is much easier to harvest a pond by seining rather than by draining and picking up the fish from the mud.

Once the number of fish caught in the successive seines drops to about a quarter of the estimated stock, the water level in the pond can be reduced to about half-way for the last seining. After this, drain the pond completely and gather the fish using scoop nets. During drainage ensure that the screen on the outlet (as well as inlet pipe) is properly fixed to prevent fish going out of the pond, unless you intend to use an exterior harvest basin. Make sure there is someone around to watch out for birds and other potential predators (including man).

Because seine nets for grow-out ponds are costly, one may have to hire a net for harvesting and sampling. Therefore, the number of times a pond has to be seined before it is completely harvested matters as it has a bearing on one's operational costs, and consequently returns. One should also endeavor to minimize the amount of labor required during sampling and harvesting. Therefore, it is better to use a seine with a bag (i.e. the recommended commercial pond seine) and have the ponds constructed as recommended. To save labor and time, each pond should be accessible by a vehicle especially if one plans to harvest 100 kg or more of fish at a time.

7.5.2 **Fish handling**

Fish handling is taking the fish out of water and carrying them about, for example when transferring them from one tank or pond to another, or for sales of live fish. It is important to be gentle with the fish and keep the amount of handling to a minimum, to avoid injury and stress that can lead to damage or death. If it is planned to sell fish alive, then handle them gently, avoid overcrowding them in containers, and do not pile them up in heaps in the net or container. Overcrowding will damage the fish (bruise the skin) and a lot of fish will die the following day. The following guidelines will help keep the fish in good condition.

- Handle the fish in the cool of morning or under shade, and use aeration and lots of flowing water.
- If fish are crowded in containers for a time, ensure water is clean, and has air bubbling or running water flowing through it.
- Fish in small containers should not be too overcrowded. A sign of overcrowding is when fish come to the surface to gulp air (piping). Either provide vigorous air bubbles through the water, or provide clean running water from a tap or hose, or reduce the number of fish per container.
- Scoop nets used for handling fish should be of soft material to avoid bruising of the fish. Seine nets should be fine-mesh, as coarse-mesh nets will trap the fish by their gills and cause injury.

- Handle fish gently: avoid dropping fish on the ground, or leaving them out of water.
- When holding or carrying adult fish, cover the eyes with one hand so that the fish will remain calmer.

7.6 Purging

It is most important that fish be allowed time to purge themselves in clean water before they are sold, since fish with an objectionable flavor such as a muddy, earthy smell and taste are not preferred by consumers. Selling fish with an off-flavor could lead to a drop in the market acceptance of fish for a long period. The cause of the off-flavor has been found to be actinomycetes or blue-green algae in the pond water. These organisms grow on mud that is high in organic matter. Off-flavor in tilapia can be controlled in two ways:

- Control of the algae in the pond
- Removal of the off-flavor from the fish by purging before marketing

One practical method is to stop feeding the fish a day before harvest and allow clean water to run through the pond. Next, the harvested fish can be held in a tank with clean running water and aeration for at least 12 hours before being sold. This gives the fish time to purge their gills and guts of any off-flavor and will “clean” them. Selling fish with good flavor will boost the reputation of tilapia as a product that people will want to buy and help maintain good prices for tilapia. The farm should have a small cement tank or plastic-lined tank (e.g. 3m x 3m x 1m) with clean running water for purging fish, and for holding live fish for sales from the farm itself.

7.7 Fish marketing

In areas where tilapia farms are established for promotion and market development, potential farmers will find it necessary to obtain contracts from market outlets that specify the amount and price of fish to be sold, before credit agencies will be willing to provide financing. Tilapia can be sold in several ways:

- As live fish in tanks: tanks and accessories are needed for sale in the marketplace
- Whole and fresh, sold soon after harvesting and sold by weighing
- Whole and fresh, sold soon after harvesting and sold by the bundle

- Whole and frozen (gutted before freezing)
- Whole and on ice
- Smoked
- Fried or cooked in the local custom

When fish are to be harvested for market, ensure that the market has been arranged first and is ready to take the fish. It is advisable, not to feed fish two days prior to harvesting for sale. If possible, get a sample of fish out yourself to check the flesh quality and/or taste. They should be kept completely off feed for at least two weeks to burn off extra fat depending on how fatty the fish are.

If you are to meet a large order, harvest the fish required the day before and keep the fish for the market in a cage within the pond. In this way, when the customer comes, all that needs to be done is load the fish. Being able to hold fish in this manner enables one make deliveries on time, especially the early morning ones. Small sales can also be made from the holding cage. Hence, the number of times the pond is seined for a farmer who sells small amounts at a time is minimized. Consequently, the less stress inflicted upon the fish that remain in the pond and survival rates improve. However, what makes life easy for the farmer also makes it easy for thieves. When in a holding cage for market, fish should not be fed. Fish can remain in a cage for a few days if the cage is well covered so they do not jump out. A customer who made an appointment for supply should not have to come to the pond and wait for you to seine the pond. Marketing and record keeping are discussed further in another (Chapter 10).

Chapter 8

FEEDING METHODS -Fertilization and Supplementary Diet Feeding

Although not essential, most farmers do use some feed for rearing tilapia. Fish grow slower and yield is lower when only fertilization is used ("green water"). The objective of feeding fish is to provide the nutritional requirements for good health, optimum growth, optimum yield and minimum waste within reasonable cost so as to optimize profits. Every farmer should be particular about the quality of feed fed to the fish because it is the feed that determines the:

- Nutrient loading (and ultimately carrying capacity) in the pond, hence water quality within the culture system
- Fish growth rate
- Economic viability of the enterprise. 60-70% of variable production costs in a normal production cycle is due to feed.
- Health status of the fish.

Table 8-1: Nutrient requirements of tilapia in intensive systems (Source: Dickson, 1989)

	Fish size				
Nutrient	**<0.5**	**0.5 – 10g**	**10 – 35g**	**35g plus**	**Broodstock**
Crude protein[1]	50%	35% - 40%	30 – 35%	25 – 30%	30%
Crude lipid[2]	10%	10%	6- 10%	6%	8%
Carbohydrate	25%	25%	25%	25%	25%
Fiber	8%	8%	8 – 10%	8 -10%	8 -10%

1. Crude Protein containing essential amino adds as follows (Expressed as %age of protein content) Arginine 28%, Histidine 1.1%, Isoleucine 2.0%, Leucine 3.4%, Lysine 3.8%, Methionine 1.0 %, Phenylalanine 2.5%, Threonine Z9%, Tyrosine 0.4%, Valine 22%.
2. Crude Lipid containing 1% n-3 and 1% n-6 essential fatty acids as %age of the diet.

8.1 Nutritional requirements of tilapia

The nutritional requirements of tilapia have not been fully determined, but seem similar to those of other warm water fish, although tilapia tends to utilize carbohydrates more efficiently, and fat less efficiently than catfish. The requirements are guidelines since experiments have been conducted on a range of species and ages under different conditions and often, using purified foodstuffs that would not be used in commercial culture (Table 8.1).

8.2 The different nutrients and their purposes

Like all other animals and humans, fish requires the following nutrients for the purposes indicated (see table 8.2).

Table 8-2: Nutrients required by fish and their purpose

Nutrient	Purpose
Protein	• Body building
Fats (lipids)	• Energy • Proper functioning of the body
Starch	• Source of energy
Minerals	• Body structure • Normal functioning of the body
Vitamins	• Protect the fish from diseases

8.3 Types of food used in fish culture

- **Natural food.** Living organisms are natural fish foods and are produced in the water where the fish live. Phytoplankton (microscopic plants), zooplankton (microscopic animals), insects and certain other plants are all examples of natural foods (Fig 8.1). Fertilization increases their abundance.

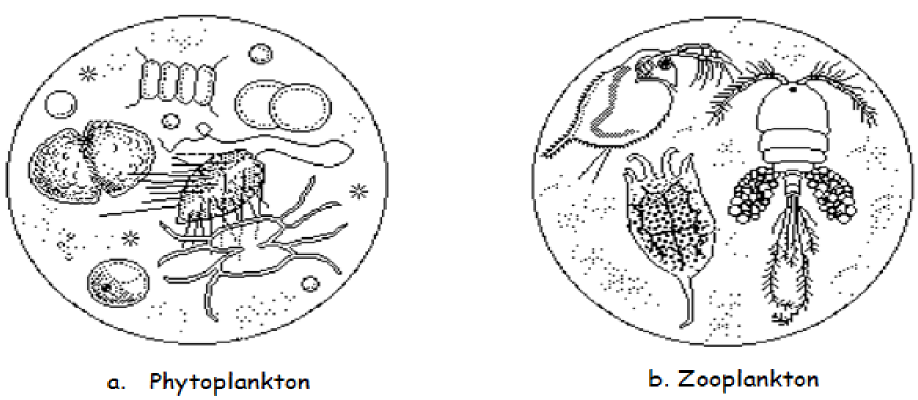


Figure 8-1: Phytoplankton and Zooplankton commonly eaten by Tilapia in ponds

- **Supplementary feeds.** When natural foods are not available in sufficient quantity to provide adequate nutrition for fish growth, feeds that are manufactured or grown outside of the fish pond may be fed at regular intervals (daily, weekly, etc.). These feeds supplement natural foods. They are not nutritionally complete, and will not adequately support fish growth in the absence of natural foods. Natural food organisms in the water will provide essential nutrients. Some examples of supplementary fish feeds are commercially produced rations for chickens and pigs, rice bran, manioc leaves, kitchen refuse, oil seed cakes, or other agricultural products and by-products.

- **Complete feeds.** In the absence of natural foods, nutritionally complete manufactured feeds that contain all essential nutrients and vitamins must be fed to fish. These feeds are used in high technology, intensive culture systems that are normally inappropriate for rural development applications and will not be discussed in detail.

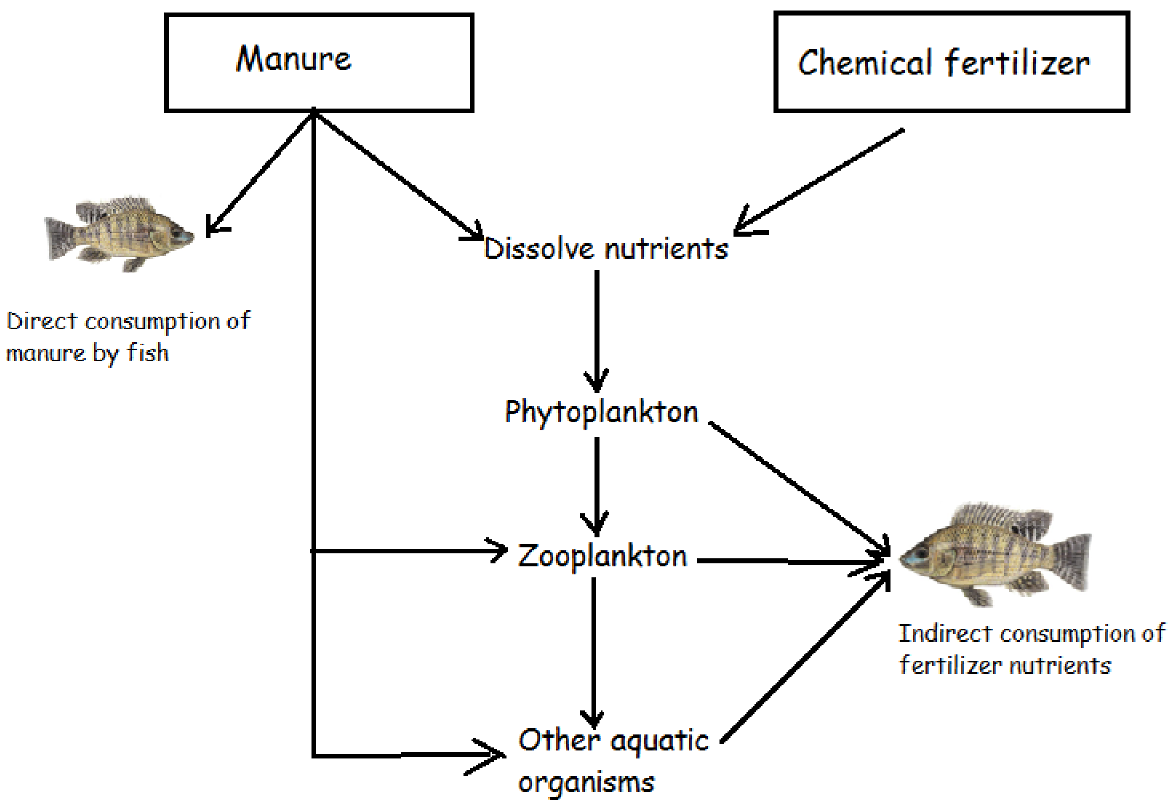


Figure 8-2: Manure and fertilizer as sources of fish food

8.4 Fertilization to stimulate natural food

Fertilizer helps in enriching water nutrients for plankton production on which fish feed (Fig 8.2). There should be regular application of fertilizer to keep the water color green. Bright green color indicates that the pond is fertile (rich in organic nutrients). Deep green color of ponds water indicates over fertility. A farmer should guide against excessive fertilizer/manure application. To avoid depletion of dissolved oxygen in pond water. The consequence of such is massive fish death. Two types of fertilizers can be used for pond fish culture. These are organic manures and inorganic or agricultural fertilizers. Application rates of these fertilizers are shown in Table 8.5.

8.4.1 Fertilizers

A large variety of animal manures is used as fertilizer in fish ponds. In general, the moisture, nitrogen (N) and phosphorus (P) contents of manures may vary considerably, depending on factors such as animal diet, purity and treatment of manures, and duration and conditions of storage. The moisture and nutrient contents listed in Table 8.3 are average values. The values may differ depending on the region and animal husbandry practices.

Why do you need to add fertilizers into the pond water?

- Fertilizers will release essential nutrients to the pond to grow natural food (plankton) in pond water. Plankton is natural food for many fish. Consist of very small or microscopic (cannot be seen by naked eye) animal (zooplanktons), microscopic plant (phytoplankton) and a bacterial component.
- Fertilizers provide nutrients to stimulate the growth of phytoplankton. Phytoplankton in turn serves as food for zooplanktons. Zooplanktons in turn are consumed by larval fish and fish fry. Therefore, application of fertilizers is essential to increase the pond productivity.
- The important two nutrients provided by fertilizers for plankton growth are nitrogen (N) and phosphorous (P).
- By increasing the phytoplankton in a pond, more food items are available for fish fry. This increases productivity, thereby increasing the amount of harvestable fish
- Plankton also shades the pond bottom, provides oxygen, reduces fluctuation in water temperature and reduces light levels in the pond.
- This dark condition prevents growth of harmful benthic algae on the pond bottom.
- Hence, maintenance of a healthy plankton bloom is beneficial for fish.
- Unfortunately, there is no single recipe of fertilizers for obtaining abundant natural foods every time in every pond or location.
- Soil and water characteristics influence the type and amount of fertilizer.

8.4.1.1 What are the fertilizers available to a farmer?

- Fertilizers are divided into two main types: inorganic and organic fertilizers.
- Usually it is better to use both inorganic and organic fertilizers because a combination of inorganic and organic fertilizers provides a broad food base to a variety of zooplanktons that are consumed by fish fry.

a) **Inorganic fertilizers**

- These are chemical fertilizers containing concentrated amount of at least one of the three major plant nutrients: nitrogen, phosphorous, and potassium.
- Some of the inorganic fertilizers available in the market are as follows:

Urea
Calcium nitrate
Sodium nitrate
Ammonium nitrate
Ammonium sulphate
Super phosphate
Triple (tri) super phosphate (TSP)
Diammonium phosphate
Calcium meta phosphate
Potassium nitrate
Potassium sulphate

Inorganic fertilizers provide three main nutrients, nitrogen (N), phosphorous (P) and potassium (K).

Table 8-3: Nutrient contents of some chemical fertilizers used in fish ponds

Chemical fertilizer	N%	P%
Urea	45	0
Ammonium Nitrate	35	0
Superphosphate	0	10
Triple Superphosphate	0	20
Diammonium phosphate	18	24

How do I select the amount of required inorganic fertilizers?

- The amount of inorganic fertilizers should be selected in order to provide 28kg of N /ha/week and 7kg of P /ha/week.

For example:

62 kg of urea and 35 kg of TSP will provide 28 kg of N and 7 kg of P, respectively

45kg of N is in 100 kg of urea (45% N)
1kg of N is in 100/45 = 2.2 kg of urea
Therefore, 28kg of N is in 2.2 x 28 = 61.6 kg (62kg)

20 kg of P is in 100 kg of TSP (20% P)
1kg of P is in 100/20 = 5 kg of TSP
Therefore, 7kg of P is in 5 x 7 = 35kg of TSP

Therefore, 62kg of urea and 35 kg of TSP will provide required nutrients of 28 kg of N and 7 kg of P, respectively for the pond

- If ammoniated fertilizers are used, do not add ammoniated fertilizers once the fish are stocked in the pond. Ammoniated fertilizers can be used during pond preparatory stages

b) **Organic fertilizers**

- Organic fertilizers are derived from animal manure, vegetable matters, plant waste and cuttings (green manure), animal and plant compost, plant meals, animal meals and other natural products.
- Organic fertilizers provide relatively low levels of nutrients to plankton growth when compared to inorganic fertilizers, but serve as a substrate for growth of bacteria and zooplanktons.
- The important contribution of organic fertilizers is that organic fertilizers are broken down by bacteria, which in turn are food for many types of zooplankton.

- Some organic fertilizers such as plant meals (rice bran and cottonseed meal) are consumed directly by some zooplankton.
- Compared to inorganic fertilizers organic fertilizers release nutrients slowly and therefore, lengthens the time that nutrients are available in the pond. This helps to prevent too rapid growth of plankton bloom which in turn cause a plankton crash (see below to know what is meant by a plankton crash).

Examples of organic fertilizers:

- Animal manure – Poultry, duck and rabbit manure, and buffalo, cattle, sheep, goat, horse/donkey and camel dung
- Animal meals – Blood meal, bone meal and fish manure
- Plant meals – Cottonseed meal
- Plant manure/crop residues – Wheat straw, Barley straw, rice straw, oats straw, maize straw, soybean straw, cotton stalks and leaves, groundnut straw, groundnut hulls, ground nut shells, bean straw, cowpea stems, cowpea roots, coffee pulp, sugarcane trash, grass, green weeds, oil palm bunch ash
- Compost – Plant compost, animal compost

Table 8.4 below indicates nitrogen and phosphorous percentages by weight in some of the commonly used organic fertilizers available

Table 8-4: Average moisture and nutrient contents of commonly used animal manures

Animal manure	Percentage of nitrogen and phosphorous (dry weight basis)	
	Nitrogen	Phosphorous
Poultry litter	2.8	1.2
Chicken manure	2.0	3.0
Duck manure (fresh)	3.7	1.7
Buffalo manure (fresh)	1.7	0.1
Cattle manure (fresh)	0.5	0.1
Sheep (fresh)	1.4	0.2
Goat	1.5	0.7

8.4.1.2 How much organic fertilizer do I have to apply?

- Manures vary in nutrient quality depending on the quality of food eaten by the animals. For example, animals like chickens which are given high quality commercial rations will have manure higher in nutrient quality than animals like horses and cattle which feed on grasses. The amount of chicken manure needed for a pond is therefore, less than the amount of cattle or horse manure to achieve equivalent results.
- The moisture content of the manure also affects its quality. Dry manure will have more of some chemical nutrients than an equal weight of wet manure because it is more concentrated, but the food value may be lower because bacteria and other organisms may have already removed much of the digestible material. Fertilizers are applied during the pond preparation stage as well as after stocking of fish
- Animal manures are usually applied to ponds during culture operation on the basis of weight per area of pond surface (kg of manure per hectare, per 100 square meters, etc.)

Animal manure application rates are usually as shown in table 8.5 below.

Table 8-5: Application rates for animal manures

Animal manure	Application rate (kg/100m^2/week)
Cattle	10 – 15
Chicken	6-8
Duck	6-8
Goat/sheep	10
Chicken + Cattle	10 (2.5 kg chicken + 7.5 kg cattle)

- By dividing the weekly dose into daily applications, low oxygen problems will be less likely to occur due to over fertilising and food in the manure will be more effectively utilized by fish.
- Apply compost to fish ponds at rate of 20 to 25 kg/100 m^2 of pond surface area every ten days as a rule-of-thumb.
- Since N:P ratios in organic fertilizers often provide imbalanced nutrient amounts required by fish ponds, it is recommended to supplement with inorganic fertilizer to make up desirable ratio.

How do I calculate the amounts of organic and inorganic fertilizers to combine and apply into ponds?

- This calculation is based on the amount of inorganic fertilizers is adjusted to the amount of applied organic fertilizers to provide 28kg of N /ha/week and 7kg of P /ha/week.

$$\text{N fertilizer (kg/pond/week)} = \frac{[28 \times (\text{manure rate}) \times (\text{N\% in manure})] \times [\text{pond surface area}]\ \text{m}^2]}{(\text{N in N-fertilizer}) \times (10{,}000\ \text{m}^2)}$$

$$\text{P fertilizer (kg/pond/week)} = \frac{[7 \times (\text{manure rate}) \times (\text{P\% in manure})] \times [\text{pond surface area m}^2]}{(\text{P in P-fertilizer}) \times (10{,}000\ \text{m}^2)}$$

When do I have to apply fertilizers into the pond?

- You have to apply fertilizers at the beginning of pond preparation in the following manner:

Fill the pond with water to about 30 cm.
Apply fertilizers according to the amounts given above
Leave the pond water to stand for about 3-4 days with the filled 30 cm water until pond water turns green to greenish brown.
Fill the pond with water to 60-80 cm
Apply 10% of fertilizer added in the first application
If the pond is deep enough to fill water to a depth of 1.0 to 1.2 m, increase water level gradually up to 1.0 to 1.2 m before each application of fertilizers during the second application.

- Do not apply cow dung daily because it has a slow action and if applied daily may over fertilize the pond.

Observe the green brown color of the water.

If the water is not turning green brown color do not add any more fertilizers. Add some green water from a known pond. This should be done as the last resort

How to apply fertilizers into the pond?

- Inorganic fertilizers come in granules, powders and liquids. Each form has its proper application method and this is critical to obtaining the best results.
- If liquid fertilizers are used, it must be diluted before it is sprayed to prevent it from sinking to the pond bottom, since liquid fertilizer is heavier than water.
- If inorganic fertilizers in powder and granular forms such as urea and super-phosphate are used, take pond water into a bucket and dissolve the mixture of fertilizers in the water. Add this dissolved fertilizer everywhere evenly into pond water.
- If cow dung or other animal manure is used keep it in dry form. Soak dry animal manure in pond water overnight before apply into the pond to prevent animal manure being accumulated in corners of the pond.
- Do not apply inorganic fertilizers in powder or granular forms directly into the pond because it may settle on the pond bottom and favors the growth of benthic algae (algae grown on the pond bottom). Some of the benthic algae may secrete toxins, which are harmful to young fish.
- Powder and granular fertilizers generally do not dissolve quickly, and when the grains hit the pond bottom, much of phosphorus in the fertilizer is absorbed by the mud and lost.
- Therefore, for the two reasons given above, granular fertilizers must be dissolved in water before applying into the pond.

Do not over fertilize your pond. You may lead to problems due to dying of plankton or plankton crash.

- Applying too much organic fertilizer can lead to plankton crash and to low dissolved oxygen, and many fish fry species are particularly sensitive to low oxygen.

What is a plankton crash?

- Over fertilization can cause heavy growth of plankton, which is known as eutrophication.
- If dissolved oxygen drops in water with a heavy growth of plankton, a large proportion of plankton may die. This situation is known as plankton crash.
- Dead plankton utilize oxygen in the pond for decomposition and deplete available oxygen for fish. Decaying dead plankton will accumulate on the pond bottom and make a very stressful environment for fish.
- Fish will reduce feeding when the pond bottom is not clean. Such spoiled pond bottoms favor the growth of pathogenic bacteria.

8.4.2 Fertilization strategies

Low cost fertilization strategies for small-scale farmers include the use of animal manure alone, chemical fertilizer alone, and the combination of animal manure and chemical fertilizers. While the nutrient input rates and ratios are the most important factors, these fertilization strategies provide a wide range of choices for small-scale farmers with various resources. The type of manures and chemical fertilizers is not of particular importance. Their cost and availability are essential factors in selecting which source to choose in particular to location.

The CRSP fertilization strategies have been tested on-station in Northeast Thailand, and are practiced by many farmers in the region (Yi et al., 2008). Some components of the strategy are presented here to provide guidance on pond fertilization.

(a) Animal manure alone

Manure types and loading rates depend on availability. The maximum manure loading rate is 1,000 kg dry weight/ha/week, beyond which the water quality in ponds may become bad, causing mass mortality. Manure is generally applied on a weekly basis. Chicken manure (CM) is one of the most commonly used animal manure. In the examples given in Table 8.6, chicken manure was applied weekly at loading rates ranging from 125 to 1,000 kg DW/ha/week. The results indicate that maximum net yield (3,500 kg/ha/yr) occurs using chicken manure at 1,000 kg/ha/wk, but this rate may cost considerably more than the yield of 3,000 kg/ha/yr using 500 kg/ha/wk of chicken manure.

Table 8-6: Examples of production of sex-reversed all-male Nile tilapia cultured at different chicken manure (CM) loading rates and stocking densities

Strategy (kg/ha/week)	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)
CM (125)	0.88	180	3,000	2,500
CM (250)	0.88	210	3,300	2,800
CM (500)	0.88	215	3,500	3,000
CM (1,000)	0.88	240	3,900	3,500
CM (500)	1.0	180	2,900	2,300
CM (500)	2.0	110	3,900	2,300
CM (500)	3.0	75	3,600	1,900

Source: Yi et al., 2008

(b) Chemical fertilizers alone

Urea and TSP are widely used chemical fertilizers in aquaculture. The optimized fertilization rate by CRSP methods is 28 kg N/ha/week and 7 kg P/ha/week, giving N:P ratio of 4:1. This fertilization rate is equivalent to 61 kg urea/ha/week and 35 kg TSP/ha/week (Table 8.7). Production for these inputs (6,000 vs. 3,500 kg/ha/yr) is considerably higher than using chicken manure alone, due to the better balance of nutrient inputs.

Table 8-7: Examples of production of sex-reversed all-male Nile tilapia cultured in ponds applied with chemical fertilizers alone (Yi et al., 2008).

Strategy (kg/ha/week)	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year
Urea(61) + TSP (35)	2.0	140	4500	4000
	2.7	150	7100	6400

(c) Animal manure supplemented with chemical fertilizers

Animal manures have unbalanced N:P ratio, resulting in poor growth performance of Nile tilapia. To balance the N:P ratio, addition of chemical fertilizers is needed. In the examples given in Table 8.8, chicken manure was loaded to ponds at rates ranging from 25-225 kg (DM)/ha/week, and the amount of urea and TSP was adjusted to the amount of applied manure to provide 28 kg N/ha/week and 7 kg P/ha/week. This strategy produces the best overall yield (7,300 kg/ha/wk) and probably the most economically beneficial one.

Table 8-8: Examples of production of sex-reversed all-male Nile tilapia cultured in ponds fertilized at different chicken manure loading rates and supplemented with urea and TSP (Yi & Lin, 2008).

Strategy (kg/ha/week)	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)
CM(225)+Urea(52)+TSP(1)	1.76	180	5000	4700
CM(175)+Urea(54)+TSP(9)	1.76	170	5100	4800
CM(125)+Urea(57)+TSP(16)	1.76	205	6200	6000
CM(75) +Urea(59)+TSP(24)	1.76	255	7600	7300
CM(25) +Urea(61)+TSP(31)	1.76	190	5500	5200

8.5 Supplementary Feeds for Fish

Supplemental feeding means providing an edible food source, usually on a daily basis, which will add to the natural food the tilapia are already eating. This food is only a partial fulfillment of the total fish's diet, as the idea is to keep costs low. Most low cost feedstuffs are low in protein. They will provide energy to the fish so that protein they consume from natural food is conserved for growth and not burned as energy. Fortunately, tilapia are fairly omnivorous and can utilize a wide variety of feedstuffs including canteen waste, cereal grain residues, brewery yeast, bread, wafer, spoiled animal feeds, crop wastes, duck weed, mill sweepings, fruit waste and more.

Feeds are provided to increase fish yields, and are especially beneficial;

- When fertilization is not practiced
- When a pond does not respond well to fertilization
- When fish are stocked at high density in a pond
- When fish are confined in a cage, pen or other culture media.
- When fish are held in tanks

Manufactured supplementary fish feeds may be available in some developing countries. The local economy determines if it is profitable to use them. Other less costly feeds may be used by farmers. Table 8.9 provides a list of supplementary feed ingredients that can be used alone or in combination;

Table 8-9: Locally available Ingredients that can be used as supplemental feeds

Ingredient	Percent Dry Matter	Percent Crude Protein	Conversion Ratio
Agricultural By-Products			
Maize (bran)	-	2.1	
Sorghum (bran)		7.8	
wheat bran	89	15	5
Millet (hulls)		4.8	
rice bran	91	10	5
Groundnut (shells)		6.2	
Sunflower (hulls)		9.8	
cotton seed meal	91	41	4
Soya (hull)		9.8	
dried, salted fish waste	-	36	-
dry poultry manure with litter	89	22	-
fresh blood (coagulated)	-	12	-
fresh livestock offal	-	12	6
Animal Meal			
blood meal	92	80	2
crab meal	92	-	-
ground fish meal	92	65	2
ground dried fish		53.1	
Commercial Feeds			
chicken starter feed	-	25	4
Fresh Leaves			
cassava leaves	-	6	15
sweet potato leaves	-	2	20
Leucaena (soaked and dried)		25	
On-Farm Products			
alfalfa leaf meal	92	17	-
cassava flour	88	2	18
crushed beans and field peas	-	24	2
dry roasted soybean seeds	90	48	-
fresh termites	-	15	7
ground dried potato	91	8	-
ground Maize	88	9	5
ground millet	90	12	5
ground paddy rice	89	8	-
ground sorghum	88	11	5
ground Groundnut		28.4	
ground sunflower		25.7	
Lucaena leaf meal	92	27	-
peanut meal extract	93	48	5
soybean meal cake	90	45	4
Grounnut oil cake		46.2	
Sunflower oil cake		37.1	
Pigeon pea		20	
sweet potato meal	-	1	-
wheat flour (white)	88	12	7
Yeast			
brewers waste (dry)	93	44	10

Source: Modified from Borolunduro, 2002

- Moist rations are prepared daily by mixing ground feed and adding about 350 ml of water per kg of ingredients to form a dough-like mixture. This ration may be stored in plastic bags or containers and divided for morning and afternoon feedings. The mix is broken apart and small pieces are dropped into the water for the fish.

8.6 Choosing Feedstuffs

Single feed ingredients may be fed to fish to supplement available natural food in a pond. Better quality supplemental feed may be made by combining ingredients. Fish should grow well on a feed containing 20 to 30% crude protein, of which 7 to 10 % of the protein is from animal sources. When natural food is abundant and fish are stocked at low densities; 20 to 25% protein content is suitable. A 30% or higher crude protein content is more suitable for commercial operations where fish are stocked at higher densities. Choose ingredients from Table 8.9 when preparing a supplemental feed, so that a feed mixture having the desired crude protein content is obtained. Inquire from poultry and livestock dealers and farmers what ingredients are locally available. Two simple methods can be used to determine how much of a selected ingredient should be used for making a fish feed with a desired crude protein content. The trial and error and Pearson's square methods are described below;

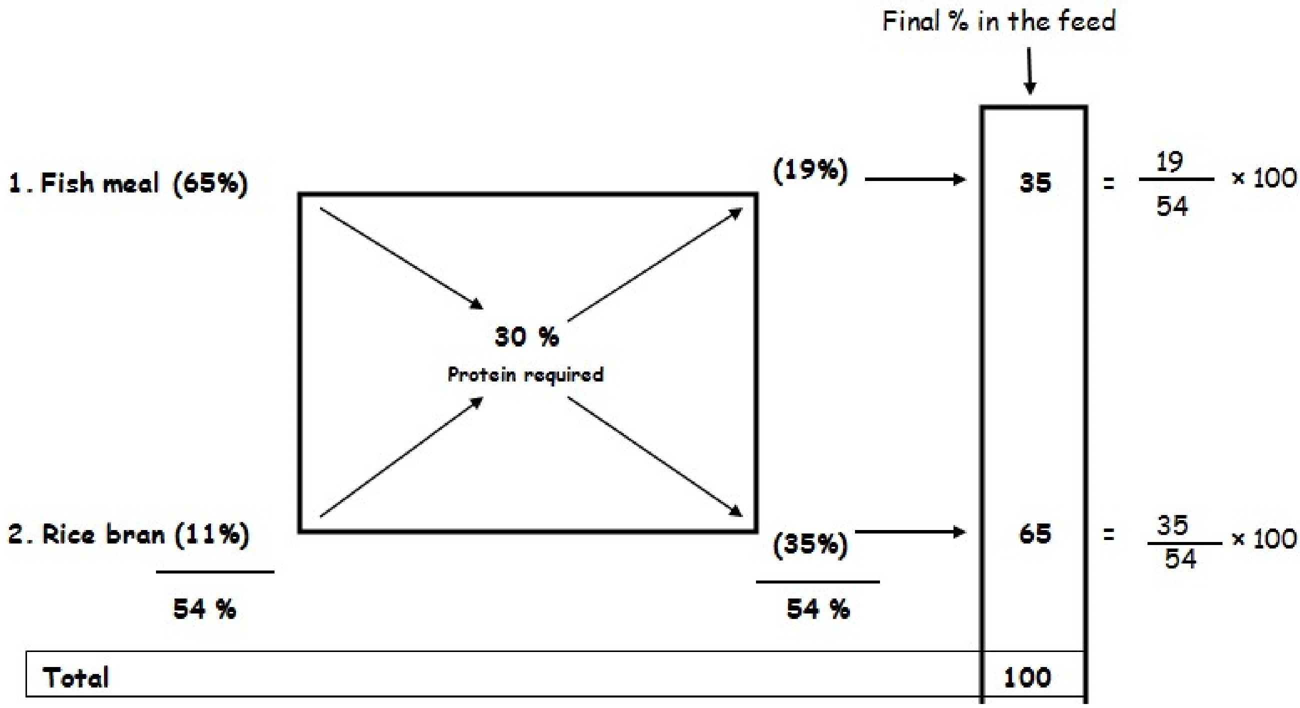
8.6.1 Method 1: Trial and error method

Choose a combination of ingredients from Table 8.9 that will provide a feed containing 25 to 30% crude protein.

Ingredient	Amount of Ingredient		% Crude Protein		Crude Protein In Feed (kg)
rice bran	47	X	10	=	4.7
copra meal	10	X	21	=	2.1
Lucaena leaf	7	X	2	=	1.9
soybean oil meal	28	X	4	=	13.4
fish meal	8	X	6	=	5.2
			5		
Totals	100				27.3

This feed would contain 27.3 kg of crude protein if 100 kg of the listed ingredients were combined as indicated. This would make a feed containing approximately 27 % crude protein by weight since (27.3 kg / 100) x 100 kg = 27.3 % protein content.

8.6.2 **Method 2:** Pearson's Square



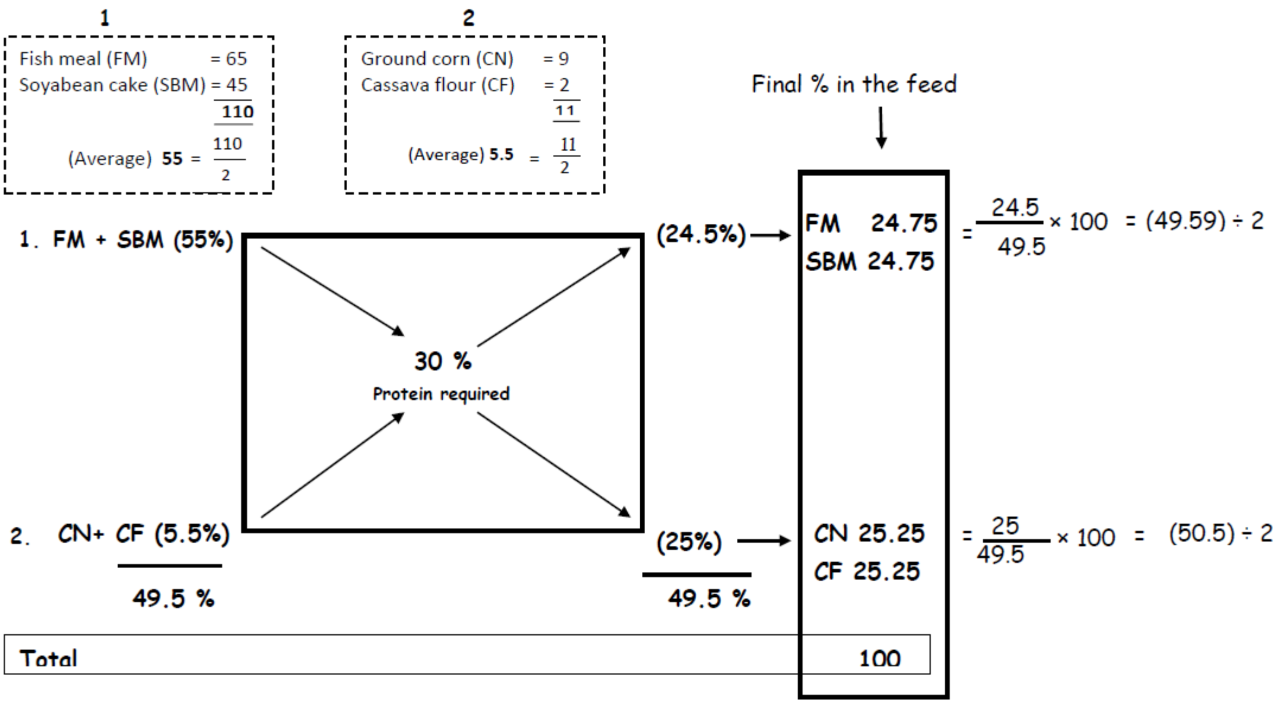
This method may be used for two or more feed ingredients and is preferable to the trial and error method.

Examples of feed formulations with two and more ingredients are shown. In this example, find the proportions of soybean meal cake, fish meal, ground corn and cassava flour needed to make a fish feed with a 30% crude protein content.

Thus, 35 kg of fish meal and 65 kg of rice bran are combined to make 100 kg of fish feed containing 30% crude protein. The feed can also be described as being composed of 35% fish meal and 65% rice bran.

Example 2: - three or more ingredients

In this example, find the proportions of soybean meal cake, fish meal, ground corn and cassava flour needed to make a fish feed with a 30% crude protein content.



Thus, to make 100 kg of fish feed containing 30% crude protein from a combination of ingredients including fish meal, soybean meal cake, ground corn and cassava meal the following proportions would be mixed.

Fish meal	24.75 kg
Soybean meal cake	24.75 kg
Ground corn	25.25 kg
Cassava flour	25.25 kg

Some recommended feed formulae in preparing varying percentages of rich protein feeds is as shown in Table 8.10.

Table 8-10: Feed Formulae for Preparing Feeds of Various Crude Protein Levels Using Locally Available Feed Ingredients

% Crude Protein	Palm Kenel Cake (kg)	Corn Bran (kg)	Rice Bran (kg)	Fish Meal (kg)	Soya bean Meal (kg)	G/nut Cake (kg)	Total Weight (kg)
20	45.30	45.3	-	3.1	3.1	3.1	99.99
20	-	35.8	35.8	-	11.20	11.20	100.00
35	-	24.0	24.0	17.3	17.3	17.3	99.99
40	21.2	21.2	-	19.2	19.2	19.2	100.00

8.6.3 How much to Feed

Feeding rates may be adjusted on a monthly basis by estimating the fish biomass in the pond. There are several ways to determine the fish biomass. The most accurate is to catch a small number of fish and weigh them. The average weight of fish in the sample is multiplied by the number of fish stocked to calculate fish biomass in the pond. This method requires a farmer to have accurate scales and to maintain good records of fish weight and number.

Table 8-11: Feeding rate of Tilapia fed 25% protein feed in monoculture at 24°C

Fish size (g)	**Amount of feed**		
	(g/fish/day)	**(% of biomass)**	**Times feed daily**
5-10	0.5	10-5	4
10-20	0.8	8-4	4
20-50	1.6	8-3.2	4
50-70	2.0	4-2.9	4
70-100	2.4	3.4-2.4	4
100-150	2.7	2.7-1.8	3
150-200	3.0	2.0-1.5	3
200-300	3.7	1.9-1.2	3
300-400	4.5	1.5-1.1	3
400-500	5.2	1.3-1.0	3
500-600	6.0	1.2-1.0	3

(modified from FAO, 1987)

Table 8.11, presents a chart showing what percentage of body weight should be fed to tilapia of a certain size. Another way to adjust feeding rates is to assume a growth rate for the fish based on previous experience. Growth rates will differ depending on the amount of natural food in the pond, the type and amount of supplementary feed given, fish species and size, the stocking rate and the water temperature. This chart may be used as a rough guide to determine feeding rates. The following example illustrates this.

Example of feeding rate determination using Table 8.11:
A farmer samples his fish pond with a net and determines the average length of his fish to be about 15.5 cm. The average individual weight would be approximately 85 g (from Table 8.11). If the farmer has 350 fish in his pond, and feeds them at 4.0% of their body weight per day, he would feed about 1.2 kg of feed.

Calculation:
(350 fish X 85 g per fish) X 0.04 of body weight/day = 1190 g of feed or about 1.2 kg/day.

8.6.4 Some supplementary feeding strategies

Size of Nile tilapia at harvest under fertilization alone usually averages 250 g in 5 months, and it may take as long as five more months to rear the fish to 500 g. In many countries, larger tilapia fetches much higher prices. To raise tilapia to large size, the addition of supplemental feeds to fertilized tilapia ponds is needed.

CRSP researchers (Yi et al., 2008) have developed an efficient supplemental feeding system as followings:

- Fertilizing ponds at 61 kg urea and 35 kg TSP/ha/week throughout the culture cycle;
- Supplementing feeds at 50% of satiation feeding level starting when tilapia reach 100 g in size; Harvest tilapia when reaching 500-600 g in size.

The method to determine satiation feeding level is:

- Give feed to tilapia during 0800-1000 h and 1500-1700 h every Monday until tilapia stop feeding;
- Add all feed consumed in both sessions together, and the total feed amount is satiation feeding level; Feed tilapia 50% of the determined satiation feeding level from Tuesday through Sunday;
- Repeat the above process every Monday.

Table 8-12: Examples of production of sex-reversed all-male Nile tilapia cultured in chemically fertilized ponds supplemented with commercial floating pelleted feed starting at different tilapia sizes.

Strategies	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)	Overall FCR
Start	3.0	59	19,600	19,000	1.1
Start	3.0	59	19,500	19,000	0.9
Start	3.0	53	15,200	14,700	0.9

In the examples given in Table 8.12, Nile tilapia stocked in chemically fertilized ponds were fed commercial floating pelleted feed containing 30% crude protein, and the yields were standardized on two 5-month cycles. The yields were achieved in the ponds without aeration and water exchange.

8.6.5 Producing of Pellets and Ground Ingredients

- Get good quality feed ingredients
- Particle size of ground ingredients should be uniform. Fine grinding is preferable. Leaf meals should be sun or oven dried before grinding.
- Measured ingredients should be mixed thoroughly in desired proportions.
- Determine what pellet type to produce i.e. whether floating or sinking types for surface feeders or bottom feeding fish respectively. Sand may serve as sinker when added to pellet. For floating pellet, add or spray oil.
- Particle size of pellets for most fish range from 2mm-9mm in diameter.
- Dry rations, such as rice bran, ground maize and leaf meals, may be stored in a cool, dry place for several weeks. Portions may be taken as needed to feed fish.
- Moist rations can be prepared daily by adding about 350ml of water per kg of ingredients to form a dough-like mixture. This ration may be stored in plastic bags or containers and divided for morning and afternoon feeding.

The following general rules should be followed when providing supplemental feed.

- Always feed fish at the same time and place
- Never overfeed the fish
- Do not feed on harvest day

8.6.6 How to store feeds

Keep feeds and ingredients dry, cool and away from pests. Poor storage of feeds and ingredients will waste money and can kill fish. Any ingredient or feed requires special care during storage to prevent deterioration in quality. Stock control is also important to ensure you have enough but not too much of each ingredient available for manufacture when needed.

- Environmental factors, such as moisture, temperature, light and oxygen influence deterioration and losses in feedstuffs. High levels of moisture favor growth of fungus or insect infestation. Fungal growth can be retarded by the use of mould inhibition agents (e.g. Myocurb). High temperatures also affect the rate of loss of heat liable vitamins and other nutrients.
- Lipids can break down into free fatty acids, causing rancidity. Rancid fats reduce the palatability of the feed and contain toxic chemicals, which may

reduce growth. Thus, ingredients should be stored for as a short period of time as possible and compounded feeds used quickly, especially in tropical conditions. The method of storage depends on the type of ingredient.

- Vitamin mixes are extremely expensive ingredients and should be given special care. They should be kept either in the manufacturer's containers or in airtight lightproof containers and preferably under air conditioning or refrigeration. Stocks should be turned over at least every six months.
- Lipids (e.g. fish oil) must be kept in sealed, preferably plastic containers, in a cool dark place. Purchase only those that have antioxidants added at manufacture.
- To store dry feed materials, provide a secure building, protected from rain, with ventilation points (windows are not recommended). The drier and cooler the store can be kept; the better will be the quality of the feed. Keep the store clean and free of vermin such as rodents. Remember dry, cool and away from pests.

Plate 8-1: Rice bran milled in Goroka, PNG. The rice bran is ground to a fine powder during this process

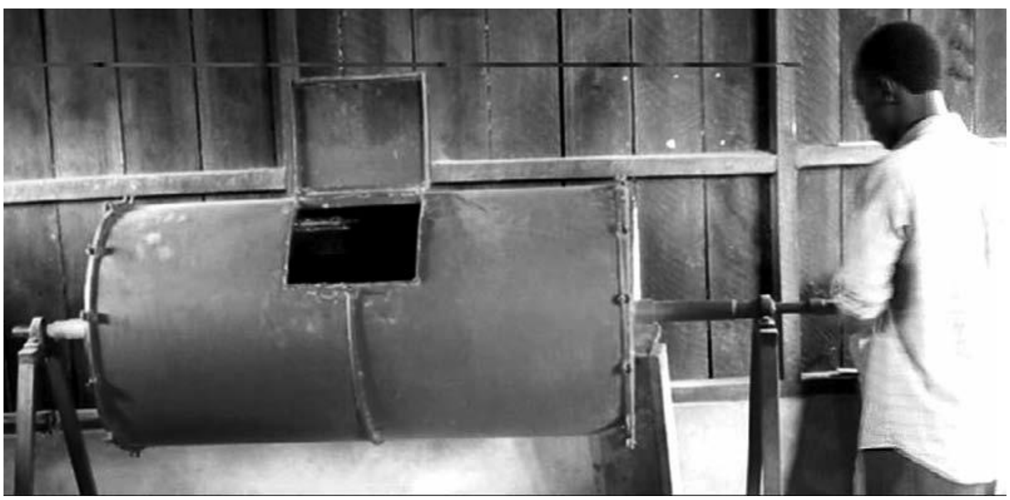


Plate 8-2: A hand-operated mixer is used to mix feed ingredients at Sagana Aquaculture Centre.

Plate 8-3: Different size pellets are made by extruding the mash (mixture of ingredients) through dies with different size holes and then cutting the strands to the required length (Gonzalez & Allan, 2007)

Chapter 9

CONTROL OF DISEASES AND PREDATORS

9.1 Fish diseases

9.1.1 What is a disease condition?

- Any abnormality in function, structure and behavior can be a disease or a disease condition. Diseases can be infectious or non-infectious.

9.1.2 What is disease diagnosis?

- Diagnosis is identification of the cause of disease.
- Causes of diseases are stress due to environmental factors or pathogenic infections.

9.1.3 What are the environmental factors that cause stress?

a) Deterioration of water quality in the pond or in the water source.

- Buildup of harmful gases (ammonia and hydrogen sulphide) and nitrite levels above the optimum levels
- Low pH, high pH and unfavorable pH fluctuations in pond water
- Depletion of oxygen
- High levels of suspended solids
- Low alkalinity
- Heavy metals in water (e.g., cadmium, chromium, lead, copper)
- Toxic substances from industrial, urban and agricultural wastes

b) Acidic pond soil

- Acid Sulphate soil with iron.

c) Growth of toxic benthic algae

d) Crash of algae

e) Spoiled or fouled pond bottom due to accumulated waste

f) Intake of water from common water sources with effluents from other ponds or farms

9.1.4 How do I check the health of fish during culture?

- Farmers should check the health of fish during the production cycle. If fish in the pond is not checked at regular intervals, any disease condition during culture may go unnoticed, unless there is unusual mortality of fish in the pond edge.
- There are two ways that you can perform health checks during culture.

  i. Observation from the dike.

  ii. Observation on sampled fish at regular intervals.

- It is necessary to perform both types of checks as the observations from the dike can only indicate a stressful pond environment and/or disease situation.
- Second type of observation provides more detailed information regarding the type of disease condition and reasons for stressful pond environment.
- In both types farmer can perform visual checks to determine the health situation of his fish
- Deviating from normal behaviour and changes to normal physical appearance may indicate disease situation or unhealthy pond condition.
- You should know what is the normal behaviour and normal physical appearance of your fish? If not, you would not notice any changes to normal behaviour and normal physical appearance.

9.1.5 What are the deviations from normal behaviour?

- Before you notice any clinical signs of fish diseases of a fish, individual fish may exhibit increased feed consumption followed by cessation of feeding, or the fish may simply go off feed alone.
- Take a note of unusually uneaten food left on feed trays or fish do not assemble at feeding places.

- Fish swimming near the surface, sinking to the bottom, loss of balance, flashing, cork-screwing or air gulping (non air-breathers) or general lethargy of fish.
- Behavioural changes often occur when a fish is under stress.
- Fish gulping, lethargyness and fish rolling with belly-up. This indicates deprivated oxygen condition may be due to blood or gill impairment.
- Fish flashing indicates surface irritation due to superficial secondary infections of surface lesions.
- Spiral or corkscrew movement may indicate neurological problems that may be disease related (e.g. viral infections)
- Fish mortalities occur persistently or mortality increases day by day. If losses persist or increase, samples should be sent for laboratory analysis.
- Mortalities that spread from one area to another may suggest the presence of an infectious disease agent and should be sampled immediately. Affected animals should be kept (isolated) as far away as possible from unaffected animals until the cause of the mortalities can be established

If fish behave abnormally take a sample of fish and examine the following areas: skin and fins, eyes, gills and body shape

a) **Skin and fins:**

- Damage to the skin and fins can be the consequence of an infectious disease
- However, pre-existing lesions due to mechanical damage from contact with rough surfaces, bad handling can also provide an opportunity for primary pathogens or secondary pathogens to invade and establish.
- Common skin changes associated with disease, which include red spots or larger patches need further action. These spots and patches tend to occur around the fins, operculum, vent and caudal area of the tail, but may sometimes be distributed over the entire surface. Darkened skin colouration is indications of deeper haemorrhages or osmotic imbalance problems
- Haemorrhagic lesions may precede skin erosion, which seriously affect osmoregulation and defence against secondary infections. Erosion is commonly found on the dorsal surfaces (head and back) and may be caused by disease, sunburn or mechanical damage.
- In some species, surface irritation may be indicated by a buildup of mucous or scale loss. Surface parasites, such as copepods, ciliates or flatworms, should also be noted.

- The parasites may be attached superficially or be larval stages encysted in the fins, or skin. Such encysted larvae may be detected as white or black spots

b) **Eyes**:

- The eyes should also be observed closely for disease indications
- Examine the eyes for changes in shape and color, cloudiness, gas bubbles and small hemorrhagic lesions (red spots).
- All indicate emerging or actual disease problems. For example, eye enlargement and distension, known as "Popeye", is associated with several diseases

c) **Gills**:

- Paleness and erosions in the gill area associated with disease conditions
- Presence of red spots in the gills indicate hemorrhagic problems which affect the normal gill function
- Fouling, mucus secretion and accumulation on gills and presence of parasites on the gills indicate reduced gill function due to other health problems

What is fouling?

- Fouling is growth of organisms and the accumulation of inorganic debris on the surface of fish.
- This is an occurrence on fish that are unhealthy for any reason.

d) **Body shape**:

- Any deviation from normal body shape in a fish is a sign of a health problem
- Common changes include "pinhead" which usually affects young fish indicating developmental problems
- Deformation in body shape such as lateral or dorso-vental bends in the spine (*i.e.*, lordosis and scoliosis) indicate nutritional or environmental water quality problems
- Swelling or bulging out of the abdomen known as "dropsy" is a strong indicator of disease problems which may include swelling of internal organs

(liver, spleen or kidney), buildup of body fluids, parasite problems, or other unknown cause.

- Dropsy is a common symptom of many of the serious diseases. It is also commonly associated with disruption of osmoregulation due to blood-cell or kidney damage.

9.1.6 Common Fish Diseases

Fish diseases are caused mostly by fish parasites. Maintaining a hygienic pond environment is the best preventive method of checking diseases outbreak. Diseases can occur in fish pond due to environmental factors that cause stress and in presence of disease causing pathogen. Diseases may be classified as;

- Bacterial and viral
- Fungal
- Protozoan
- Worms
- Crustacean
- Environmental, and
- Nutritional

The following should be followed in treatment of infected ponds.

- Ponds with infections should be drained and badly infected fish culled.
- Dry the pond under the sun for about seven days
- Dampen the pond bottom
- Spread Lime (Calcium carbonate) evenly over entire surface of pond bottom at the rate of 1500 kg/Ha.
- Wait for 15 days then restock the pond with healthy stock

Table 9-1: Common Fish Diseases, Causative Agents, Symptoms and Recommended Treatment

DISEASE	SYMPTOMS	TREATMENT
VIRUSES Irido- and birna viruses	Dark color; lethargy; distended abdomen; pale gills; opaque eyes; internal organs pale; swollen kidneys; mortality to 50%.	Control of management and environmental variables.
BACTERIAL Aeromonas spp., Vibrio spp., Pseudomonas spp.	Frayed fins; inflamed skin and fins; scale loss; ulcers on the head and mouth; bulging eyes with opaque corneas; swollen abdomens; liver pale and/or mottled with red spots; liver, spleen and kidney necrotic; lethargy and mortality to 20%.	As above; For external bacteria: Potassium permanganate @ 2-4 mg/l indefinitely, or @ 4-10 mg/l for 1 h; CuSO4 @ 0.5-3.0 mg/l indefinitely; Chloramine-T @ 10-20 mg/l for 1-72 h. Antibiotic such as chloramphenicol. 1gm/kg of feed or 5ml injection
Edwardsiella sp.	Lethargy; swimming on side; enlarged abdomen; swollen, opaque, bloodshot eyes; gas-filled cavities; liver pale and mottled; swollen spleen and kidneys; inflamed intestine.	For internal bacteria: Terramycin @ 50 mg/kg/d in feed 12-14 d with 21-d withdrawal; Romet 30 @ 50 mg/kg/d in feed 5 d with 42-d withdrawal; Erythromycin @ 50mg/ kg/d in feed 12 d; Amoxycillin @50-80 mg/kg/d in feed 10 d.
Streptococcus spp.	Lethargy; erratic swimming; whirling at the surface; dark skin pigmentation; bulging, bloodshot eyes; bloated abdomen; ulcers; pale liver; bloody intestinal fluid; Reduction of feeding; skin lesions; fin rot; gill rot; bloated belly.	
FUNGAL a. Gill or Branchiomyiosis b. Saprolegnia infection	Red spots on the gill Appears as fussy, Grey whitish blotches on skin	Reduce handling stress and injury. Flush with Formalin or immerse with H_2O_2 @ 500 µl/l for 15 min. to treat eggs or for 1 h to treat body surface; $CuSO_4$, $KMnO_4$, salt are also used but seldom effective.
PARASITES Protozoans - 'Ich', Trichodina, Ichthyobodo, Chilodonella, Epistylis	Lethargy; grayish color; gasping at surface; inflamed, necrotic skin having white spots scale loss.	$KMnO_4$ @ 2-4 mg/l or Formalin @ 20-25 µl/l or $CuSO_4$ @ 0.5-3.0 mg/l for indefinite immersion. UV irradiation or ozone treatment of water and filtration of water can reduce densities of free-swimming stages.

Modified from Hanley, 2005

DISEASE	SYMPTOMS		TREATMENT
TREMATODES - Dactylogyrus spp, Gyrodactylus spp.	Skin covered with the leach cause excessive weakness, mortality Gills swells and turn grey		Formalin @ 25µl/l for indefinite immersion or @ 167 µl/l for 1 h. Drain the pond. Treat fish in salt solution of 25gm per liter of water for 10 seconds.
DISEASE CAUSED By Crustacean Argutus Infection	The string of the fish lice cause red patches on the fish skin		Drain and lime pond. Treat fish in solution of $KMnO_4$ or Lysol both 1gm/1tr.
ENVIRONMENTAL DISEASES a. Acidic water	Low PH below 5	Fish skin covered with whitish film, gills turn brownish. Mortality of fish	Apply 500kg of a $CaCo_3$ /ha of pond.
b. Alkaline water	High PH above 9	Mortality of fish	Apply lime in a sufficient quantity according to PH level. Drain pond and change water
c. Low DO	Asphyxia	Fish regularly come out to gasp for atmospheric air. Mass mortality of fish with wide open mouth and gills wide apart.	Aerate the pond if device is available or flush fresh water by high velocity into the pond
NUTRITIONAL DISEASE	Enteritis	If abdomen is pressed lightly a yellow-red liquid flows from the anus Intestine is red congested and highly inflamed	Use balance diet fed with high proportion of protein or vitamin to correct nutritional deficiency.

(Continuation of Table 9.1)

Quarantine procedures should be instituted to protect resident stock from potential diseases present in introduced stock. This requires the presence of a quarantine area that is isolated from the rest of the farm. In the quarantine area there should be:

- Separate water supply and drainage from other farm areas;
- No cross-movement of personnel or equipment from other farm areas
- Proper biosecurity measures for disinfection of people and equipment
- The removal of dead fish for incineration separate from other farm mortalities
- The isolation of fish for up to 6 weeks to observe for disease signs
- Regular veterinary checks for the presence of parasites or disease and the appropriate treatment.
- Ponds containing diseased fish may be disinfected by spreading slaked lime (Calcium hydroxide) or quicklime (Calcium oxide) over the drained but wetted soil in the amount of 0.25 kg/m^2. Concrete tanks may be disinfected using a 10 ppm solution of chlorine (Calcium hypochlorite).

9.2 **Fish predators and their control**

Predators are a major source of stress to fish and can also cause significant losses (Table 9.2).

Predators:

- consume the fish in the pond,
- consume the fish's feed
- may transmit parasites and other infections to fish
- Scare the fish when they are chasing them up, and cause physical injury to several fish in the process of hunting.
- May trans-locate fish to a different pond
- The wounded fish left in the pond consequently cannot get to the feed as well as the other normal fish. This is because, for example, their eyes might be injured or their open wounds might get infected, etc. Consequently, their growth rate slows and chance of survival drops.
- Controlling predators is therefore important in commercial production.

If the situation is bad, then trapping or shooting can be used as the last resort in cases of birds and otters but in consultation with the relevant authorities. Be very careful when poisoning predators, humans and non-target animals can be affected.

The table below shows the common predators and their control methods.

Table 9-2: Common predators of fish and their control

Predator	Predator Type of fish	Control measure
Insects and insect larvae	Juvenile fish and eggs and fish just hatched.	• Oil emulsion to prevent aerial breathing. • Use of fish that feed on insect larvae especially those that have gills and can remain in the bottom.
Frogs and toads	juveniles of tilapia and catfish	• Fence with frog proof wire mesh. • Use a polythene fence between the shallow water edge and dike avoid tadpoles entering the pond • Clear bush around pond. Screen both in and outlets. • Use traps. Adult catfish and bass eat frogs
Fish	all types of fish	• Use screen in the inlets and outlets. • Drain and dry the pond periodically • Predatory fish which tend to burrow into the mud, such as mudfish, can be totally eliminated by using tobacco dust at the rate of 500 kg/ha. • If a pond cannot be completely drained, and dried there can be predatory fish in areas with water. In such cases fish poisons can be used. However, fish poisons should be used well before the pond is stocked, at least a week before. Rotenone or derris root is recommended at a rate of 1.5 – 2.0 g rotenone for each m^3 of pond water should be added. You should not use fish poisons once the fish are stocked
Snakes	destroy larval and juvenile fish	• Clear bush around the pond and fence properly. • Farmer interventions have shown that tobacco scares away snakes from fish farms. Farmers may plant a few plants of tobacco around pond dykes
Crocodiles, alligators and large lizards.	All types of fish	• Proper fencing and keeping dense bushes cut down, though fencing is expensive and may not be practical.

Predator	**Predator Type of fish**	**Control measure**
Birds: Wading birds e.g., Herons and egrets Diving birds. Kingfisher, fish eagle cormorants, pelicans	All types of fish and at all stages especially in shallow waters. Cormorants feed on fish just after the fish are fed- when they are most concentrated.	• Proper fencing all round and then above with netting material or ropes/strings on poles with bright colored cloth or a bird net over the pond. though this measure is very expensive and may not the practical • use flash guns, windmills that revolves and flash brilliantly and bells to scare the birds a way. • Pond water should not be allowed to fall to levels where birds can see the pond bottom • Ponds constructed without shallow areas are not attractive to predatory birds such as herons, kingfishers. If water over the main pond bottom area is kept deep enough and colored with a growth of phytoplankton and zooplankton, the birds cannot see the bottom and will not land. • Special precautions can be taken in small ponds and in nursery ponds because of their small area. Some farmers run lines of string in a 'zig zag manner closely between posts set in the pond dikes so that wading birds cannot land in the pond. Sometimes farmers attach bright colored pieces of cloth metal or polythene stripes to the strings to scare birds.
Otters	Prey on large fish at night killing more than they can eat. They burrow and live under the roots of trees near the water. Otters are very clever They can even open latches on gates.	• Proper fencing around the ponds. • The otters can also be trapped using special otter traps set in their passages since otters generally follow the same path. • Guard by use of trained dogs. • Fence the pond half way across giving allowance for fish to pass through but not the otter thus providing hiding places for fish.
Man (theft)	All types of fish. This is also considered among the major predators through which fish are lost.	Extremely difficult to control and is most common in cage culture and other intensive fish farming. Can however be controlled by • Clear shrubs or bushes around the ponds • Employing security personnel • Use of trained dogs • Hidden obstruction to prevent pond seining. • Fence the farm and lock securely. • Burglar alarms or electrified fence

Plate 9-1: Common predatory birds of fish; from the left Egret, King fisher and Hammercop (Source: Isyagi et al., 2009)

Plate 9-2: African fish eagle on the left and Monitor lizard on the right

Plate 9-3: Snakes such as pythons on the left and animals like Otters are aggressive fish predators

Chapter 10

TILAPIA BUSINESS PLANNING

The objective of commercial fish farming is to produce fish for sale and earn profits. Therefore, production should be planned from the onset to target identified markets. This means one should:

- have the required product (size and form) available when the market wants it
- be able to produce adequate volumes to sustain targeted markets,
- produce at a competitive price and profit.

10.1 Record keeping

Records are sets of information that have been systematically and carefully collected and appropriately stored for a specific purpose. To be able to run any economic enterprise successfully, carefully thought out and properly collected records are a must. Comprehensive record keeping will assist both in tracking farm activities and expenses and in assessing the level of investment, the motivation of the investor, and the management skills of the farmer. As the management level rises, culture systems become more complex and so does the record keeping. This is the reason the farmer must think very carefully about which records need to be kept.

10.1.1 Importance of record keeping

Maintaining good records helps you with the following:

- Provide a basis for farm credit and financing
- Control the business and improve the management and efficiency of the farm
- Provide information to competent authorities for policy formulation
- Determine the relative profitability of the various production techniques and /or systems
- Provide information for tax purposes
- Provide basis for deciding future plans of the farm

The accounting and financial information may also be required by a number of other users or stake holders interested in the performance of the business such as investors, employees, lenders, suppliers, Government and the general public.

10.1.2 Types of aquaculture records

Fish farming records can be classified into:

(a) **Pond management record**, for example

- Pond utilization table schedule
- Sampling record sheet
- Fertilization and liming
- Fish health records
- Water quality records
- Feeding records
- Harvesting records

Table 10-1: Templates of tables for pond management records

a. Pond utilization table

Pond number	Date stocked	Pond size	Species stocked	Number of fish stocked	Expected harvest date	Expected harvest (kg)	Actual harvest (kg)

b. Sampling record sheet

Date of sampling	Date of stocking	Pond No.	Number of fish examined	Fish Species	Average fish weight (g)	Remarks

c. Fertilization and liming

Date	Species	Pond number	Pond Size (m^2)	Name of fertilizer/lime		Amount of fertilizer/lime (kg)		Cost of fertilizer/Lime		Remarks
				Fertilizer	Lime	Fertilizer	Lime	Fertilizer	Lime	

d. Fish health records

Date	Pond/tank number	Pond/tank size	Species	Age or size of fish	Usual responses	No. dead	Symptoms	Action taken

e. Water quality records

Pond number…………………………				Description………………………………
Date	Parameter	Reading		Remarks
		Am	Pm	
	PH			
	Temperature			
	DO			
	Turbidity			

f. Harvesting records

Pond number…………		Pond size ………		Description………		
Date	Number of fish stocked	Number harvested	Species stocked	Average weight (kg)	Expected harvest date	Total weight harvested (Kg)

g. Feeding records

Pond number………....... Description…………………………………….						
Pond number	**No. of fish stocked**	**Stocking date**	**Total weight of fish**	Weight of feed fed (kg)		
				AM	**PM**	**Cost of feed**

(b) Breeding and larval rearing records

Fish breeding entails an understanding of stock management, genetics and management of fry/fingerlings. Some of the key breeding and larval rearing records include:

- Spawning and hatching records
- Data sheet template for tilapia seed harvest records.
- Data sheet template for sex-reversal survival records.

Table 10-2: Templates of tables for breeding records

a) Records on breeders

	POND /HAPA NO.)	**NUMBER OF FISH**		**BATCH WEIGHTS (KG)**		**REMARKS**
Date of stocking:		Females	Males	Females	Males	

b) Data sheet template for sex-reversal survival records.

	Sex-reversal hapa	**Number of swim-up fry in (A)**	**No. Of fry**	**% output = (B/A *100)**	**Remarks**
Date of seed out from the sex-reversal hapa					

c) Data sheet template for tilapia seed harvest records.

	POND /HAPA NO.)	NO. OF SEED COLLECTED					REMARKS
Egg harvest dates:		**Stage I** (just laid eggs)	**Stage II** (with eye spots)	**Stage III** (with small tail)	**Stage IV** (With yolk- sac)	**Stage V** (Swim-up larvae)	

(c) **Financial management** records such as

- Purchase of inputs, including quantities and costs
- Records of input usage, e.g., feeds and labor
- Costs of labor, including the type and duration
- Costs of new construction or repairs
- Salaries, both in cash and in kind
- Sales records, including what was sold, quantities, and prices
- Inventory of equipment
- Costs of renting or hiring equipment, machinery, services, etc.
- Records of significant events at the farm, including
- Visits by extension officers and recommendations given
- Unusual weather that may affect pond productivity or farm operations

Table 10-3: Example of sales records

a. Data sheet template for fry/fingerling sales records

	Customer details (name, address and tel)	Date of sex-reversal	Number of fry sold (A)	Price of fry (B)	Total revenue =(B x A)	Remarks
Date of seed sale						

b. Data sheet template for table fish sales records

	Customer details (name, address and tel)	Kg of fish sold (A)	Price of fish per kg (B)	Total revenue = (B x A)	Remarks
Date of sale					

10.2 Fish farming economics

10.2.1 Definition of economics

Economics is the study of the production and distribution of economic goods and services, bearing in mind that the necessary resources (land, water, money, inputs, etc.) are always limited. Farmers therefore have to make choices on how best to utilize the resources that are available to them for maximum benefit.

10.2.2 Opportunity cost

Opportunity cost is the next best opportunity one foregoes as a result of selecting one out of several possibilities. For example, if a farmer decides to invest in fish farming, that decision implies a loss of the benefits that would have resulted from investing in poultry farming, crop farming, cattle-rearing, or another farming enterprise.

10.2.3 Farm management

In a commercial setup, the fish farmer has to understand that fish are usually reared for economic benefit. The farm manager has to make many organizational and operational decisions; key among these are:

- What species of fish to produce?
- What quantity of the selected species to produce?
- What mix of resources and technology to use?
- When and where to sell or buy?
- How to finance the operation?

10.2.4 Enterprise Budgets

An enterprise budget is a tool you can use to estimate all expected costs and income for your enterprise over a specified period of time, e.g., your fish production operation during one growing season or one year. Preparing an enterprise budget helps you predict whether or not the fish farming enterprise will be profitable.

If we assume that a farmer has made all the capital investments required to start the enterprise, normal operating costs incurred and revenues received per unit time (e.g., one year) can be summarized into an enterprise budget.

To develop an enterprise budget, the following types of assumptions must be made:

- Establish the source of operating funds: Are they from loans or from savings?
- There is a ready market for the fish
- The investor is not salaried; she/he relies solely on farm profits
- Establish the interval of harvest (growing period) and expected yield
- Estimated mortality or survival rate for the fish stock
- Prevailing bank interest rate

10.2.5 Components of an enterprise budget

a) **Gross Receipts**

The first step in developing an enterprise budget is to estimate the total fish production and expected output price. The total value of the fish sold is called the Gross Receipts.

b) **Variable Costs**

The second step is to estimate the variable costs. Variable Costs are the cash expenses directly related to production. These costs vary with the scale of production or farm size.

c) **Fixed Costs**

Fixed Costs are incurred regardless of whether or not production occurs. Certain items that outlive one production period must be purchased. Expenses related to land and equipment should be considered (land lease, annual depreciation of machinery, interest rates) together with ponds construction costs. Salaries for permanent staff may also be considered.

d) **Total Costs**

This is the sum of Variable and Fixed Costs.

e) **Net Returns**

This is the difference between Gross Receipts and Total Costs.

f) **Break-even Analysis**

A "break-even price" can be calculated and used to gauge whether your operational costs are covered by your income. The break-even price is the price at which expenses per kg and income per kg are just equal. It is expressed in K per unit weight (kg).

g) **Break-even Price**

This can be calculated to cover:

i. Variable expenses:
   Total variable expenses (K)/total fish produced (kg)
ii. Total expenses:
   Total expenses (K)/total fish produced (kg)

h) Break-even Yield

i. Break even yield (BEY) above total cost (TC) is defined as production where total gross receipts are equal to total costs. This is calculated as follows:

   BEY above TC = Total costs/price per unit

ii. Break even yield (BEY) above total variable cost (TVC) is defined as production where total gross receipts are equal to total variable costs. This is calculated as follows:

   BEY above TVC = Total variable costs/price per unit

i) Income per Unit Area

Some people may want to find out how much they are earning per unit area of pond water. To calculate earnings per unit area:

Income = Net Income (K)/Total area of pond (ha)

A Sample Enterprise Budget

Table 10-4: Example of an enterprise budget for a mini hatchery

Item	Unit	Quantity	Unit Cost	Total cost
POND CONSTRUCTION COSTS				
• Clearing • Dike Construction • Pond bottom sloping • water supply PVC pipe • drainage culvert pipe, • overflow PVC, • Backup diesel generator • Construction of caretaker's hut • Construction of storage hut				
Total investment cost				
OPERATIONAL COSTS				
BREEDERS				
• Females • Males **including allowance for mortality*				
FERTILIZERS/LIME				
• Organic (Chicken Manure) • Inorganic • Lime				
FEEDS				
• Breeders • Fingerlings				
SERVICE INPUT				
• Salaries and Wages • Supplies and Materials				
DEPRECIATION				
• Ponds, dikes, etc.@10 years • Equipment @5years • Caretaker's house and storage@5years • Fishing gears, etc. @5years				
SUB-TOTAL				
OTHER EXPENSES				
• Harvesting expenses – 5% of gross sales • Fishing Gears, etc. • Miscellaneous Expenses • Caretaker's/Helper's Incentive • Repair and Maintenance – 3% of gross sales				
Total (K)				
Grand Total (K)				

Table 10-5: Cost and Return Analysis of the Tilapia Hatchery (One-year Operation)

ITEM	
Revenue • 5, 000 fingerlings @ 5 ngwee	
Less Expenses • Breeders • Fertilizers • Feeds • Salaries and Wages • Supplies and Materials • Harvesting Expenses • Miscellaneous expenses • Caretaker's Incentive • Repair and Maintenance	
Income before depreciation	
Less: Depreciation	
Net Income	

10.2.6 Production Analysis

Production analysis of fish ponds was performed at the end of the final harvesting. Net production, mortality rate, specific growth rate and food conversion ratio were obtained from the following formula.

Net production = Final wt. at the harvesting – Initial wt. at the stocking

$$\text{Mortality rate (\%)} = \frac{\text{No. of fish at stocking} - \text{No. of fish at harvesting}}{\text{No. of fish at stocking}} \times 100$$

$$\text{Specific Growth Rate (SGR) (\%)} = \frac{\ln (W\,t1) - \ln (W\,t0)}{t} \times 100$$

$$\text{Mortality rate (\%)} = \frac{\text{No. of initial stock} - \text{No. of final harvest}}{\text{No. of initial stock}} \times 100$$

$$\text{Food Conversion Ratio (FCR)} = \frac{\text{Feed given}}{\text{Weight gain of fish}}$$

10.2.7 Economic Analysis

Actual price of pond materials, fish fries and feed were used. The valuation of fish price was done by local market price.

Net profit (K) = Total sale (K) – Per cycle investment (K)

$$\text{Return on total investment (\%)} = \frac{\text{Net profit (K)}}{\text{Total cost (K)}} \times 100$$

10.2.8 Business planning

A business plan is a decision making tool that takes the form of a formal document. It states your business goals, why you think you can achieve them, and lays out your plan for doing so. Business planning is also a process, not an end product. A farm business plan is a work in progress, which farm business owners or operators will want to revisit regularly. A Farm or enterprise budget seen earlier is an integral part of the business plan.

A business plan describes;

- What you will produce (describe your product, e.g. table size tilapia, fingerling supply or both)
- How you will produce it
- Resources required to set up and operate systems
- Who you will sell it to
- Costs of production
- Whether it will be profitable or not

In compiling a business plan and anticipating the costs of starting-up a business, a simple business plan must cover the following aspects:

(a) A project overview that concisely describes the project concept.

(b) The reason for initiating the project: what advantages the project has, describing its overall design and method of operation.

(c) A costing exercise for the project, divided into the following aspects:

- Initiation costs: the costs of obtaining permits, surveys, water rights, business partnerships and other legal aspects in setting up a business.
- Construction costs: all the anticipated material and labor costs, including capital items such as land, vehicles and machinery.
- Start-up costs: these include obtaining broodstock, stationary and office equipment, feeds and medications, electrical and telephone connections, etc.
- Running costs: these include all expenses incurred before the project provides a return that equals or exceeds the running costs (profit). Examples are electricity, telephone, staff salaries, feed, fuel, transport, etc. run, including staff hierarchy and duties, stocking plan, anticipated growth, and harvest schedules.
- A description of marketing potential and techniques to penetrate local or other markets, including any potential prospects for value adding to the product offered for sale.
- Strengths and weaknesses of the project: these can be grouped under headings such as site, facilities, species, anticipated production volume, local markets, distant markets, and potential for expansion or diversification.
- Future potential prospects for the project.

10.2.9 Financial planning

Starting an aquaculture business can be an expensive exercise. It is important that you first acknowledge that starting an aquaculture business is a big decision and requires serious commitment. Like any other business venture, some research needs to be done before money is invested. Depending on what you intend to use the fish for (i.e. only to feed you and your family, or to sell and eat a few) will also influence the size, scale and expense of the fish-farming operation.

10.2.10 Economic considerations

- Do you own or have access to an appropriate site?
- Have you determined what your financial responsibilities will be to start your fish farm?
- How much money would you need?

- When would you need the money?
- What would the money be used for?
- Would you require financial assistance and if so, how would you repay it?
- If you need a loan, can you secure sufficient money at a reasonable interest rate?
- Have you made a realistic assessment of the timing and scale of expected returns on your investment?
- Are there adequate cash reserves for unanticipated costs, such as equipment and/or unexpected loss of the fish?

10.3 Factors to consider for profitable aquaculture

Under the right condition, aquaculture can be very profitable. The following checklist of questions can help determine whether an aquaculture enterprise is feasible for a particular situation or not. This does not overlook the other aspects of accounting principles which we will not go study detail. Also answering "yes" to cost of items/issues raised would not guarantee success just as answering "no" does not guarantee automatic failure. It is very advisable to contact your local extension agents for more technical details.

10.3.1 Management

The role of management is central to the success of any business enterprise. Management involves the integration of manpower, materials and money in a judicious way, such that anticipated profits can be assured. Practicing and potential aquaculturists should be guided by the following questions.

- Do you already have suitable pond or a site suitable for ponds?
- Do you have most of the machinery and equipment needed?
- Do you have the necessary financial resources?
- Is the potential of profit higher in aquaculture than that of other possible enterprises?
- Will the expected profit be adequate compensation for your labor, management and risk?
- Will investment and operating capital interest rates permit a reasonable profit?
- Is tilapia breeding business the most suitable for your situation?
- Will you be able to forego income until you sell your fingerlings or fish crop? Are you able to absorb occasional losses?
- Are you willing to devote daily the time and effort required?

Aquaculture is capable of significantly expanding the availability of fish products and the basic economic law of demand and supply will cause prices to fall as supplies increase.

10.3.2 Marketing fish in general

In fish farming, market has key role to play in the management decisions taken on any aspect. Management decisions, which affect customers, are part of marketing and must be considered from marketing point of view. Marketing strategies for fish farmers involve the following procedures.

- Identify changing demands of market places
- Match production to market need
- Select ideal candidate fish species for culture i.e. fast growers, hardy, and good feed converters•
- Evaluate market acceptance of fish species to be grown
- Attempt satisfying buying pattern of consumers. More demand should lead to farm expansion.
- Match production and consumers needs to available resources.

Apply the marketing mix concept. (4ps)

- Product planning and development
- Place for transfer of product to consumer i.e. ideal selling location.
- Promotion of product sales by advertisement and other sales promotion
- Price determination and pricing policy

Relevant questions in marketing the fish are:

- Do you know any established market for your fish?
- Will the market for your fish at the planned sales time be available?
- Are there suitable arrangements for harvesting your fish?
- Can you be flexible and harvest fish during the off-season?
- Is there an alternative marketing strategy which you hope to fall back to in case there is a problem with current arrangement?

10.3.3 Marketing considerations for fry/ fingerlings

Marketing is an important aspect of seed production. In order to increase seed production and sales, a good marketing strategy is needed. The fundamental principle is that it is wise to produce seed at a time when there is good demand.

When fry/fingerlings are sold and transported, the following steps should be followed:

- Fry/fingerlings should be nursed in small hapa(s) before delivery. It is best to keep them in an area easily seen by and accessible to potential customers e.g. near to road side. Any fry producer has to give information to the farmers or fry traders that he/she is producing quality fry for which appropriate media have to be selected. Importantly, customer satisfaction is the key factor in attracting more clients. A satisfied local customer can bring many of their neighbors, relatives and friends. Thus, word of mouth advertising can't be overlooked.
- Decreasing the price and advertising can attract more customers though it may decrease overall profits.
- Demand for fry is seasonal. As fry cannot be stored for long periods (max 3 months), production has to be streamlined with the demand. It is extremely difficult to forecast; however, an experience manager can possibly determine demand patterns over time.
- Advanced nursing can be a valuable tool to produce returns in the following season on previously unsold fry.

10.3.4 Quality assessment and certification

- Fry quality can be assessed by observing the movement, color, shape, size and responses to feed and strangers.
- Fry quality can also be tested using the salinity challenge test (select 100 fry, submerge in 24 ppt salt solution for two hours; repeat it twice or thrice; observe survival, it should be about 50%, the batches with higher survival rates can be considered as better quality which increases market value).
- Each hatchery should carry out quality monitoring either by themselves or by an independent body e.g. research institutions or private companies.
- Quality of sex-reversed fry is monitored mainly in terms of percentage of male. As basic requirement 99% or higher should be the percentage of male. Hatchery owners should assess the quality regularly (at least monthly) in order to be confident for themselves and also assure for their customers.

10.3.5 Physical Conditions

Good physical conditions that are required for fish to grow well under culture are prerequisites to successful enterprise. Topography, soil structure, regular water supply, and security issues are important. Consider these questions in meeting adequate physical conditions;

- Is the topography of the area suitable for pond construction?
- Will the soil retain water?
- Are there enough water supplies to replace any water loss?
- Is the pond area liable to flooding?
- Are the drains adequate for proper water drainage?
- Is the pond bottom stump-free to prevent difficulties in harvesting?
- Is the pond close to your residence for prompt management and monitoring?

10.3.6 Production

Major factors of production that are indispensable in economics are: land, labor and capital. In aquaculture, the source of fingerlings, adequacy of feed inputs and drugs, availability of technical support (extension and consultancy) and feed storage facilities are also important production factors. Farmers should face the challenges of the following questions for enhanced production:

- Are good quality feeds readily available at competitive prices?
- Do you have reliable supply of drugs and other chemicals?
- Is the source of your fingerlings or broodstock reliable?
- Do you have dependable labor?
- Is your feed storage facility a good one?
- Do you know the extension agent/fishery officer in your area?

10.4 Tilapia supply chain major players

Small holders operate in a critical supply chains, thus, value chain becomes necessary for sustaining smallholder growth. Supply chain management provides one conceptual approach to build the capacity of producers to match the products that they will be aiming to supply. Supply chain improvement not only benefits the private sector but also creates spin-offs that stimulate social, economic, environmental and sustainable development (employment generation, added value, minimization of product losses etc.).

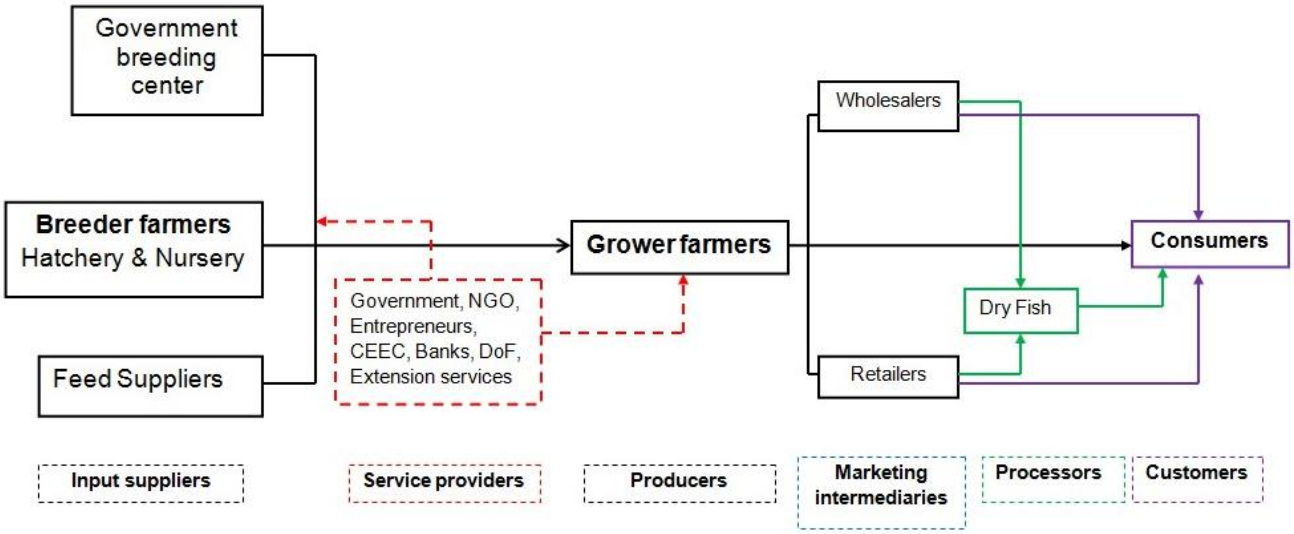


Figure 10-1: Tilapia supply chain

10.5 Tilapia breeder and cluster farmer groups

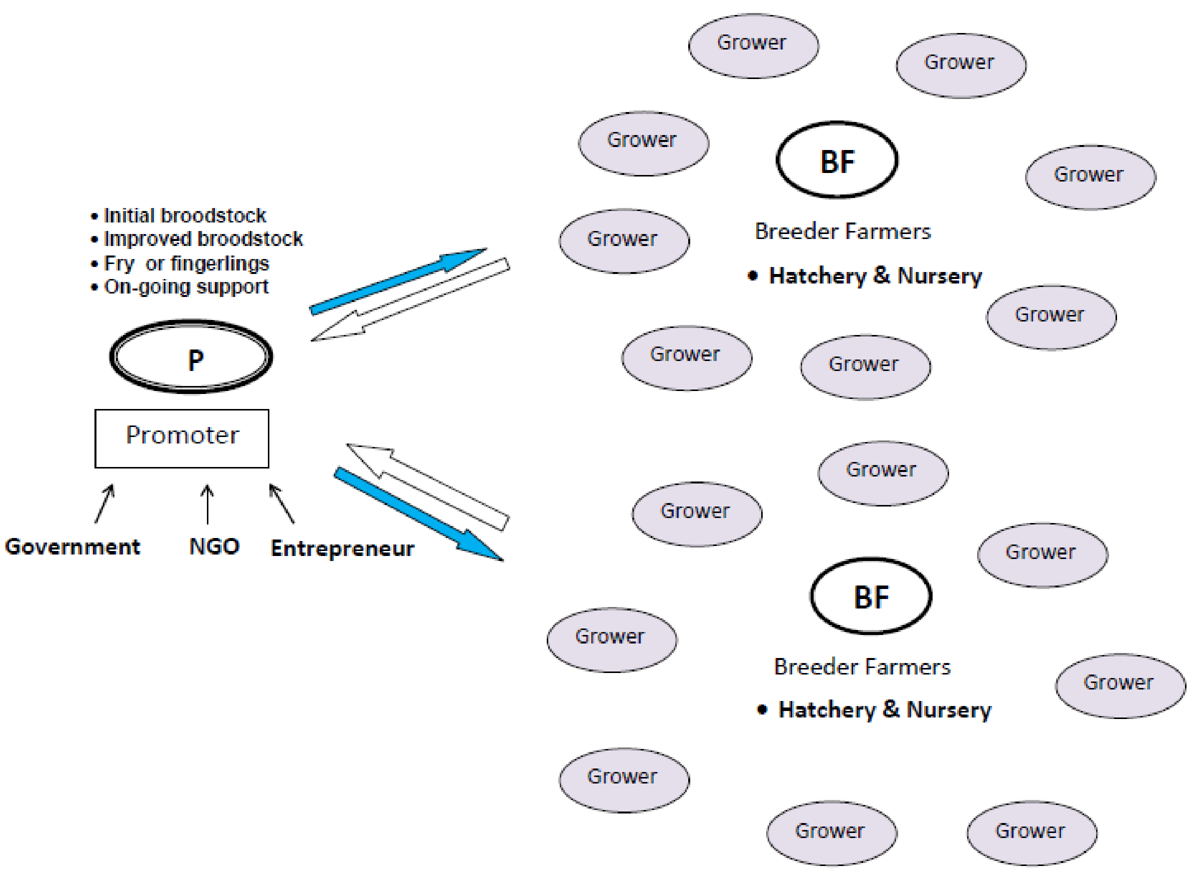


Figure 10-2: Organizational diagram of promoter, breeders and cluster groups

10.6 Concept of cluster or small farmer groups

A cluster in this context consists of grower farmers positioned around breeder farmers so as to productive advantage from their mutual proximity and connections. In more general terms, clusters can be defined as groups of farmers, related aquaculture actors, and support institutions that are located near each other and have reached a sufficient scale to develop specialized expertise, services, resources, suppliers and skills

10.6.1 Characteristics of Clusters

The clusters may have the following characteristics:

- Common needs and interests
- Interdependent and overlapping
- Talent and creativity
- Innovation

10.6.2 Effectiveness and benefits of clusters

- Clusters are defined by interdependencies and are inclusive of other economic development approaches.

- Clusters drive innovation and innovation drives productivity. Clusters provide the critical mass for this to occur by facilitating interaction by participants

- Thirdly, clusters provide benefits to all involved. It provides them with access to all players, attracting brainpower, expertise and local suppliers.

10.6.3 Elements of cluster development

a) **Legitimacy**
Cluster initiatives need both leadership (provided mostly by private sector) and legitimacy (provided mostly by public sector).

b) **Cluster facilitator**
Facilitators can play a central role in the process of cluster development. Cluster development can be 'sparked' by a facilitator, providing their integrity, honesty and trust-worthiness are evident.

c) **Association**

Association encourages and facilitates business networks and cluster-specific business associations by supporting facilitators and collaborative projects.

d) **Support**

Establishing integrated public sector support for a cluster is significant but not an easy achievement.

e) **Specialization**

Specialization affects business and technical assistance, research and development, market assistance and information, and often most importantly education and training, shaping it to the particular needs of the farmers in the cluster.

f) **Collaboration**

Clustering is one form of collaborative engagement. Complementing this within clusters are other forms including soft and hard networks, and value/supply chains.

10.6.4 What makes a cluster successful?

Ideally the following pre-requisites are needed for effective clusters:

- Good input conditions (such as skills and knowledge, raw resources).
- Supporting industries
- Demand (sophisticated customers who can distinguish different qualities and brands and demand high standards).
- Rivalry (competition) and the desire to work together. Effective clusters involve a combination of pressure (competition) and support

APPENDICES

APPENDIX 1: How to use a secchi disk

How to use a secchi disk with reference water color chart and interpret results?

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 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)

- Lower the secchi disc until the black and white areas of the disc are not visible separately.
- Record the depth.
- Raise the disc in the water gradually and record the depth at which the black and white areas are separately visible again.
- Take the average of the two depth recordings as the transparency of pond water.
- Look at the reference color chart to assess what sort of turbidity you have (whether phytoplankton or clay)

The Pond Reference Color 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 fertilizer or lime to the pond. The colors are an indication of the different kinds of turbidity-clay turbidity and turbidity caused by plankton blooms.

Common pond colors	Comments and personal notes

Brownish Waters are normally caused by soil particles suspended in the water column. Clay is among the causes. The color 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 color 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 behavior of the fish.

Greenish colors 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.

Interpretation of the Results

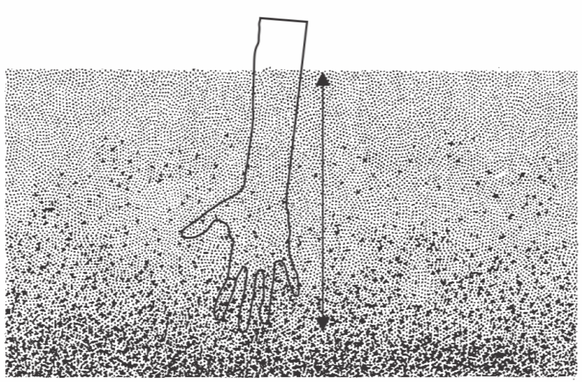
The results of the secchi disc readings and the reference color chart are interpreted as described in the table below.

The relationship between Secchi Disc Visibility, and Management Requirements for Maintaining Phytoplankton Blooms

Secchi Disk Reading (cm)	Comments
Less than 20	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 (e.g clay), productivity will be low. Do not add more fertilizer. If there is a foul smell, flush the pond.
20-30cm	Turbidity is good for tilapia production. Do not add more fertilizer if turbidity is less than 25 cm. Levels of fertilization during production should be to maintain this level with the prescribed level of fertilization.
30-45cm	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.
45-60cm	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 fertilizer. Weed them out first.

How to estimation of transparency without a seechi disc

- A rough indication of the transparency can be obtained by immersing your hand into the pond and see at what depth you cannot see your tip of the middle finger.



Appendix II. SOME USEFUL CONVERSION FACTORS

To Convert	Multiply By	To
are	100	sq. meter
acres	0.4047	hectares
acres	4047	sq. meters
celsius, degrees	32	fahrenheit, degrees
cubic meters	264.2	gallons (US)
cubic meters	1000	Liters
foot	0.3048	meters
gallons (US)	3.785	liters
gallons/min.	0.06308	liters/sec.
hectare	10000	sq. meters
hectare	2.47	acres
horsepower	745.7	watts
kilograms	2.2046	pounds
kilograms	1000	gram
kilograms	0.001	tons (metric)
kilometers	1000	meters
kilometer	0.6214	miles
kilowatt	1000	watts
kilowatt	1.34	horsepower
square feet	0.0929	sq. meters
square meters	0.0001	hectares
tons (metric)	2205	pounds
teaspoon	4.9	milliliters
tablespoon	14.8	milliliters

Appendix III. FLOW RATES

1 gal(US)/min = 0.00223 ft^3/sec = 0.0631 L/sec = 5.42 m^3/day

1 ft3/sec = 449 gal(US)/min = 28.3 L/sec = 0.0283 m^3/sec = 2,450 m^3/day

1 L/sec = 15.9 gal(US)/min = 0.0353 ft^3/sec = 86.4 m^3/day

1 m3/sec = 15,800 gal(US)/min = 35.3 ft^3/sec = 86,400 m^3/day

(modified from Hanley, 2005)

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