

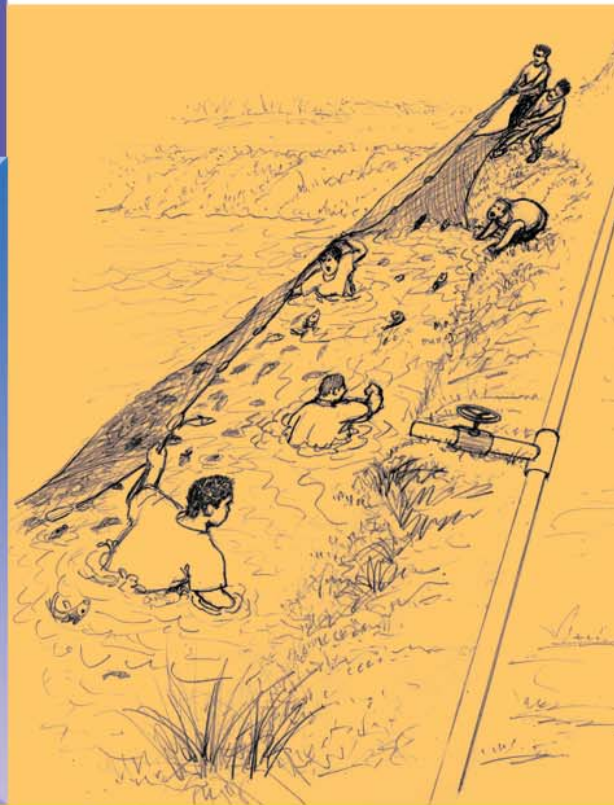
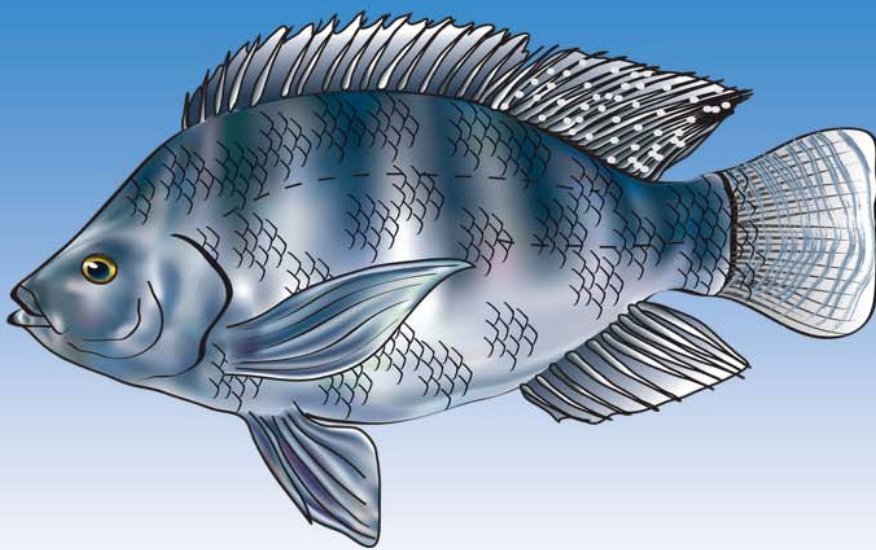
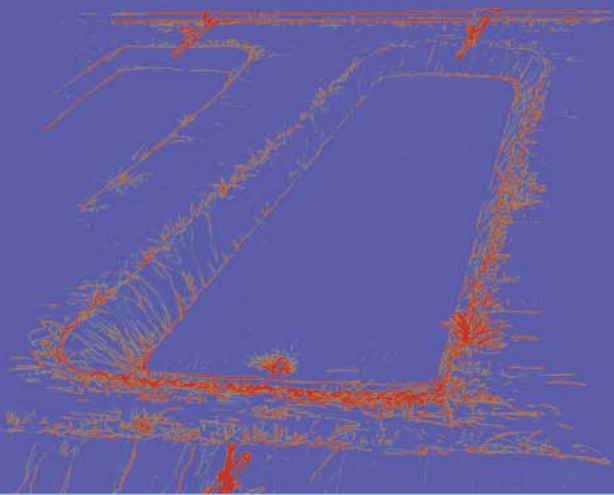
Tilapia fish farming in Pacific Island countries

Volume: 2

Tilapia Grow-out in Ponds

By
Satya Nandlal

and
Timothy Pickering



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Volume Two

Tilapia Grow-out in ponds

By

**Satya Nandlal
Secretariat of the Pacific Community**

and

**Timothy Pickering
The University of the South Pacific**

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Secretariat of the Pacific Community
BP D5
98848 Noumea Cedex
New Caledonia
Tel: 687 26.20.00
Fax: 687 26.38.18
Email: spc@spc.int
<http://www.spc.int>

Marine Studies Program
The University of the South Pacific (USP)
Private Bag
Suva
Fiji Islands
www.usp.ac.fj/marine
www.usp.ac.fj/imr

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Preface

This book was developed from training workshops run in Fiji Islands from 2002 to 2004 jointly by the Marine Studies Program and the Institute of Marine Resources of the University of the South Pacific (USP) and the Aquaculture Programme of the Secretariat of the Pacific Community (SPC), with funding provided by the Government of Canada under the Canada – South Pacific Oceans Development Programme Phase II (C-SPODP-II). The book's production costs were met by C-SPODP funds granted to USP's Marine Studies Program and by AusAID funds granted to SPC's Aquaculture Programme.

The book is intended for fish farmers at subsistence or small-scale commercial level, and can be used as a textbook for training by the Fisheries Department officers, staff of rural community development projects, school teachers, or other people responsible for imparting good fish-culture practices to people engaged in tilapia fish farming in Pacific Island countries.

Compared with Volume One, *Tilapia Hatchery Operation*, this volume, *Tilapia Grow-out in Ponds* assumes less biological knowledge and has more emphasis on practical techniques for raising tilapia in ponds. This makes it more suitable for people who are new to fish farming, or who only want to be involved in the grow-out of tilapia.

There are many booklets and training materials already available in the world for tilapia farming. However, these are written mainly for Asian readers and contain a lot of detailed information. This book is written for Pacific Island countries based upon practical experience of what works in the region's varied environmental and cultural circumstances, and provides the essential information needed for a fish farmer to get started.

Satya Nandlal
Aquaculture Programme
Secretariat of the Pacific Community

Timothy Pickering
Marine Studies Program
The University of the South Pacific



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Introduction

Tilapia fish originate from Africa, and were introduced for farming to Asia and some Pacific Island countries from the 1950s onwards. Tilapia farming is expanding world-wide in both developed and developing countries, because of the rapid growth rate and hardy characteristics of this freshwater fish. Tilapia can be commercially farmed in ponds, in cages in lakes or rivers, or in tanks or raceways.

In the Pacific Island region, by 2004 there were about 100ha of freshwater fish ponds, and some fish cages in lakes and reservoirs. The main farming method used in this region is the pond method. In Fiji, harvest of farmed tilapia has now surpassed 400 metric tonnes, and tilapia is the most widely farmed freshwater fish.

According to newspaper articles, Mozambique tilapia (*Oreochromis mossambicus*) was introduced from Asia to the Pacific in the 1950s. In Fiji, initially they were introduced to feed to pigs but people also began eating them. By the mid 1960s tilapia had been introduced into almost all the major rivers of the two main islands of Viti Levu and Vanua Levu. Tilapia was also introduced to Tuvalu, Kiribati, Papua New Guinea, Solomon Islands, Samoa, American Samoa, Cook Islands, and other islands.

Some past introductions of Mozambique tilapia into lakes and rivers of Pacific Island countries have been inappropriate, causing problems in some places through predation on native fishes and competition with other farmed fish like milkfish. Another problem with Mozambique tilapia is that they breed at the age of only 2–3 months, so they are very small at first breeding. Mozambique tilapia is nowadays considered less suitable for farming than the Nile tilapia.

Because of the problems that tilapia might cause, we urge caution and restraint regarding any further introductions of tilapia into new countries, provinces or water catchments where it has not yet been introduced. However, where Mozambique tilapia is already well established and impossible to eradicate, Nile tilapia could be taken there to turn the presence of tilapia from a “minus” to a “plus” through well managed farming.

A lot of people express interest in fish farming, but before making a decision they must investigate carefully the costs and requirements for becoming a successful farmer. Fish farming is not for everyone and is certainly not for the “weekend farmer”, because fish are living animals that require daily attention and patience. Other educational materials available from USP and SPC (for example, *Profiles of High Interest Aquaculture Commodities for Pacific Island Countries and Economic Models for Aquaculture and Agriculture Commodities*) can, with assistance from the Fisheries Department, help people to decide whether to become involved in fish farming or not.

This book assumes that the decision to become a tilapia fish farmer has already been made, and provides practical information on site selection, construction of ponds, pond preparation, fish stocking and management, harvest of fish, and other information needed for subsistence or small-scale commercial grow-out of tilapia using the pond method in Pacific Island countries.

Tilapia fish farming

Tilapia have good characteristics for fish farming, and are now so domesticated that they have earned the title “the aquatic chicken”. They are fast-growing, able to survive in poor water conditions, eat a wide range of food types, and breed easily with no need for special hatchery technology.

Tilapia are one of the best researched species for aquaculture. They are tough and tolerate a wide range of environmental conditions, so little environmental modification is needed and aquaculture systems can be low-tech. Earthen ponds in non-flood-prone areas will be sufficient. Concrete tanks or raceways can be used, but are more expensive to build and usually cannot be justified. Cages in lakes or rivers can also be used.

Tilapia also have some bad characteristics for aquaculture. Uncontrolled breeding in ponds can lead to overcrowding and stunted growth. Once tilapia are present in a pond, they are difficult to get rid of except by poisoning or by draining the place and leaving it to dry until the bottom has baked hard in the sun. They need to live in warm water and do not grow well if the water temperature is lower than 22°C.

Efficient tilapia farming calls for a farming method where

- (1) Nile tilapia — not Mozambique tilapia — are used
- (2) the pond can be prepared properly
- (3) adequate numbers of good-quality and similar-sized fingerlings can be obtained for stocking, and
- (4) the ponds are managed well.

Types of tilapia

All commercially important tilapia outside of Asia and Africa belong to the genus *Oreochromis*. The most popular farmed species is the Nile tilapia, *Oreochromis niloticus*. Less commonly farmed species are red hybrid tilapia, Mozambique tilapia *Oreochromis mossambicus*, and blue tilapia *Oreochromis aureus*.

The appearance and external anatomy of tilapia is shown in Fig. 1. Tilapia usually can be distinguished by different banding patterns on the caudal fin. Nile tilapia have strong vertical bands whereas Mozambique tilapia have weak or no bands on the caudal fins. Colour patterns on the body and fins can also be used to distinguish species. Mature male Nile tilapia have grey or pink pigmentation in the throat region, while Mozambique tilapia have a more yellow colouration. However, colouration is often an unreliable method of distinguishing tilapia species because environment, state of sexual maturity, and food source greatly influence colour intensity.

In ponds, Nile tilapia become sexually mature at three to five months of age and weigh 150–200g, while Mozambique tilapia mature earlier (2–3 months) and at a much smaller size. This is why Nile tilapia are a better fish for farming: they have a longer time to grow to a good size before they breed (which is when growth slows down).

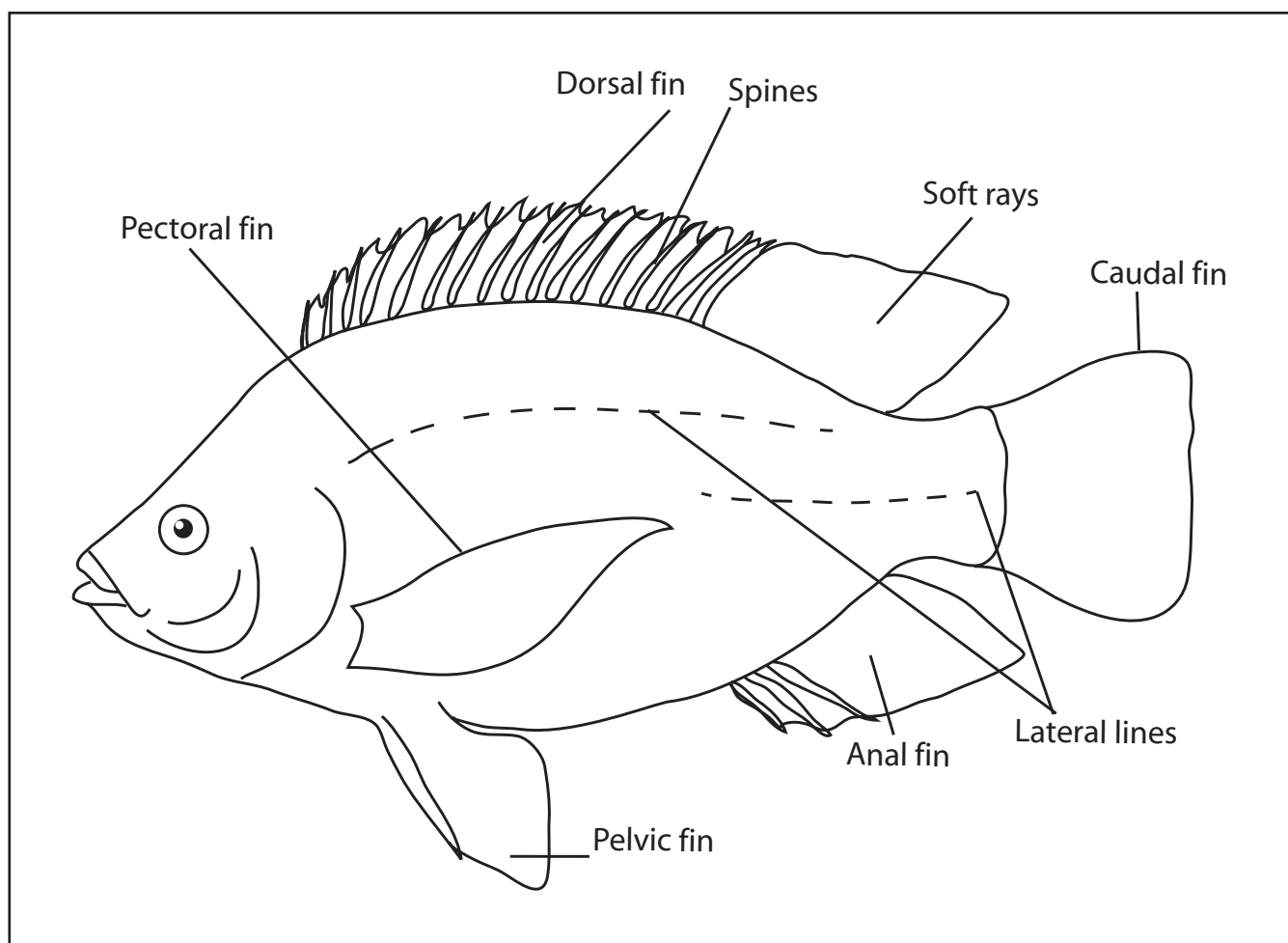


Fig. 1. External anatomy of tilapia

Site selection

Considerable thought and planning should go into selecting sites for ponds. The site selected should be compatible with tilapia culture. For example, it must have dependable water supply, soil with good water-holding capability, and land that has gentle slope.

Tilapia are hardy fish and can be grown in very harsh environments. However, for successful farming it is necessary to ensure the site can provide an environment where the water quality factors can be maintained in the range known to be good for tilapia. The important factors to be checked are water temperature, dissolved oxygen, acidity (pH) and salinity.

Ideally a farmer should look at different possible farm sites, and choose one that not only meets the needs of tilapia culture but is a place where the farmer can live close by (Fig. 2). Having the ponds near the farmer's house will give easy access for carrying out daily activities and also reduce losses to poachers. The following are the important factors for the pond site:

- Flat or gently sloping land that does not get flooded
- Water source of sufficient volume and quality, preferably at a higher level than the ponds so that water can fill the ponds by gravity rather than by pumping
- Water source preferably on land owned by the farmer
- Place for water to drain away is lower than the ponds, so that ponds can be emptied by gravity rather than by pumping out
- Water drained out will not mix with water used for domestic purposes
- Soil with enough clay to hold water
- Close to farmer's house

If gravity flow of water into or out of the ponds is not possible, the farmer will need to pump the water in or out. The cost of fuel or electricity for the pump needs to be taken into account when planning, as well as the cost of hoses and pump, or rental of pump.

If there is limited choice, then as many of the above criteria as possible should be met. For example, a farm can still succeed if water has to be either pumped in to fill ponds, or pumped out to empty them; however, the chances of success are less if both have to be done.

If there are other farmers already successfully farming tilapia nearby on similar land, then there is a good probability that the new farm will also be successful. The Fisheries Department can help with more advice on site selection if needed.

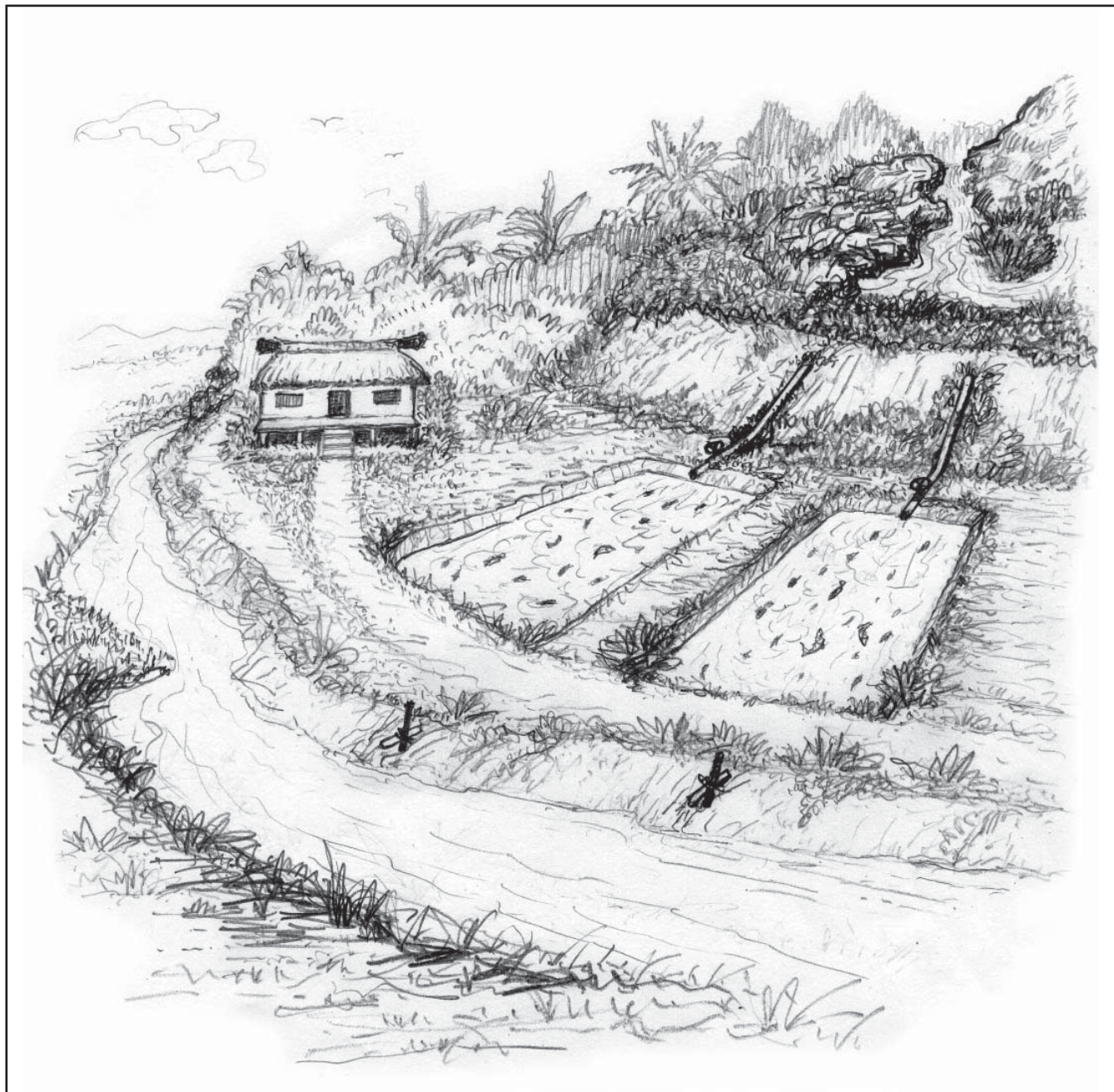


Fig. 2. Ideal farm layout

Once a site has been identified, there are other questions that need to be answered honestly by the farmer:

- Who owns the land?
- If it belongs to the farmer, are the necessary ownership documents available?
- If the land is owned by a clan or traditional land-owning group, does the farmer have the necessary documents showing approvals for lease, or any customary approvals that may be needed?
- Will there ever be developments upstream (e.g. pig farm, pesticide spraying, factories etc.) that may spoil the water source for the fish farm?
- Is there space to add more ponds in the future?
- Will the cost of pumping water be affordable from the fish farm income?
- How far is it to markets for selling the fish?
- Are the road conditions good to allow trucks to transport supplies and fish for selling?

The worst error a fish farmer can make is to develop an area in haste and without any program of activities. Money will be wasted and operation of the project may be difficult if not carefully planned. Poor planning has been a major cause of project failures in the Pacific. Once constructed, the physical structures become permanent and difficult to correct.

Whether the farmer will use personal money or apply for a loan from banks to finance the development of the project, a feasibility study of the area will be needed (if developing semi-commercial or commercial farms). The feasibility study will guide the development and management of the project. Items such as construction costs, operational costs, and financial analysis to determine returns on investment should be considered carefully as part of the feasibility study. The rest of this section below covers other matters that the feasibility study should take into account.

Water source

Water is the most important factor to consider in determining the suitability of a site, especially for semi-commercial or commercial tilapia farming. Fish will not grow unless there is enough water. Water is essential: (1) to fill the ponds for stocking, (2) to refill ponds to replace losses due to seepage or evaporation, (3) to flush the pond regularly, and (4) in emergencies, to flush out ponds if water quality gets bad so that fish start dying.

The water may come from a stream or river, spring, groundwater (well or borehole) or reservoir, surface run-off, or brackish water. The water source should not dry up in the dry season. The pond should have its own water source, and not share with a school or village that in times of drought will take priority.

The land basin that drains into the site of the pond is called the water catchment. The farmer needs to consider the size and slope of this catchment, who owns it, and what it is being used for, before building a pond. Pond water obtained from streams and surface run-off originates from the catchment. Generally a 1000m² pond should have a hectare of catchment.

If too much water drains towards the pond, spillway structures will be needed to shelter the pond from large inflows of water after heavy storms. On the other hand, if the catchment is too small, then sufficient water levels may not be maintained during dry conditions. Achieving the proper water catchment-to-pond size ratio is one reason that technical guidance is important in building a pond.

It is difficult to provide any set rule about how much water volume or flow rate needs to be available, except that the amount of water should be sufficient to keep the ponds full all year round. In some high-rainfall areas this can be achieved with ponds that are rain-fed, with no additional water from any other sources. However, a water supply will be needed if the pond takes months to hold water after digging, or if evaporation takes out water (for example, in dry sunny areas), or for ponds dug in sandy soils that hold water poorly. A good supply of water from a stream, river, lake or canal, or from a purpose-built reservoir, is also needed if the pond has to be flushed out when water quality gets out of control especially for semi-intensive farming.

The best water comes from fast-flowing streams or rivers with rocky or stony beds. Such water is usually rich in oxygen and contains at least some nutrients. But care should be taken as streams and rivers usually contain wild fish that can get into the pond and cause problems. Wild fish can be stopped from entering the ponds by a screen over the pond water inlet (see Fig. 10).

Underground water (from a spring, well or borehole) will not have wild fish in it, but generally water from these sources is poor in oxygen and nutrients. Water from marshes or peat swamps should not be used as it is acidic (low pH).



The water should be free from agricultural pesticides and any type of pollution. It should be clear of mud and silt.

The water can be tested to find out whether the pH, hardness and salinity values are within the range that is good for tilapia growth. If the farmer does not have access to the equipment to make these checks, this service could be requested from the Fisheries Department, or provided by a professional water analytical laboratory.

Water quality values known to be good for raising tilapia are given in Table 1 in the Daily Management section.

Type of soil

The farmer, with guidance from the Fisheries Department, needs to identify the type of soil at the proposed pond location, since different types of soil have differing abilities to hold water. The pond soil must have enough clay content to ensure that the pond will hold water. When clay soil absorbs water it swells and seals the bottom and sides of the pond.

Soil with clay content in the range of 20–50% clay down to a depth of about one metre is best. Soil that is too sandy will cause problems: pond banks will erode easily and water will leak out through the pond bottom. If the soil is too sandy, then either an alternative site must be chosen, or a layer of clay soil will need to be compacted over the pond sides and bottom to prevent water seepage.

There are three simple tests to check if the soil has enough clay content: the water retention test (Fig. 3), the soil ball test and the soil ribbon test (Fig. 4).

Water retention test

1. Use a spade to dig 3–4 holes 1m deep in several parts of the proposed pond site.
2. Get a bucket and fill the holes about 10–20cm deep with water.
3. Wait about 15 minutes for the surrounding soil to get thoroughly wet, then make a mark on a stick, and drive the stick into the hole bottom until the mark matches with the water level.
4. Check each hole again after an hour or so, take the new level mark, and measure how much the water level has dropped, in millimetres. If the level has dropped by 3mm/hour or less, the soil is perfect. If the water level drop is between 3mm/hr and 5mm/hr, then the soil is satisfactory. If the water level drops by more than 5mm/hour, the soil is unsuitable.

Worked example of water retention test

The hole is filled with water at 3.17 p.m. At 4.53 p.m. (96 minutes later) the level has dropped by 7mm.

$$\begin{aligned}\text{Rate of seepage} &= 7\text{mm}/96\text{min} \\ &= 7/96 \text{ mm/min} \\ &= 0.0729\text{mm/min} \times 60\text{min} \\ &= 4.375\text{mm/hour}\end{aligned}$$

The water level has dropped less than 5mm/hour, indicating that the soil is satisfactory.

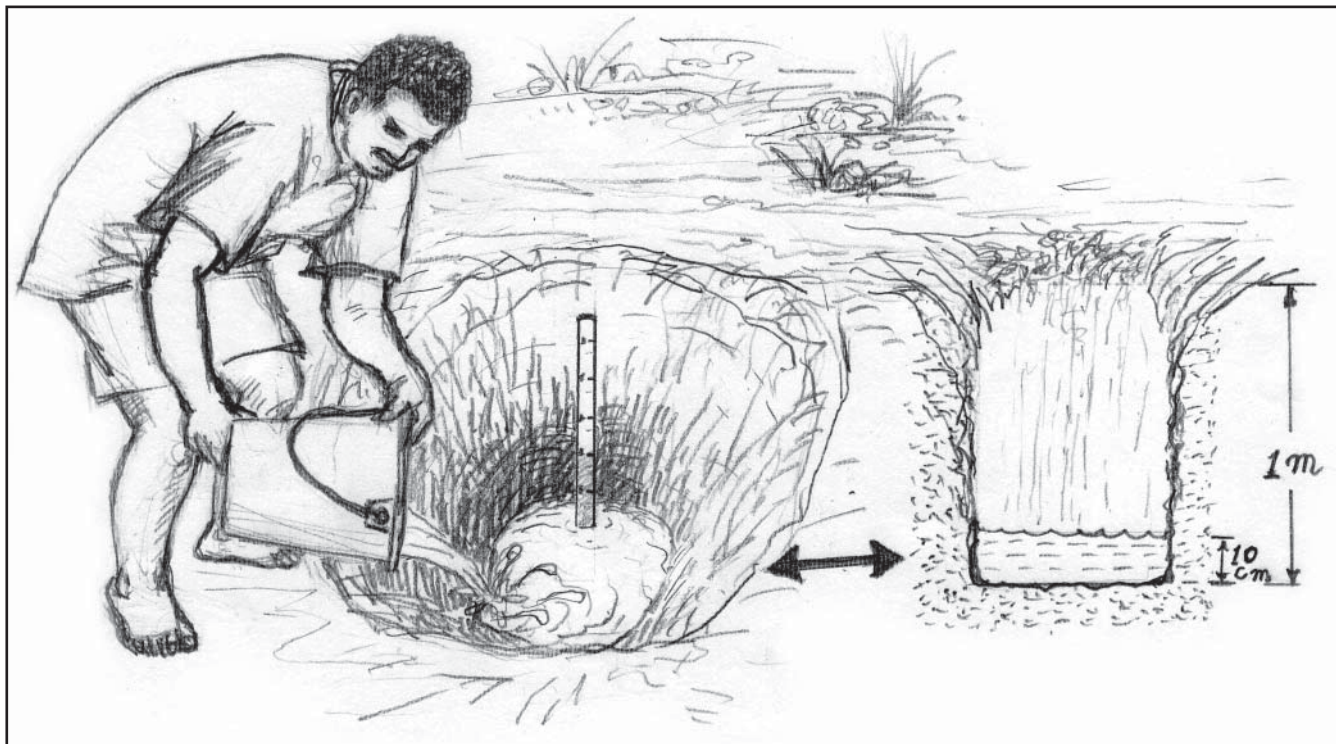


Fig. 3. Water retention test

Soil ball test

1. Take some of the soil dug earlier from the bottom of the hole.
2. Wet it slightly and form it into a round ball, slightly bigger than the size of a fist.
3. Drop the ball from head height onto flat ground. If the ball retains its shape, or goes only slightly out of shape, it has enough clay content and is thus good for pond construction. A ball made from soil that is too sandy will flatten out, crack open, or even shatter on impact to the ground. Alternatively, if the ball remains intact and does not crumble after considerable handling, there is enough clay in the soil.

Soil ribbon test

1. Take some of the soil dug earlier from the bottom of the hole.
2. Wet it slightly, and attempt to mould it into a flat ribbon of earth about 3cm wide and 6mm thick. If the moist soil forms into a ribbon of these dimensions, the soil has enough clay content. If the ribbon cracks and falls apart, the soil is too sandy and not suitable for pond construction.

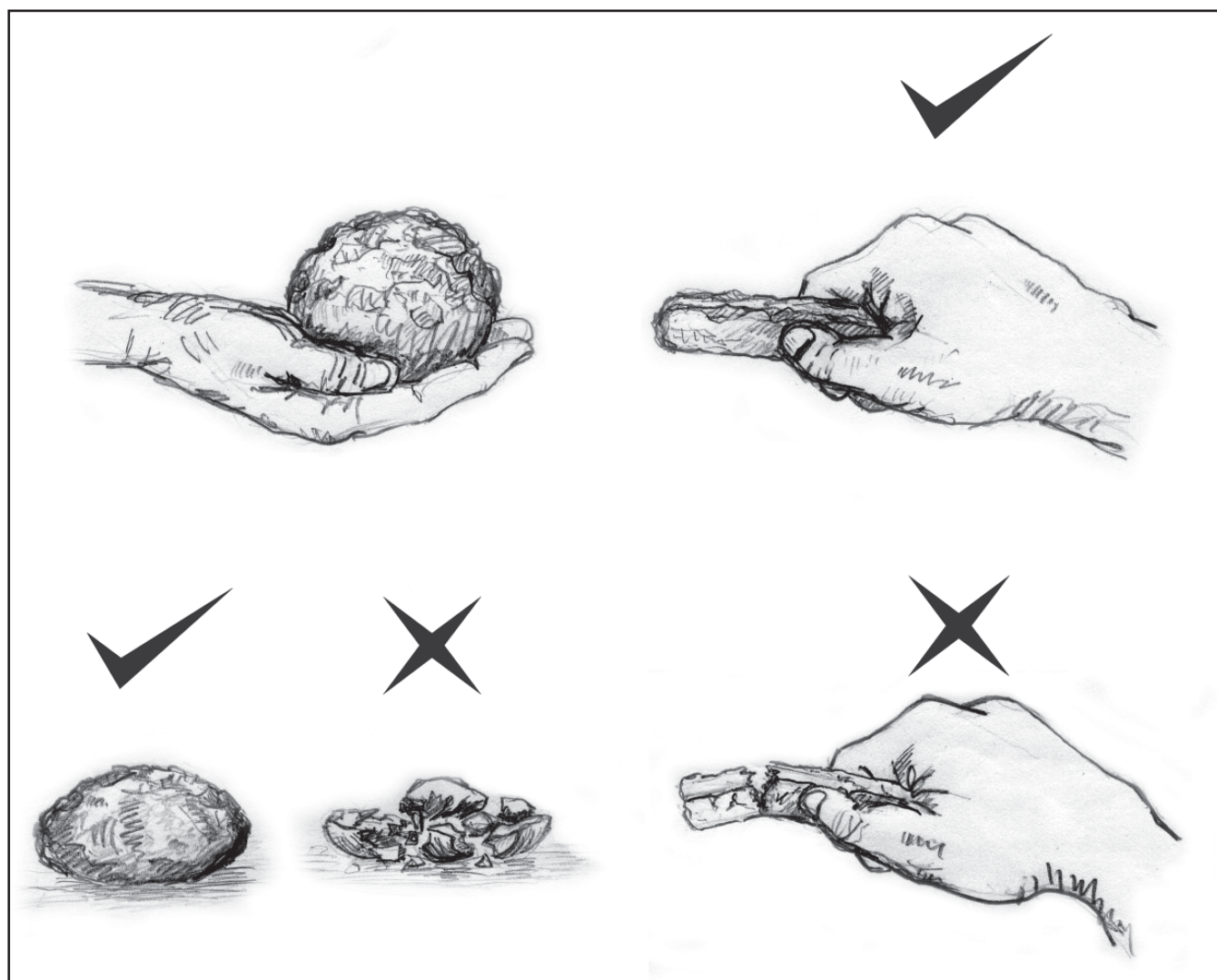


Fig. 4 Soil ball test (left) and ribbon test (right)

Topography

The topography or “lay of the land” is its shape: for example hilly, rolling, sloping or flat. Hilly and mountainous area should be ruled out as it is costly to move large quantities of soil during pond excavation. A moderately sloping area within a close distance of a water source is preferable.

Low-lying flat areas usually require high and large dykes (pond walls), to protect the ponds from floodwaters. Therefore in some instances soil will have to be moved in from outside the site for making the dykes. If the area is very low-lying, pond drainage will also be a problem.

Other site factors

Flood hazard

The risk of flooding has to be considered in site selection. Since floods cannot be controlled, it is important to choose a pond site that is free from flood hazard.

In order to plan to avoid flooding of the selected site, it is necessary to know the weather patterns in the locality. The rainfall records for at least the last 10 years need to be analyzed and the size of creeks, rivers and drainage canals checked to find out whether they can accommodate the run-off water in the area of the fish pond. The local government weather station or people who have stayed in the area for many years will know the highest flood occurring in the area.

Wind direction

Wind plays a role in fish pond design. Strong wind generates wave actions that damage the sides of the dyke. This causes expense in maintenance of the ponds. However, the problem can be minimized with proper planning and design. For example, the longer dimension of the pond should be positioned in the same direction as the prevailing wind (see Fig.5). This will mean only the shorter sides of the pond will be exposed to wave action.

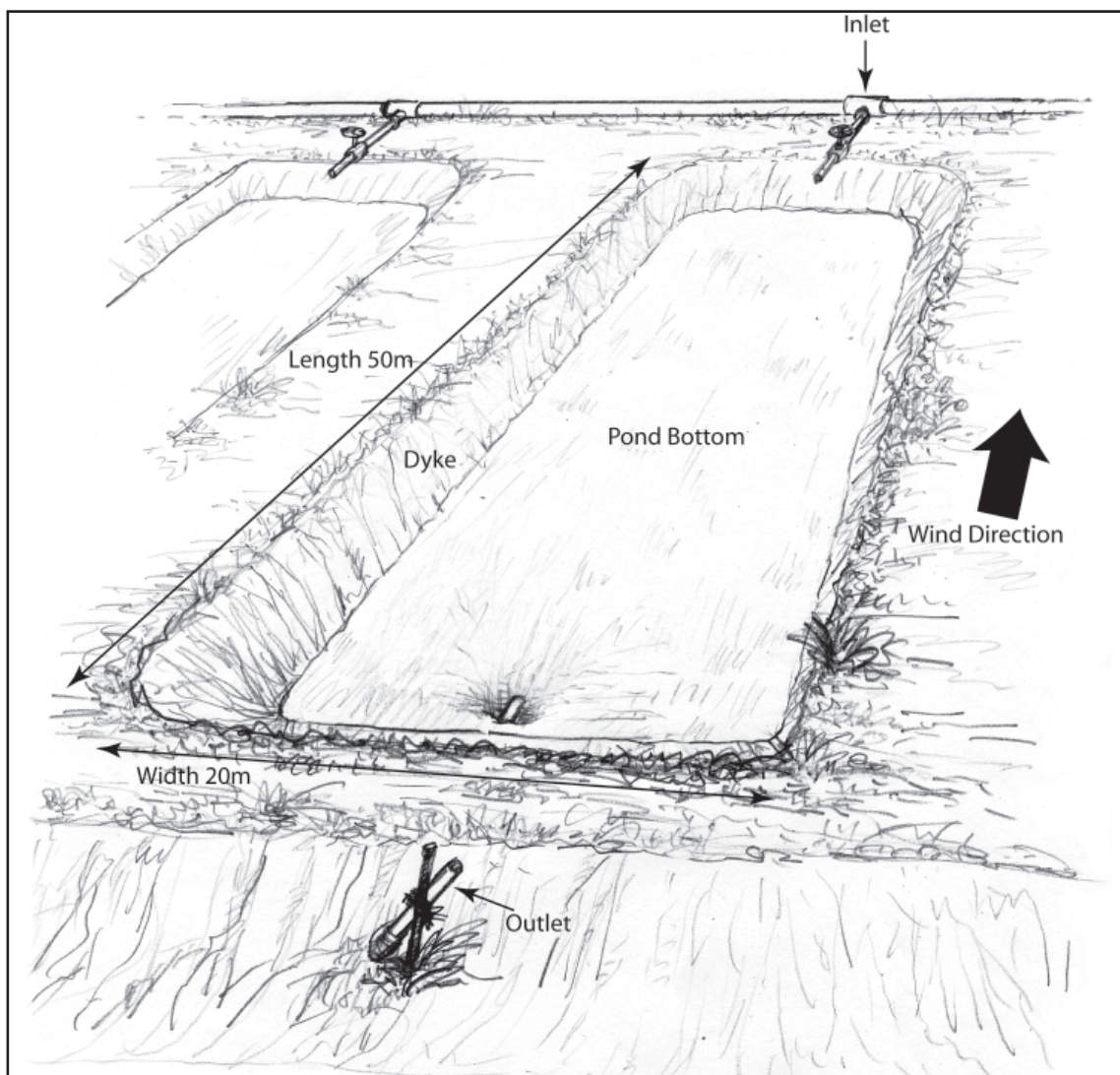


Fig. 5. Pond features



Type of vegetation

The type of vegetation, its density, and the size and root system of individual trees greatly affect the costs of clearing for farm development.

Availability of technical assistance

It is important to have access to technical services and advice from the Fisheries Department, or other service, and from financing institutions. Many fish farming projects in the Pacific have failed due to non-availability of quality technical services.

Sources of fingerlings

The farmer must find out about the availability and cost of fingerlings from local hatcheries.

Competing use of land and water sources

The uses made of nearby land and water have to be considered to find out whether they will have any effects on the project. Activities to assess include fishing, manufacturing industries, public utilities and recreation. Problems can arise particularly if the activities of local people are disrupted. It is important to ensure that the project does not interfere with traditional rights of way, or interfere with other work. In addition, check for underground water pipes and power lines before allowing heavy machinery onto the site.

Supplies and equipment

Ensure that supplies and equipment needed for the project are obtainable locally. For example, fine-mesh net material for screening or fertilizer might be difficult to obtain or available only infrequently. If material has to be imported, there may be restrictions or extra costs involved.

Marketing opportunities

It is important to determine the opportunities for selling the tilapia and to plan the production activities to suit the market. In some cases, partial harvesting or harvesting only one pond at a time may suit the local market situation. On the other hand, where fish have to be shipped out to a distant market, it is better to plan to be able to harvest and market large quantities at one time.

Pond features

Layout of ponds

It is very important to consider the layout of the ponds in relation to the topography of land, the source of water, and drainage. Also important is to allow for expansion of the fish farm at a later stage. The ponds, drainage canals and other facilities should be laid out in such a way that additional ponds can be constructed at a later stage.

A well-built pond is easier to operate, so careful attention to all the features of a pond will be well rewarded later. Below are features found in a well built pond.

Pond size and shape

Ponds of 500–2000m² are easy to manage by household farmers. Although the number of ponds is an individual decision, a few large ponds will be cheaper to construct than many small ponds of the same total surface area.

Most farmers build rectangular ponds, though irregularly shaped and even round ponds have been built. With rectangular ponds, the long axis of the pond can be placed to take advantage of winds blowing across the pond that aerate the water. In places where high winds are a problem, the long axis can be built parallel to the prevailing wind, thus minimising erosion from waves. In addition, rectangular ponds are more suitable for harvesting fish with a net. The length of the pond does not matter much but the preferred width is 15–20 metres, to suit the standard size of seine nets used for harvesting.

Pond bottom

In order for the water to drain out, the pond bottom slopes gently towards the outlet end of the pond. A minimum bottom slope of 0.1–0.2% is recommended. The pond bottom should be smooth and free from bumps and hollows, to make it easier to haul the seine nets and to catch as many fish as possible.

A catch pit or harvesting sump may be excavated around the water outlet (Fig. 6). Fish will swim into this pit as pond water drains out. The catch pit should be big enough to be able to contain almost all the fish in the pond at the time of harvesting. It also needs to have a supply of fresh water and/or aeration for the period that fish are concentrated in it.

Pond 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 (level of dyke above water, see Fig. 6). 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.

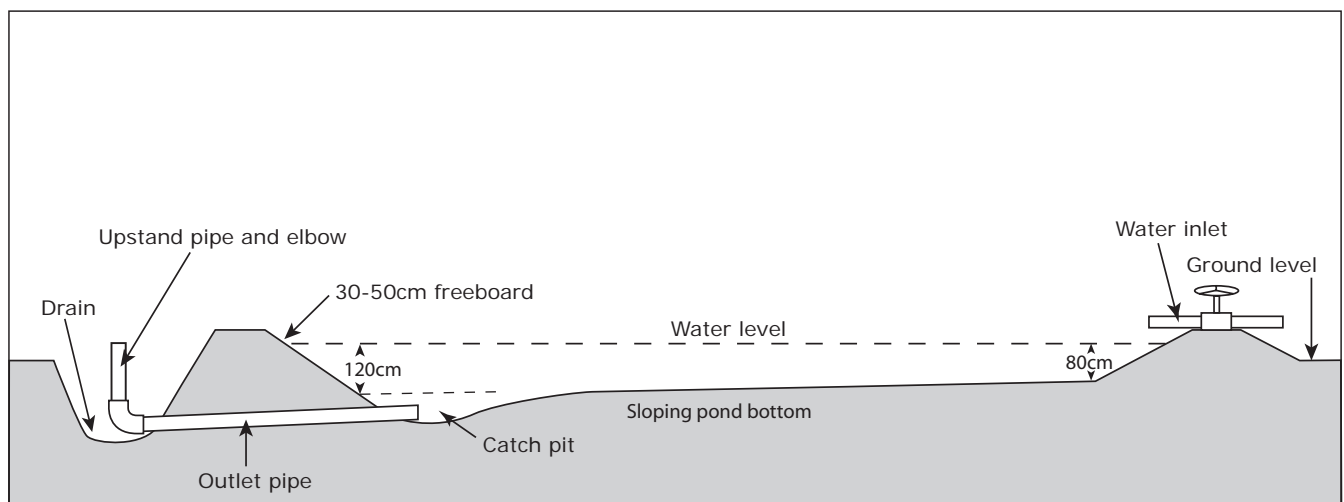


Fig. 6. Cross-section of pond along length of the pond

Dyke

Dykes are also called dikes, banks, walls, 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. The slope on the inside of the dyke should be somewhere from 2:1 to 3:1. The slope on the outside of the dyke can be steeper at about 1.5:1 to 2:1, but when there is a series of ponds next to one another the slopes for both sides of the dyke will be the same (as shown in Fig. 9b).

The amount of slope depends on the type of soil used to make the dyke. Dykes made of clay soils can have steeper slopes than dykes made of soft soils such as sandy loam. In hand-dug ponds the width at the top should be about the same as the height of the dyke (see Fig. 7). Where the ponds are excavated by machines, the top width is dependent on the width of the machine base (track) as well as on the type of soil and size of the pond.

The soil used for the dyke should not contain large amounts of rocks, sand, wood, grass or plants, as these will cause the dyke to leak water. Do not plant crops with big tap roots on dykes, as digging them up again will weaken the dyke.

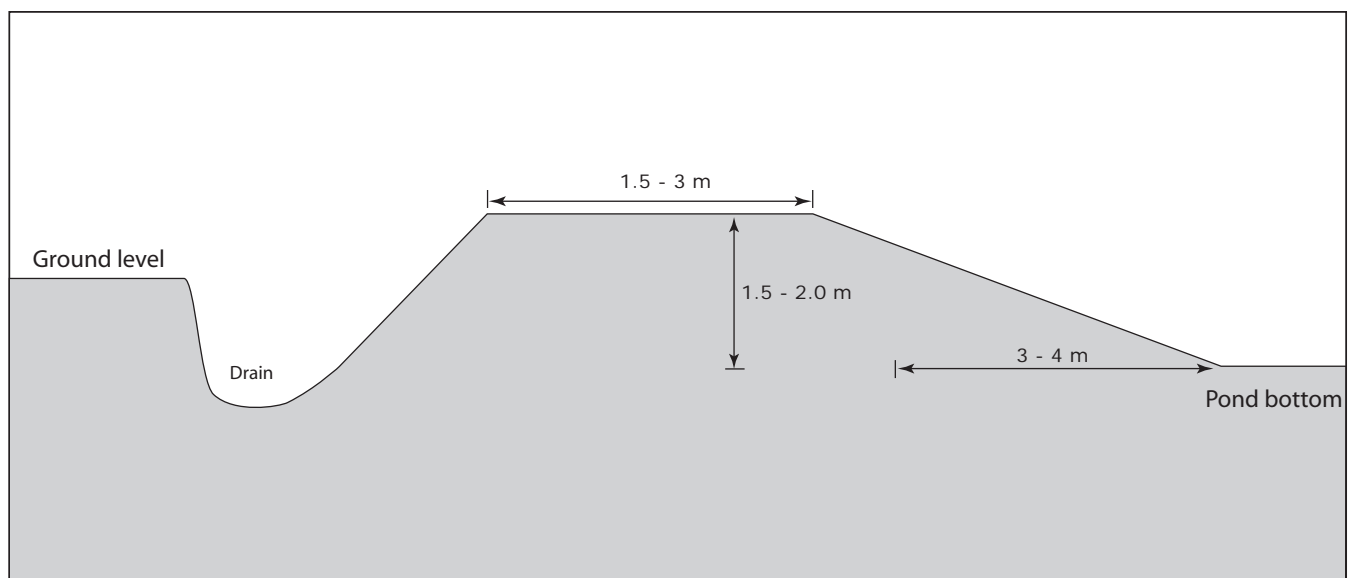


Fig. 7. Dyke cross-section

Water inlet

An inlet is to let water into the pond. The location of the inlet will depend on the shape of the land in relation to the water source.

There are various types of inlets that can be used, for example PVC pipe, polyethylene pipe, galvanised pipe, open earth canal, concrete channel, pump etc. PCV pipes are expensive but are used commonly as they are easy to install, durable, and make it easy to control the water supply. A PVC pipe of 25–50mm in diameter is sufficient in most cases. An earth channel going direct into the pond is cheapest and easiest to make, but it is cumbersome to screen and to control the water supply. Water flowing through the channel also cuts into the soil where it enters the pond, causing erosion.

The flow of water into each pond must be controlled by valves (if piped) or shut-gates (if channelled). Water inlets should have a screen to keep out wild fish, twigs, leaves and other trash (Fig. 10).

Each pond should have its own individual water supply from a central water distribution pipe or channel that brings water from the water source. No pond should receive the water outflow from any other pond. Transfer of water from one pond to another is not recommended since it means poorer water quality conditions in the next pond, and brings the risk of disease transfer. There should also not be any contact between incoming water and water drained out from ponds.

Ideally, water should be distributed to ponds by gravity, if the land topography allows it. This means the water source and inlet pipes or channels need to be at a level higher than the pond water level.

Water outlet

An outlet is to let water flow out of the pond. The outlet should be at the deepest end of the pond so that all the water can be drained out of the pond by gravity.

There are several types of outlets that can be used: for example PVC pipe, siphon, or pump.

If the outlet has an upstand pipe mounted on an elbow fitting (Fig. 8) then it can control the water level in the pond. To drain the pond, the upstand pipe is turned on its elbow and laid down flat. At other times it is tied to a pole driven into the ground to prevent it falling over and accidentally draining the pond. A PVC outlet and upstand pipe is more expensive, but this is the most common type of outlet used in the Pacific.

The diameter of the outlet pipe depends on the size of the pond. Usually 100–150mm is adequate for small (500–1000m²) ponds. For larger size ponds, pipes with a larger diameter can be used, or several 100mm pipes. A larger diameter pipe allows for quicker drain-down of ponds during harvesting.

Outlets pipes should have a screen on the end inside the pond to prevent the fish escaping.

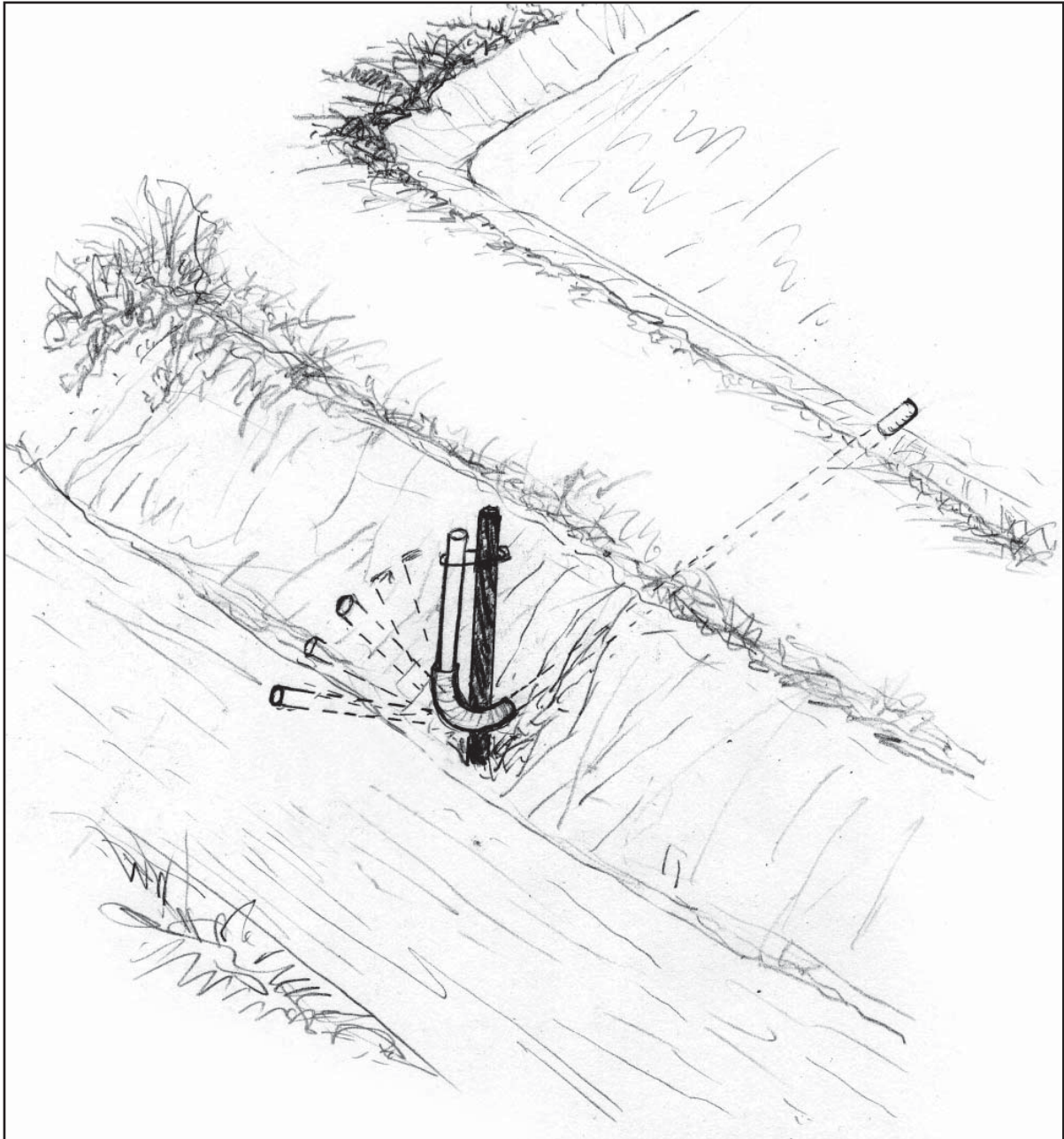


Fig. 8. Water outlet with upstand pipe

Water overflow pipe

An overflow is an extra pipe to let excess water flow away during heavy rainfall. It should be placed towards the outlet side, about 20–30cm below the top of the dyke, about 20cm above normal water level. The overflow pipe should also have screen to prevent the fish escaping.

Screens

Box screens on the water inlet to prevent pest fish entering the pond are common and effective. A cloth filter on the inlet may be necessary to remove fish eggs if water is being obtained from a river or canals containing fish (see Fig. 10). Initially, 1-mm galvanized or plastic mesh screen (similar to mosquito screen) is used on both the inlet and outlet. The outlet screen can be changed to a larger mesh every month as the fish grow. Screens will need to be checked regularly for clogging.

Methods of pond construction

Fish ponds are dug either mechanically using heavy equipment, or by hand labour (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 labour is usually used for small, family ponds.

Construction costs vary considerably when using heavy equipment. Private firms usually rent excavators, bulldozers etc. by the hour and also make contracts based on the volume of soil to be removed. Pond construction tends to be quite expensive, and transportation costs for equipment must be borne by the farmer as well. The Fisheries Department in some countries may sometimes arrange to dig ponds on a cost-sharing basis (government subsidies) but these subsidies are often difficult to obtain and arrangements are specific to each country.

Hand construction takes longer, and in some cases the costs may actually work out to be about the same as mechanical construction. If no machines are available, however, then digging by hand will be the only option for constructing the ponds. The cost of manual labour is usually based on the volume of soil dug; the price per unit volume varies from country to country and is normally agreed upon after negotiation.

Farmers often use hired labour because it is convenient and easy to organize. It keeps the money within the community and enhances goodwill among neighbours. In many Pacific Island communities, traditional relationships or kinship ties can make it possible to mobilize sufficient labour for pond construction.

Hand construction of ponds

Ponds dug by hand are generally small (100–300m²). The tools required for digging include: spade, hoe, mud-scoop spade, fork, wheelbarrow and wooden mullet (ram). The steps in construction are as follows.

Marking the pond area

1. First, prepare a sketch plan of the pond area (see Fig. 9).
2. 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.
3. 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 same dyke-width dimension and just make the central area bigger on the plan. The corners of this rectangle can be marked with pegs, and a string can be run between the pegs.
4. 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.
5. 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.

6. 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.

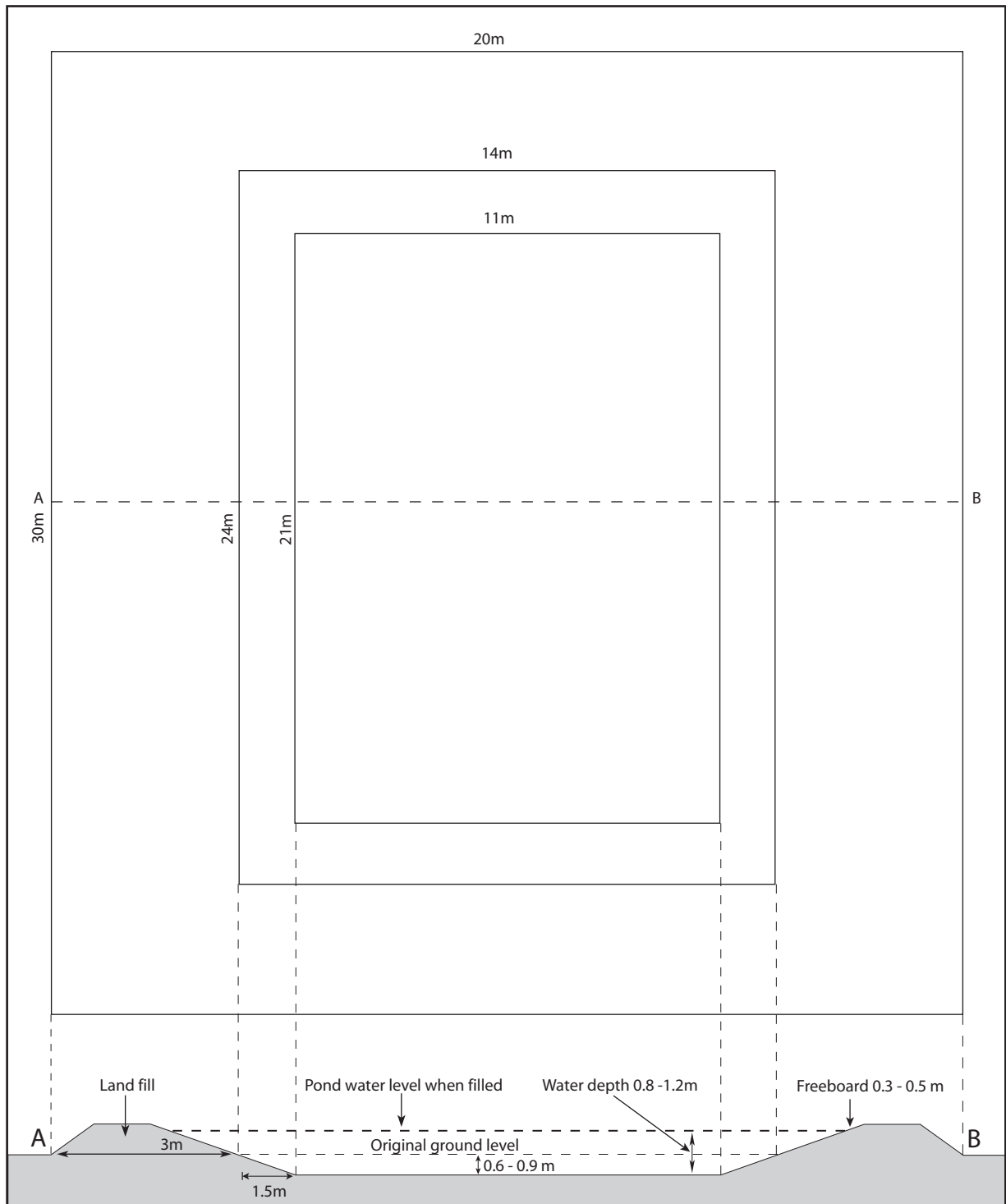


Fig. 9a. Ground plan for a hand-dug pond (top) and cross-section of pond along A-B (bottom)

The digging process

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.

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.

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. 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.

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.

Shaping the dyke

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. 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. 7 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.

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.

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 (Fig. 9b).

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



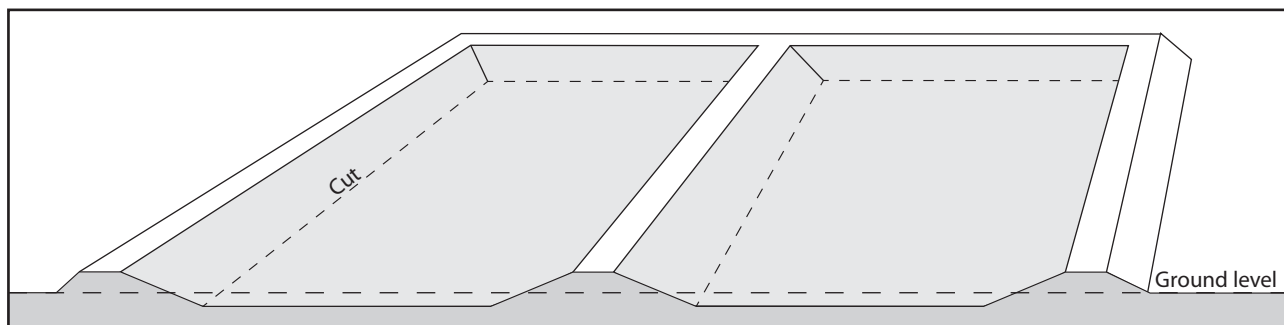


Fig.9b

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.

Installing the water outlet

The water outlet is made at the bottom of the dyke at the deepest end of the pond (Fig. 6). 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 metres of outlet pipe will be needed. It may be possible to join pieces of pipe together to make the required length.

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.

Installing an upstand pipe

The water level in the pond can be regulated by an upstand pipe. This is mounted on the outlet pipe in an upright position, usually on the end outside the pond, using an elbow fitting. Alternatively, the upstand pipe could be installed inside the pond at the entrance to the outlet pipe, to avoid accidental drainage of the pond, although the outside position is preferable, as it allows the excess water to be drained off from the bottom of the pond. The top of the upright pipe should be at about 3–5cm above the water level of the pond. If water rises above this level, it will overflow into the drain.

The upstand pipe should be tied securely to a pole driven into the ground, so that it does not slip down accidentally and let the water out of the pond (see Fig. 5). When the pond needs to be emptied, the upstand pipe can be untied and gently pushed down, allowing water to flow out of the pond gradually (Fig. 8).

Using a siphon

During harvesting and other times, a siphon can also be used to increase the flow of water out of the pond. This could be a 25–50mm flexible hose, long enough to reach over the dyke from pond to drainage ditch. It must be long enough to extend from the deepest part of the pond, over the

top of the dyke and down to the level of the drain on the other side of the dyke (10–20m long). To activate the flow of water, the hose must first be completely filled with water, with no air spaces inside it. One end must be covered with a tightly sealing plug or end-cap and the other end left open. This open end stays underwater, while the closed end is pulled over the dyke and down into the drainage ditch. Unplugging this end will then cause the water to flow rapidly out of the pond.

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. 10).

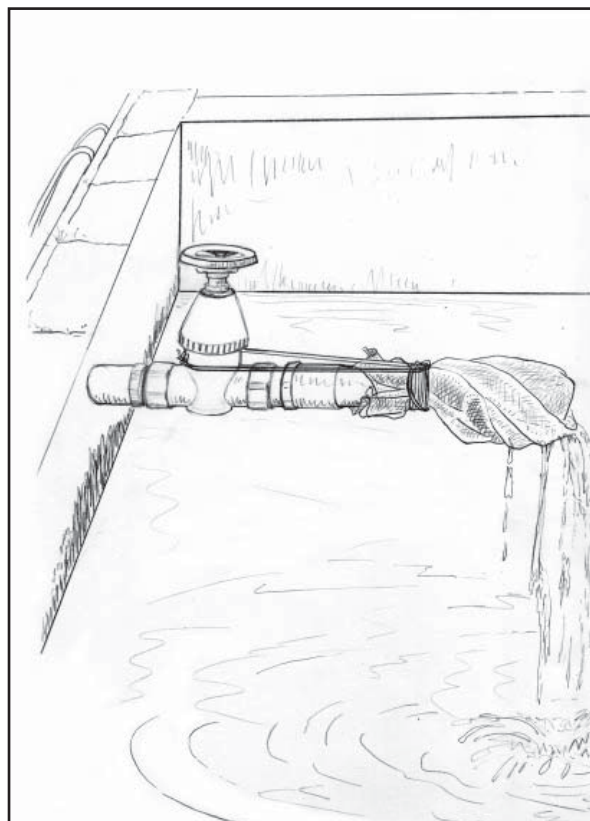


Fig. 10. Mesh screen on inlet pipe

Mechanical construction of ponds

Heavy machinery used for pond construction includes excavators (for example, Hitachi EX-60 model), bulldozers and backhoes. Bulldozers are best, due to their rapid earth moving capabilities and good compacting action. Excavators are a little slow but are very good at making pond dyke slopes and drains. In areas with a high water table, the soil may be too soft to support such heavy equipment. Consult the Fisheries Department for technical assistance.

The usual strategy is to dig out the pond area and use the fill to construct the pond dyke. During the excavation, the machine is run over the pond dykes while they are being constructed in order to continually compact the soil.

The design and layout of the pond is the same as the hand-dug pond, with some adjustments. Normally the top of the dyke would be wider (up to 3m). The operator of the machine should be

briefed thoroughly about pond shape, size, bottom-slope and other features, and should follow a similar procedure to that set out for digging a pond manually. The construction should preferably be carried out during the dry season.

The local aquaculture officer or an appropriately qualified person should be present to supervise the digging operation, to ensure the required procedures are followed.

Grow-out of tilapia

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

- Size and quality of fingerlings at stocking
- Stocking density of fish in the pond
- Time of stocking
- Length of culture period
- Size of fish at harvest
- Fertilization
- Feed and feeding methods

Most of these factors are interdependent. It is important that these relationships should be carefully thought out.

Feed and oxygen are consumed by the fish. When the supply of feed or oxygen becomes limited at higher stocking density of fish, then less food or oxygen is available per fish and more fish wastes accumulate in pond water. To overcome food shortage, the farmer can increase feeding. To overcome oxygen shortage and accumulation of fish wastes, water can be used to flush out some of the pond water.

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. 11). 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:

1. Repair and maintenance (preparation of the pond)
2. Application of lime and fertilizer
3. Filling the pond
4. Additional fertilization
5. Stocking of fingerlings
6. Feeding
7. Daily maintenance
8. Sampling (of fish to determine feeding rate)
9. Harvesting
10. Purging
11. Marketing
12. Record keeping

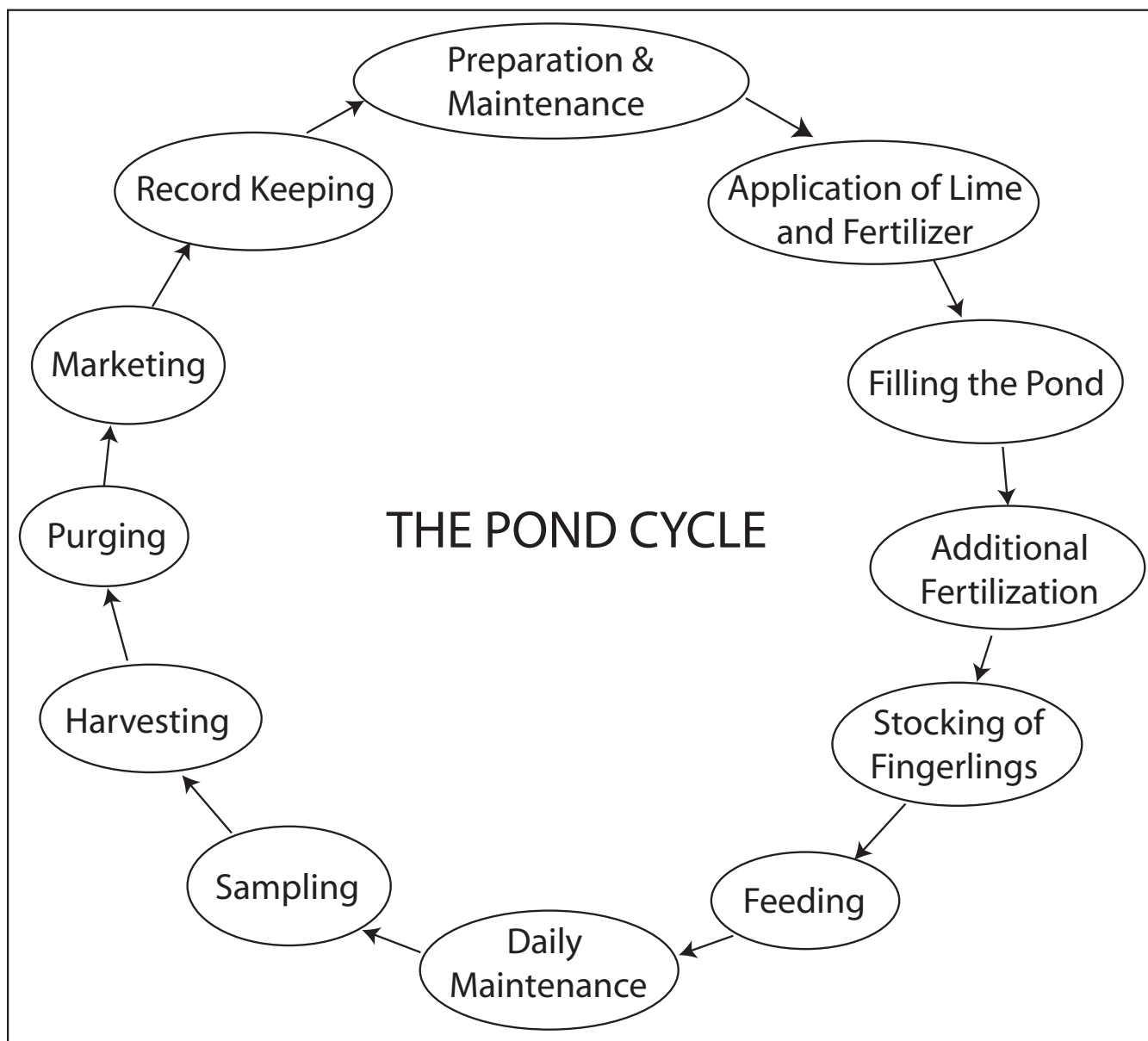


Fig. 11. The pond cycle

Pond preparation

Pond preparation is necessary prior to stocking, to create a favourable environment for fish growth. Ponds should be drained and dried, if possible until the pond bottom cracks. A dry pond enables the farmer to remove excessive silt and weeds, level the pond bottom, and repair the dykes where they have been damaged.

The grass around the pond should be kept short to allow breezes to blow over the pond water, enhancing pond oxygenation. Grass should not be completely removed, however, as it helps to hold soil on the dykes and reduce erosion. Tall grasses and plants that have grown on the pond bottom should be removed.

The screens on inlet and outlet pipes should be repaired or replaced. Drains should be kept free of wood, trash, or any other blockages.



Pest elimination

If ponds cannot be dried out completely, they should be treated (7–10 days prior to stocking) to eliminate any predatory fish or other pests. Common pond treatments are teaseed cake, rotenone (derris roots, which can be available locally), quicklime, or hydrated lime. When applying lime or other preparations, appropriate protective clothing should be worn (Fig. 12).

Teaseed cake. This is a residue of the fruit of a plant (*Camellia sasanqua* or *Camellia semiserrata*) after the fruit oil is extracted. The by-product contains saponin, which is a poison to fish. At a concentration of 10ppm (parts per million), saponin causes fish to die in a few hours. The general dosage is 1kg per 15m² of pond area, for a water depth of 1m. Teaseed cake in powder form is first soaked in water until dissolved, and this water is then evenly spread into the pond.

Rotenone. This is extracted from the roots of a plant (*Derris uliginosa* or *Derris elliptica*). The extracted solution contains about 25% rotenone, which is a poison to fish. The recommended rotenone concentration for pond clearing is about 1.3kg/660m² of pond area for a water depth of 1m (2ppm). The rotenone solution is first diluted 10–15 times with water and then evenly spread into the pond.

Lime application

Lime is added to correct acidity in the pond soil so as to create a favourable environment for the fish. Acidic water will not support the growth of phytoplankton, zooplankton and detritus-digesting bacteria. All these organisms are important to provide a good environment for tilapia growth.

Liming is generally not necessary in inland areas of the Pacific Island countries or in areas with a lot of limestone, because soil in these areas is not usually acidic. Lime may be necessary in coastal locations, especially near mangrove areas where acid-sulfate soils are found.

Analysis of soil pH is necessary. The pH (measure of soil acidity) can be measured by using portable colour-test kits or instruments, or by pH meter at a water quality laboratory. The Fisheries Department may assist with the test to determine soil pH, usually at the start of the project. Lime needs to be added to any ponds where the soil pH is less than pH 6.5.

Lime is usually applied once only, at the beginning of each pond cycle. New ponds need to be limed to reduce soil acidity. After that, the need for liming and the quantity of lime used will depend on the soil characteristics.

There are several forms of lime. The type of lime most commonly available is agricultural lime or powdered limestone (the kind that is used by gardeners and for white-washing stones etc.), while other types are quicklime and hydrated lime. They differ in strength, so have different application rates. If quicklime or hydrated lime is used, it also kills unwanted pests, so is an alternative to using teaseed cake or rotenone.

Rates of application:

Limestone (powdered) CaCO ₃	1000–2000kg/ha	1–2kg/10m ²
Quicklime CaO	400kg/ha	400g/10m ²
Hydrated lime Ca(OH) ₂	600kg/ha	600g/10m ²

Quicklime. When quicklime (CaO) absorbs water, it transforms into calcium hydroxide Ca(OH)₂. This raises pH and draws oxygen from the water. The effect of quicklime is to kill unwanted fish, pests and bacteria as well as to reduce soil acidity (raise pH).

Limestone. Agricultural lime (powdered limestone) can also be used to raise the pH of pond water. The rate of application for limestone is generally twice that of quicklime. It should be added to the pond before filling with water.

A typical application rate for lime can be from 1kg for every 10m² (for established ponds) to 1kg per 5m² (for new or very acidic ponds).

Lime is usually sold in 20kg bags, and can be applied by hand after cutting the bags open (see Fig. 12). Avoid breathing in the lime dust, by wearing a spray-painting mask or similar protective gear, and wear gloves. Quicklime is more dangerous than agricultural lime. Read the safety instructions and wear eye protection.

Spread the lime out over the damp earth in a thin layer that covers the entire pond bottom. Close the pond water outlet so that rain or seeping water does not wash the lime out of the pond. Allow the lime to settle for 2–4 days before fertilizing and filling the pond with water. This will allow time for the lime to soak into the soil and condition it properly.

When the pond is filled, if the pH of the water is too high (above pH 9), it can be improved by “ageing”. This means leaving the water 2–4 weeks before stocking, to allow natural biological processes to adjust the pH.

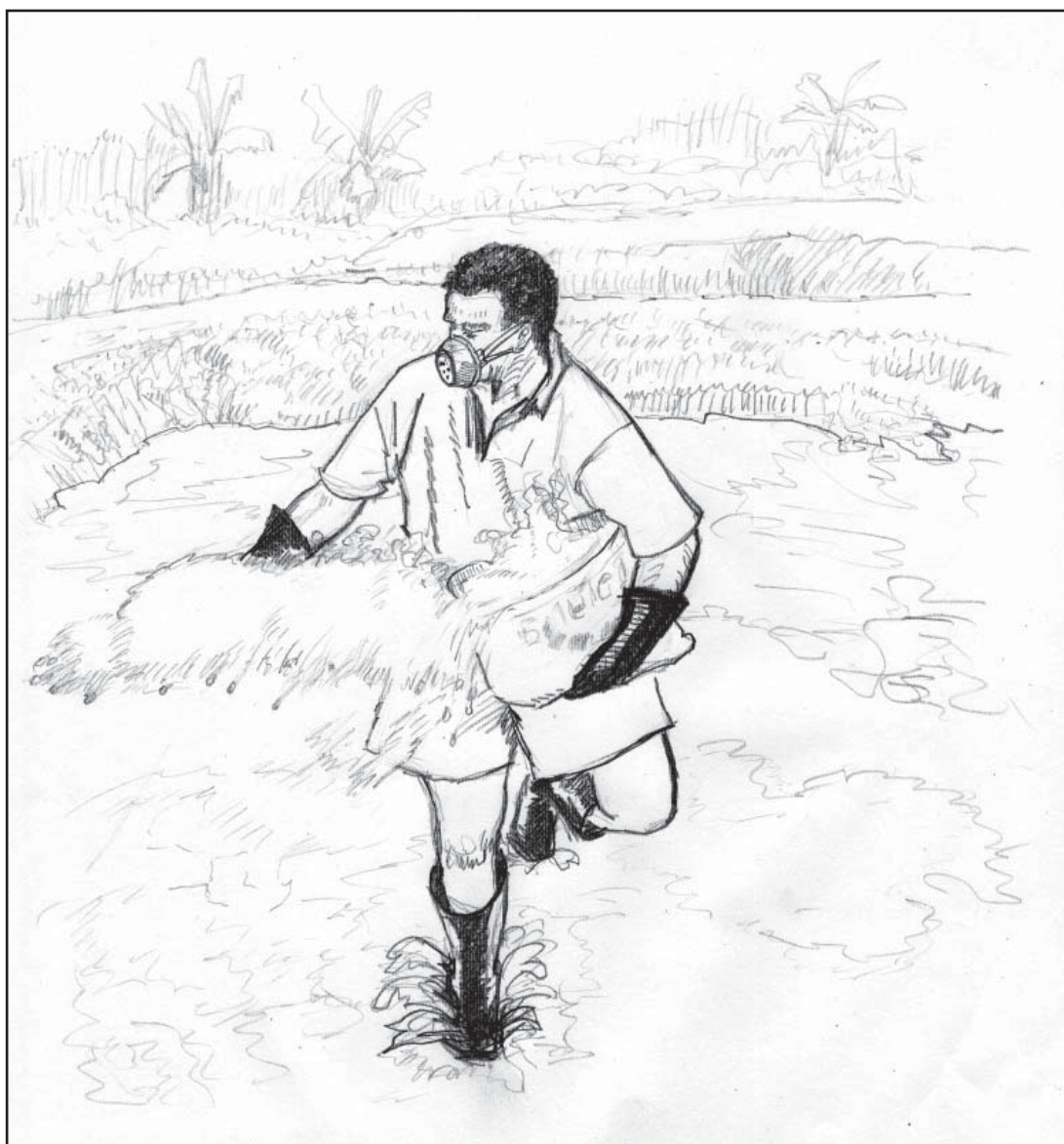


Fig. 12. Application of lime

Fertilizing and filling the pond

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, at the rate of 100–200kg/ha, can also be applied in combination with the chicken manure. 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 also be added, in a sack floated in the pond (Fig. 13). 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 the Fertilizer section.

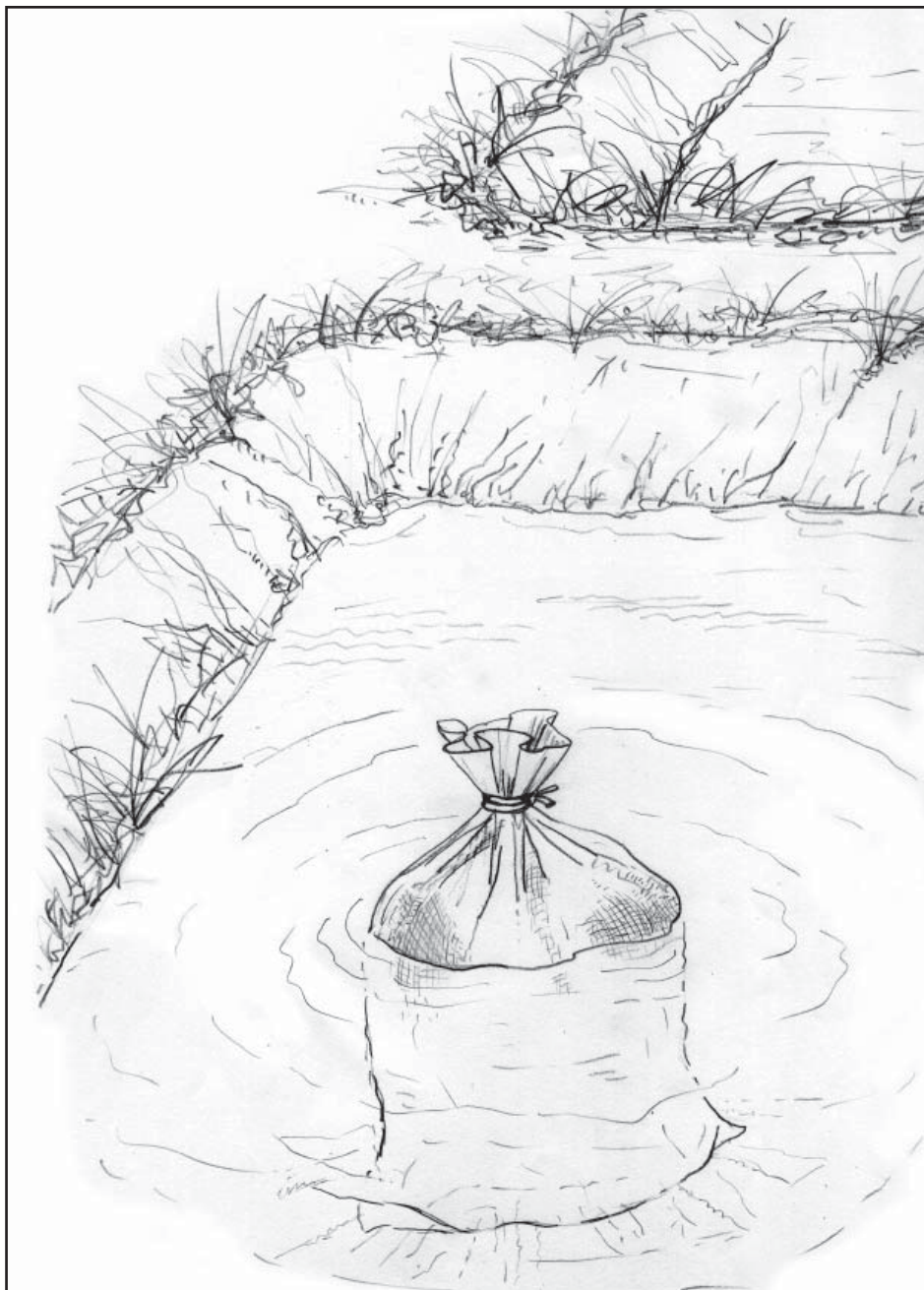


Fig. 13. Sack of manure in the pond

Stocking of fingerlings

When sufficient natural food (plankton) is present in the pond (see Daily Management section), the pond is ready for stocking. Usually fingerlings about 4–5 weeks old and 2–3g average body weight are used to stock the grow-out pond, where they will remain until harvesting. The pond water depth, initially about 30–50cm, can be increased to 80cm after about 30 days to provide more water for these fish as they grow bigger.

Good-quality fingerlings of similar age and size must be stocked. Do not use small fish from creeks or drains, or the ones leftover in ponds after harvest, as their ages and quality are unknown and these fish may start to breed early.

Transporting the fingerlings

If the hatchery supplying the fingerlings is a long distance away by road or on another island, the supplier will need to carefully prepare and package the fingerlings for transportation. The methods used for fingerling packing and transportation are described in Volume One, *Tilapia Hatchery Operation*.

On receiving the shipment of fingerlings, the farmer should not delay in releasing them into the pond. Most importantly, the fingerlings should not be left in the hot sun to get too warm.

On arrival at the pond site, the fish should not be immediately released into the pond, because sudden changes in water temperature or water quality can harm the fish. In the pond, the fish need to adjust gradually to the temperature of their new environment, especially when there is a difference of 5°C or more in temperature between the transport container and the pond water. Bag water temperature can be adjusted slowly to pond water temperature by floating the transportation bags in the pond for 15–20 minutes before opening them (Fig. 14, top).

Sudden changes in water quality (for example, water pH) can also be harmful, so the fish need time to adjust to their new water conditions. Once bags are open, splash in some pond water by hand to mix 50:50 with the water in the bag or container (Fig. 14, middle). After another 15 minutes, tip the bag on its side and allow the fish to swim out by themselves (Fig. 14, bottom).

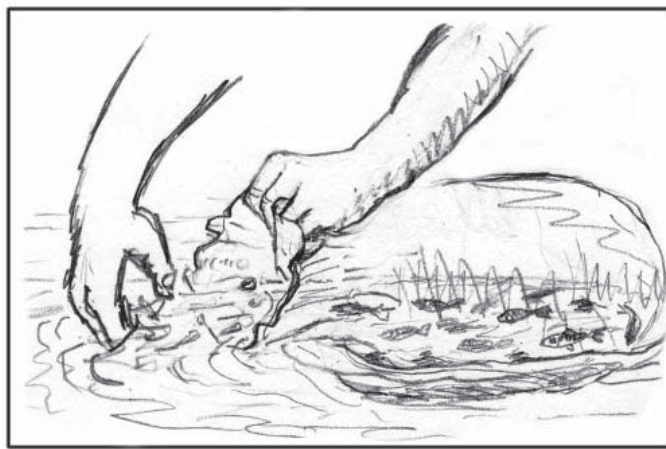
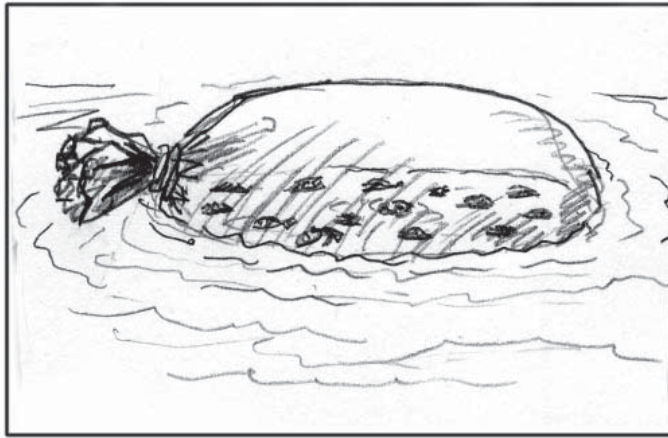


Fig. 14. When releasing tilapia fingerlings, first float the unopened bag in the pond for at least 15 minutes so that fish have time to adjust to the pond water temperature (upper diagram). Next open the bag and splash in enough pond water to make a half:half mixture of pond and bag water (middle diagram), then wait for at least another 15 minutes so that fish can get used to pond water. Finally, sink the neck of the bag down into the water of the pond, and allow the fish to swim out by themselves (so that any dead ones will remain in the bag and can be counted)

Stocking density

In order to maximize the profit from the fish farm, the stocking density needs to be as high as possible. Fish stocked at low density will grow faster than fish stocked at a high density in fertilized ponds, but densely-stocked fish can also grow fast if they are given supplementary food and managed properly. If there are too many fish in the pond, however, they will feel crowded and stressed and will grow much more slowly.

There are three kinds of culture systems based on stocking density, level of inputs and management.

- Extensive culture, where fish depend on the natural food present in the pond, stimulated by fertilization. No supplemental feed is given to the fish and stocking density is 1 fingerling/m² (10,000 fish/ha).
- Semi-intensive culture, where the fish are given supplementary feeds in addition to having the natural food present in the pond, stimulated by fertilization. In this system the stocking density is 3–8 fingerlings/m² (30,000–80,000 fish/ha). In some farms it can be higher than 8 fish/m².
- Intensive culture, with stocking density of more than 8 fish/m² and intensive feeding plus water movement and aeration in order to maintain a high oxygen level in the pond. Water quality is monitored regularly. This system can use tanks or raceways as alternatives to ponds.

Another factor in choosing the stocking density is the market size desired at harvest. The farmer should determine what size fish are wanted and stock the ponds accordingly. Factors to take into account when deciding how many fish to stock include the following.

- It may be your first time growing fish and you do not have enough money to buy feed, so you decide to use natural food and a low stocking density. After the first harvest some of the money made can be used to buy supplementary food that will allow more fish to be stocked.
- It may be the dry season and the pond is shallow. It is not necessary to wait for the wet season to start growing fish.
- If buyers only want large size fish, then stocking fewer fish in the pond will allow them to achieve more rapid growth and large size fish.

Daily management

Because tilapia tolerate 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 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, salinity, dissolved oxygen and acidity (pH), to ensure that values remain in the range known to be good for tilapia growth (see Table 1).



Table 1. Threshold water quality values for tilapia farming

Water factors	Level
Temperature	25–30°C
Dissolved oxygen (DO)	3mg/L
pH	6.5–9.0
Salinity	<5–10ppt
Water colour (amount of plankton)	30–35cm Secchi reading

Temperature

Fish are cold-blooded animals and their body temperature depends on the temperature of the water. Tilapia do not thrive at low water temperature but are very tolerant to high temperatures. Activity and feeding of tilapias are reduced below 20°C and feeding stops completely around 16°C. It is difficult to have control over water temperature of the ponds in cooler months, except by reducing the water depth and cutting back shade around the pond, to allow the water to be warmed by sunshine during the day.

Salinity

Adult Nile tilapia can tolerate salinity of up to 30ppt (parts per thousand) if the salinity increases gradually so they have time to get used to it. Fingerlings and small juveniles are happiest at less than 10ppt and will all die if water goes above 14ppt. There is no need to worry about salinity if the ponds are far from the sea.

Acidity

The pH of the water is a measure of acidity (the hydrogen ion content in the water). The water is “acidic” when the pH is 1–7 and “basic” or “alkaline” when pH is 7–14. At pH 7 the water is “neutral”. Tilapia can survive in a wide range of water pH. However, the recommended pH for good growth of tilapia is 6.5–9. Acidic water (with a low pH) will not support the growth of the phytoplankton, zooplankton and detritus-digesting bacteria that are important for fish growth.

If the pond is limed properly during its preparation, there is no need to add any more lime while fish are in the pond. The pH of the pond water will vary on a daily basis, because during the day, when the sun is shining, phytoplankton, remove CO₂ from the water and use it for photosynthesis. This removal of CO₂ can make the pH of the pond rise to about 9 on a sunny day. During the night, however, phytoplankton will release CO₂, causing the water to become more acidic and the pH to drop again. These day–night fluctuations in pH are normal. There is no need to worry about them so long as pH values are mostly in the “good fish growth” range of 6.5–9.0. Tilapia can tolerate pH of 5.0–10.5 without dying, although such extreme values are not good for growth.

Dissolved oxygen (DO)

Like all living things, fish need oxygen to live. Tilapia can survive in extremely low oxygen levels but will not grow well under such conditions. Phytoplankton produce oxygen in the day but use it at night, so pond oxygen levels will be higher in the daytime and lower at night. For good fish growth, the oxygen level should ideally be above 3mg/L in the daytime, though as low as 1mg/L measured in the early morning has been found acceptable.

Oxygen dissolves into pond water (1) from the air, slowly, (2) from phytoplankton in the water, during the daytime, (3) by the action of waves created by wind, (4) by addition of new water, and

(5) by rain water splashing onto the water's surface.

The following should be noted:

- Fingerlings use more oxygen than adult fish
- Healthy, fat fish use more oxygen than unhealthy, thin fish
- Fish use more oxygen when they are active, so more oxygen is needed during the day than at night
- The more excited fish become, the more energy they consume and the more oxygen they use

Plankton

These are microscopic organisms that live in the pond water. They include plants (phytoplankton), animals (zooplankton) and bacteria. Plankton provides both natural food and oxygen for the fish. When there is enough phytoplankton in the water to give it a green or brown colour, the water is said to have a plankton “bloom”. The best type of “bloom” is green in colour, as the water then has phytoplankton in sufficient density to provide adequate oxygen in the daytime, and sufficient natural food for the fish. The bloom may be controlled through fertilization to increase plankton growth or by adding fresh water to reduce plankton by washing it out of the pond.

Phytoplankton, being microscopic plants, add oxygen to the water during the daytime but stop producing oxygen during the night and start using it. The plankton “bloom” provides the fish with oxygen during the day. However, it can use so much oxygen during the night that fish may end up dead if the plankton bloom is too heavy. The early morning (before dawn) is when DO will be lowest, so this is the most dangerous time for the fish.

Daily activities

The condition of the ponds and the behaviour of fish should be observed twice daily, morning and afternoon. Water colour, water smell, and fish activities including surfacing behaviour should be noted. If the fish gasp for air at the water surface in early morning (behaviour 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 (Fig. 15). A Secchi disc base can be made from a white ice cream container lid, 20 cm in diameter, painted with alternate black and white quadrants, and nailed onto the end of a metre-long stick marked with a centimetre scale.

The disc is held underwater and at the depth where it just disappears from view, the depth is read off the marked scale. Ideally, the plankton density should be such that a Secchi disc immersed in the water just disappears from view at a depth of 30cm. If the Secchi disc disappears at a depth of 20cm or less, the water is too turbid, and new water should be immediately flowed into the pond to wash some of it out.

Alternatively, the plankton density in the water is ideal when the up-turned palm of the hand just disappears from view when the arm is immersed up to the elbow.





Fig. 15. A Secchi disc in use

If the “bloom” is too heavy (Secchi value of less than 20cm), for example during hot dry weather with a lot of sunshine, the phytoplankton will use large amounts of oxygen at night. This can cause die-off of both fish and plankton. In such cases the colour of the water will change from green to brown and even to black.

Fish will die in the night from lack of oxygen will be seen floating at the water surface. If this happens, flush out the pond with new water. If there is a shortage of water and flushing cannot be done, then reduce or stop feeding the fish, stop adding fertilizer, and remove any fertilizer bags in the pond.

Management of a pond involves a daily routine of tasks, which may include checks on:

- pond water level (at least 80cm deep)
- activities of fish (actively feeding, or gasping at surface)
- water inlet and outlet, to ensure mesh screens are in place and not clogged
- colour of pond water (Secchi disc reading 30cm or more)
- growth of aquatic weeds, dyke erosion, damaged water lines
- any dead fish floating

The daily observations should be written down in a notebook or pond logbook. These records will provide information on the performance of the ponds at different times of the year or under different management methods.

Sample “Pond Logbook” page

Date: 10 November 2004

Pond 1 – Temperature 29 degrees. Water colour is brownish-green (Secchi = 35cm). Fish are grabbing the pellets, eating well, look fit and active.

Pond 2 – Temperature 30 degrees. Water very dark green, has green scum floating on surface (Secchi = 15cm). Only a few fish are grabbing the food, many were gulping air at the surface in the early morning. Today opened up the water inlet to flow water and flush out plankton. Pond looks too shallow (50cm) – tomorrow will raise upstand pipe on outlet to make water 30cm deeper.

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:

- Fertilizer provides nutrients for phytoplankton growth. The two main nutrients are nitrogen and phosphorus
- Tilapia will eat plankton all day long
- Plankton contains a lot of protein. Protein is useful in body building, and puts more meat on the fish

There are two main types of fertilizers that can be used. Natural *organic fertilizers* include manure of animals such as chickens, cows, goats, pigs, or horses. Manmade or *inorganic fertilizers* commonly used are urea, TSP and superphosphate. Inorganic fertilizers may be *single element fertilizers* that contain a single nutrient like nitrogen (in ammonium sulfate, urea) or phosphorus, *incomplete fertilizers* that contain two nutrients such as nitrogen and phosphorus, or *complete fertilizers* that contain the three important plant nutrients, nitrogen (N), phosphorus (P), and potassium (K).

The advantage of organic fertilizer is that it is cheaper, or may even be obtained free-of-charge. It may also be more easily available in many rural areas. The disadvantages are that it requires more work to collect, is smelly to work with, and people may not want to buy the fish because they think the fish are being fed on manure.

The advantages of inorganic fertilizers are that they are easy to use, do not smell, and are always the same strength. The disadvantage is that they are more expensive to buy.

If there is a range of choices, then experience over time will give an idea of which fertilizer gives the best value for money.



Table 2. Recommended fertilizer application rates

Type of fertilizer	Amount to use per m ²
Urea	6g
TSP	3.5g
Superphosphate	7g
Chicken manure	15g
Cow manure	70g
Pig manure	50g

Always measure the quantity of fertilizer required. If there are no scales for weighing, then use a canned-fish tin as a scoop to measure it out (Table 3).

Table 3. Fish tin measurements

Fertilizer	Small fish tin	Large fish tin
Urea	180g	315g
TSP	250g	480g
Superphosphate	250g	480g

There are two ways to apply organic fertilizers. For fast action to quickly stimulate a plankton bloom (for example, when the pond is initially filled with water), first dissolve the manure in a drum of water then pour it into the pond. Inorganic fertilizers can also be dissolved in a bucket of water for fast action. TSP needs warm or hot water to dissolve properly.

For a slower action (to slowly release nutrients over time to maintain a steady plankton bloom), put manure into flour sacks and tie the top (see Fig. 13), and leave the sacks floating in the pond. Take the sacks out again if the Secchi disc reading tells you that the bloom is getting too heavy.

If the pond water is not very green (Secchi value is greater than 30cm) then add a little bit more fertilizer. If the pond water is very green (Secchi value is less than about 20cm) then take out any sacks from the pond, or open the water inlet for a short time to flush the pond.

Fertilizer should be stored in a dry, airy place that is well protected from rain. To keep inorganic fertilizer from getting damp, which will make it go hard, do not allow the fertilizer bags to touch cement or dirt floors. Store them on wooden pallets.

Feed and feeding

Although tilapia feed on plankton in pond water (natural food) and so can be grown without supplementary feeding, supplementary feeding will result in better growth and thus more profit. With natural food alone, the production of tilapia can be around 500kg/ha/cycle. With supplementary feeding (Fig. 16), production can increase to 6000kg/ha/cycle.

Since the growth of fish is strongly dependent on their foods and pattern of feeding, to make a good profit from tilapia farming it is necessary to understand the food requirements of tilapia. Tilapias are omnivores, generally feeding on phytoplankton, zooplankton, organisms living on the pond bottom (benthic organisms), detritus (waste produced by organisms in the pond), small fish, and aquatic plants. In captivity, tilapia readily accept artificial diets such as a powder mash or crumbled or pellet feed, if sized appropriately to fit into their mouth. This means that a wide

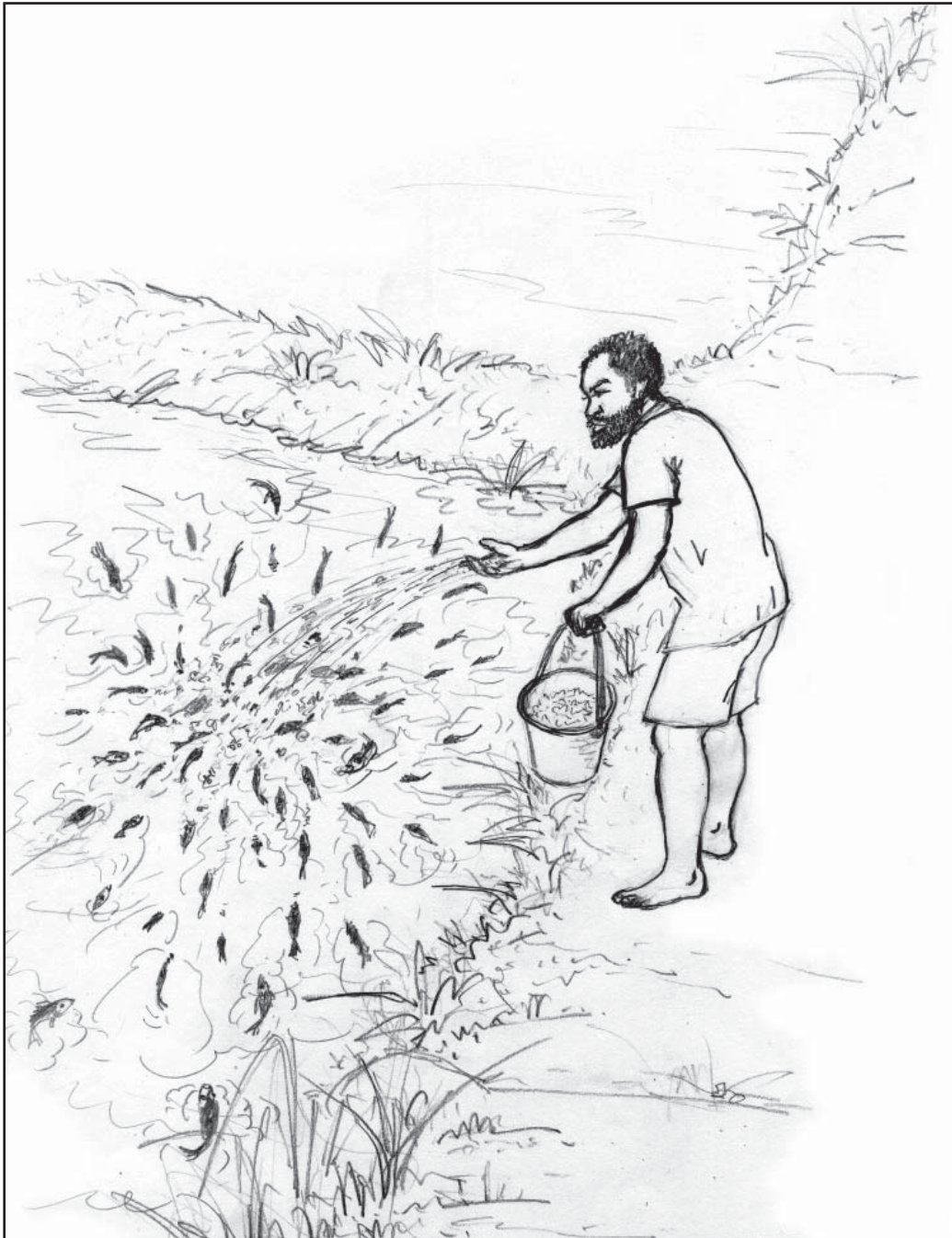


Fig. 16. Supplementary feeding of fish

range of supplementary feed can be used. Supplementary feed can be either agricultural by-products (of plant origin, or animal origin), or specially formulated diets.

Feeds of plant origin

- *Forages.* These are leaves of grasses, aquatic plants, and vegetation in general. A good example is chopped cassava leaf (use the sweet kind with red stems, and only give to fish older than 1 month; chop the cassava leaf very finely).
- *Root crops.* These are tubers of sweet potato, cassava etc.
- *Grains.* These include rice bran, rice pollard, corn and corn meal, soya bean meal, broken rice, wheat-flour mill mix. They are fed whole, or ground into meal and mixed with other feed ingredients, or made into pellets.
- *Fruits.* Fruits, nuts, seeds, including copra meal or the grated and squeezed coconut left over after making coconut cream.

Feeds of animal origin

- *Manures.* Fish will eat good quality, dried chicken manure directly if they are hungry.
- *Meat, fish and their by-products.* For example, fish meal, meat-and-bone meal.
- *Formulated diets.* These are a mixture of ingredients formulated to give fish a nutritionally balanced diet. The feeds can be supplemental (“partial” diet), or complete (containing all essential nutrients in amounts necessary for normal growth). Supplemental feeds in combination with natural food in the pond (plankton) can provide a nutritionally complete diet for tilapia.

When the stocking density is low (less than 2 fish/m²), the natural food in a fertilized pond is sufficient to support adequate growth of fish. With a higher stocking density the natural food will be insufficient and growth of fish will be slowed as the fish grow larger. A point is reached where available natural food is sufficient only for maintenance of a fish population that has stopped growing. This point is termed the “carrying capacity” of the pond. To increase the carrying capacity (and so increase fish production from the pond) the fish need to be given supplementary feed.

Natural plankton food contains 50–60% protein on a dry matter basis. This is above the protein requirement for tilapia (which is 23–35% for adults). When tilapia live exclusively on natural food, the excess protein is used for energy. When the carrying capacity is reached, it is energy that is in short supply, not protein. For this reason, supplementary diets should be relatively high-energy feedstuffs (for example, high in carbohydrate). Such feedstuffs are usually cheaper than those high in protein (protein from animal sources is especially expensive).

Most formulated diets come in powder, meal, crumble or pellet form. Powder or meal forms are used normally for fry, crumble for fingerlings and juveniles, and pellets for the adult fish. Good tilapia feeds contain 25–35% protein, 2–10% fat, and 4–12% fibre. For fry and fish under intensive culture, a feed with higher protein levels and added vitamins and minerals is needed.

Guidelines for feeding

- Feed every day or at least 6 days per week, unless conditions of low dissolved oxygen arise.
- Weigh out the fish food into the amount to be given at each feeding time.
- If there is no weighing scale, take a scoop (empty fish tin or some other container) and some feed to the Fisheries Department or a shop, and weigh one scoopful of feed. From the weight of one scoop, work out how many scoops to give to the fish at each feeding time.
- Feed according to the total weight of fish in the pond, and increase the amount of feed as fish weight increases. Sample the fish every 2–3 weeks to calculate the weight increase (See the section below entitled Daily Feed Ration for an explanation about how to calculate the amount of daily feed from the fish sample weights).
- Feed 2–4 times each day, in the same place and at the same time if the pond is small. If the pond is large, feed along the length of the dyke.
- Feed slowly; do not “dump” feed all at once.
- Feed with the wind behind, so that any dust (called “fines”) blows into the pond and can also be eaten.
- Reduce feeding on overcast days, or if fish are “piping”.
- Do not overfeed. Watch the fish to ensure they are feeding properly. Check the pond bottom for any uneaten, rotting feed.
- Tilapia are not very active during the night, so it is no use feeding them after dark.

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. The fish can be weighed individually or all together. Two buckets are required, one with holes and one to hold water (Fig. 17). The bucket with holes is weighed, then placed in the second bucket, and filled with water. The fish are netted and transferred to this bucket. After the fish have been added, the bucket with holes is lifted gently, allowing the water to drain into the second bucket. Allow time for the water in the bucket to drain as much as possible while gently shaking the bucket. Weigh the bucket using a spring balance that can weigh accurately, or a top-loading balance.

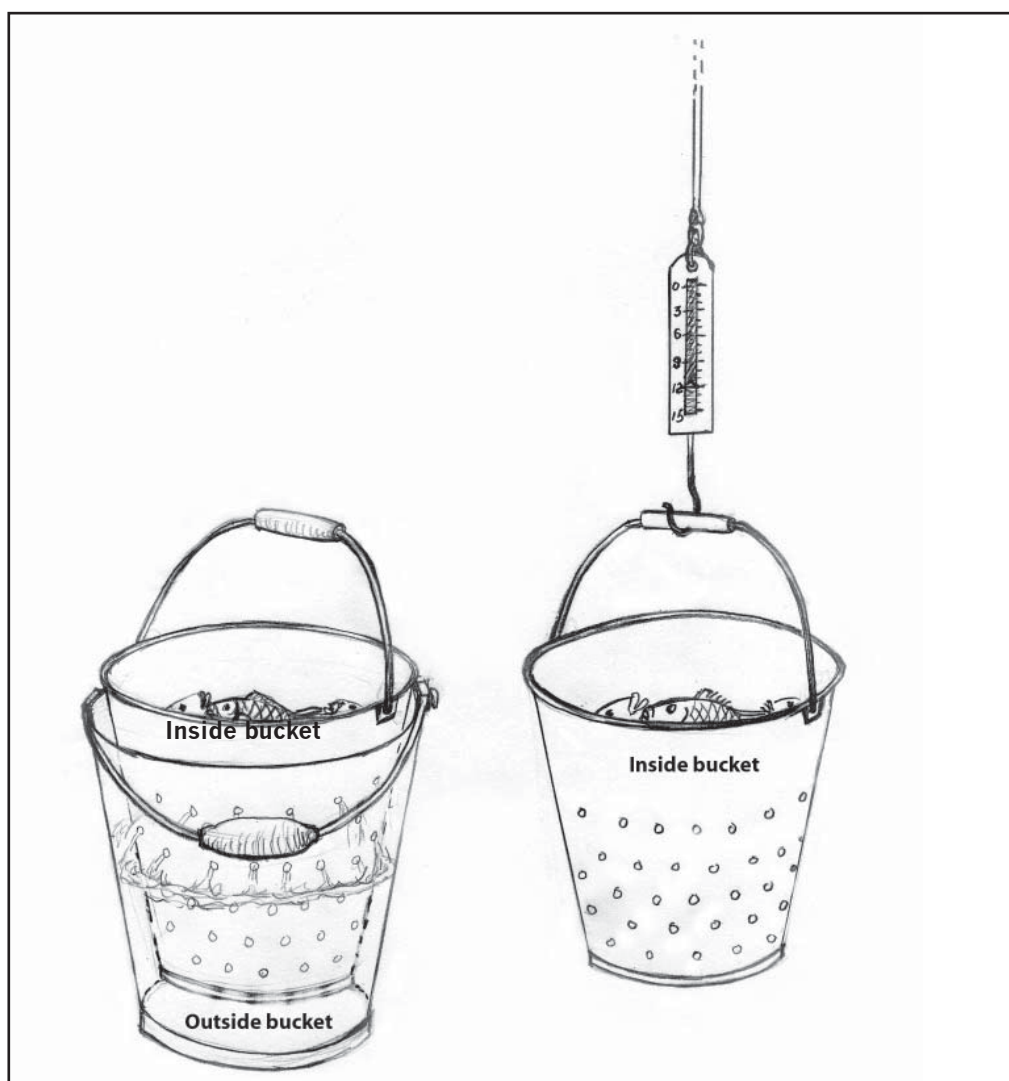


Fig. 17. Weighing of fish sample



The weight of fish in the bucket is the difference between the weight of the empty bucket and the weight when the bucket contains the fish. The Average Body Weight (ABW) is calculated by dividing the weight of the sample of fish by the number of fish in the sample:

$$\text{ABW} = \frac{\text{Total weight of a random sample of 30–50 fish}}{\text{Number of fish in sample}}$$

Daily feed ration

The amount of food to give is calculated from the amount of food required by one fish each day, expressed as a percentage of the fish body weight (*the feeding rate per day*). The feeding rate is different depending upon the size and age of the fish. Table 4 provides a guide for feeding tilapia at 24–30°C using quality formulated feed.

Table 4. A guide for supplementary feeding of tilapia

Body weight of fish (g)	Number of fish per kilogram	Feeding rate	No. of feeds per day
1–5	1000–200	10–6%	4–6
5–25	200–40	5%	4
25–150	40–7	4–3%	4
150–250	7–4	3%	3–4
250–450	4–2	2–3%	2–3

The Daily Feed Ration (DFR) is calculated by multiplying the estimated total weight of fish in the pond (number of fish stocked into the pond at the beginning multiplied by the Average Body Weight of the fish sampled) by the feeding rate appropriate for the fish at their current size.

$$\text{DFR} = \text{Feeding rate per day} \times \text{ABW} \times \text{Total number of fish}$$

This total daily feed amount is divided up into several feeds a day. Small fish need to be fed more often each day than large fish. For example, for a daily feed amount of 4kg for small fish being fed four times a day, 4kg is divided by 4. In other words, give out 1kg of fish food at each feeding time, four times a day.

Worked example of Daily Feed Ration

What will be the total amount of food needed each day by 1000 fish with average body weight (ABW) of 3g?

$$\begin{aligned}\text{Total weight of fish in the pond} &= 1000 \times 3\text{g} \\ &= 3000\text{g}\end{aligned}$$

At this 3g size, the fish should be fed at the rate of 6–10% of their body weight daily. If we take a value of 10%, then:

$$\begin{aligned}\text{DFR} &= 0.10 \times 3000\text{g} \\ &= \mathbf{300\text{g}} \text{ of food per day}\end{aligned}$$

Fish of 3g size should be fed four times per day, so:

$$\begin{aligned}\text{Amount of feed} &= \frac{300}{4} \\ &= 75\text{g at each feeding time}\end{aligned}$$

Total feed requirement

The Total Feed Requirement (TFR) is the total amount of food needed for a whole pond cycle from stocking to harvest. TFR is found by first calculating the amount of feed given between each of the sampling dates (by multiplying the daily food ration DFR by the number of days that a particular DFR was given from the previous sampling to next sampling), then adding all these amounts together.

Total Feed Requirement between sampling dates 1 and 2:

$$\text{TFR}_1 = \text{DFR}_1 \times \text{Number of days from date 1 to date 2}$$

Calculate a separate TFR for the time period that each DFR value was used, then add all these TFR values together.

Recording this in the logbook will guide you in future on how much feed to buy, and on how much money should be set aside to buy fish food during a pond cycle.



Worked example of Total Feed Requirement

A pond was stocked with 250 fish at 3g size. At the initial feeding rate of 10%:

$$\begin{aligned}\text{DFR}_1 &= 0.10 \times 250 \times 3\text{g} \\ &= 75\text{g of food per day}\end{aligned}$$

After 21 days, the fish were sampled and ABW was 20g. At the new feeding rate of 5%:

$$\begin{aligned}\text{DFR}_2 &= 0.05 \times 250 \times 20\text{g} \\ &= 250\text{g of food per day}\end{aligned}$$

After another 21 days, fish were again sampled and ABW was 35g. Feeding rate was now 4%:

$$\begin{aligned}\text{DFR}_3 &= 0.04 \times 250 \times 35\text{g} \\ &= 350\text{g of food per day}\end{aligned}$$

The fish were fed for another 21 days before sale. What is the Total Feed Requirement over this period?

$$\begin{aligned}\text{TFR} &= (\text{DFR}_1 \times 21 \text{ days}) + (\text{DFR}_2 \times 21 \text{ days}) + (\text{DFR}_3 \times 21 \text{ days}) \\ &= (75\text{g} \times 21 \text{ days}) + (250\text{g} \times 21 \text{ days}) + (350\text{g} \times 21 \text{ days}) \\ &= 1575\text{g} + 5250\text{g} + 7350\text{g} \\ &= 14,175\text{g}\end{aligned}$$

A total of 14,175g (14.2kg) of fish food was fed over this 63-day grow-out period.

Food Conversion Ratio

The Food Conversion Ratio (FCR) is the amount of food used to produce one kilogram of fish.

Calculating the FCR shows whether the fish are overfed or underfed. For example, if fish are fed according to the suggested guidelines, but they seem to be growing rather slowly and the FCR value is low, this indicates they can be given more food to speed up their growth. On the other hand, a high FCR value can indicate overfeeding.

FCR over one pond cycle is calculated from the Total Feed Requirement (TFR) and the Total Weight Gain (TWG) of fish. The TWG is the difference between the total weight of fish harvested and the initial weight of fish stocked. It can be calculated from an estimate of the ABW at time of harvest multiplied by the number of fish harvested, or taken directly from pond fish-sales records.

$$\text{TWG} = (\text{Final ABW} \times \text{Number of fish}) - (\text{Initial ABW} \times \text{Number of fish})$$

$$\text{FCR} = \frac{\text{TFR}}{\text{TWG}}$$

An FCR value of 1.5 means that 1.5kg of supplementary feed was used to produce 1kg of fish.

For semi-intensive culture, FCR values of 1.2–1.5 are considered good. In intensive systems, higher FCR values of 2–2.5 are likely because hardly any natural food will be available in the pond.

If the FCR value is very high, for example FCR of 7, then it is likely that not all the food is being eaten, and so food is being wasted. Another explanation is that the food is of very low quality, so that much more of it has to be eaten by the fish in order to grow.

Harvesting

Tilapia can be harvested starting from about 3–4 months after the fingerlings have been stocked, provided water temperature remains suitable and good quality supplementary feed is provided. The exact time for harvesting is determined by factors like the preferred market size for fish, and by opportunities to achieve good volume of sales and good prices (for example, Fridays, civil service paydays, Christmas time etc.).

There are two types of harvest: partial harvest, and complete harvest. A partial harvest can be done using a seine net or a cast net, but for a complete harvest the pond is seined 3–4 times and then drained to get all the remaining fish.

Do not feed the fish on the day before harvesting, so as to allow the fish to empty their guts. This will improve the survival and condition of the fish during handling. If necessary, run clean water through the pond for a day to reduce any off-flavour in the fish. (See more about this in the Purging section.)

It is preferable to harvest early in the morning so that the pond water is still cool while the pond is emptied. This will reduce fish stress while they are being seined or collected. All equipment needs to be prepared in advance: for example aeration, inflow of clean water, holding tanks or hapas, buckets, seine nets, scoop nets etc.

A seine of 1–2cm mesh size with a height of 2–3m is commonly used. For every 2m of pond width, 3m length of seine net is needed.

To effectively harvest tilapia in ponds, several people are needed, to hold the lead line of the net firmly on the bottom of the pond, the float line above the water surface and to pull the ends of the lines. Tilapia are adept at escaping a seine net by jumping over or burrowing or slipping under it. Stretch the seine from dyke to dyke and haul it gradually (Fig. 18).

Even with several people, harvest of more than 40% of the tilapia per seine haul is difficult. In order to harvest all the fish in the pond, seining is carried out 3–4 times and then the pond is emptied.

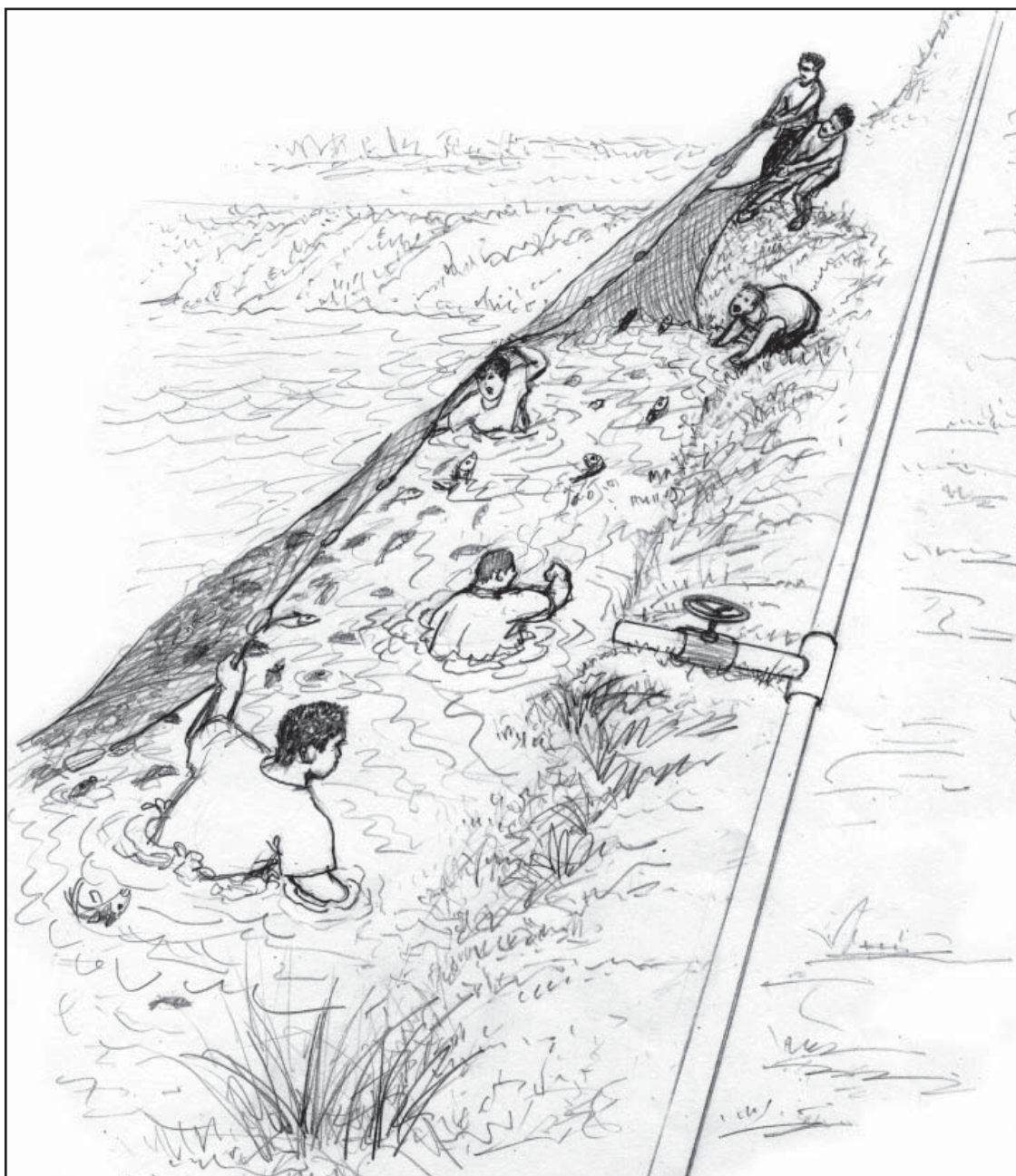


Fig. 18. Harvesting fish using seine net

Partial harvesting

A partial harvest is catching only some of the fish in the pond. For example, the farmer may wish to take only the big size fish to sell in the market or to feed his family or for a special occasion. Partial harvest can be done either by seining or by using a cast net.

The harvesting can start at about 3 months after stocking the fingerlings, or when the fish are big enough to eat (200–300g size). Partial harvests can be continued until the fish have been in the pond for 5–7 months, or until there are only few left.

When most of the fish have been harvested, drain the pond and collect the remaining fish. Do not leave any fish in the pond. Kill any unwanted fish (e.g. by liming the pond) before refilling for another pond cycle. Keep records of all the fish taken out (see Record Keeping section). Count the number of fish taken out each time or at the very least record the weight of fish taken each time you harvest.

Complete harvest

A complete harvest is usually carried out 4 months after stocking. Complete harvest requires draining of the pond. To speed up the harvesting, seining is carried out while the pond is draining. When the pond is drained completely, fish are confined in the catch pit or in puddles of water and these remaining fish are scooped or collected by hand. A net bag can be held on the outside of the outlet pipe to catch any fish that escape down the pipe, or the inside of the pond can be screened around the outlet pipe to stop fish from escaping.

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 (Fig. 19).



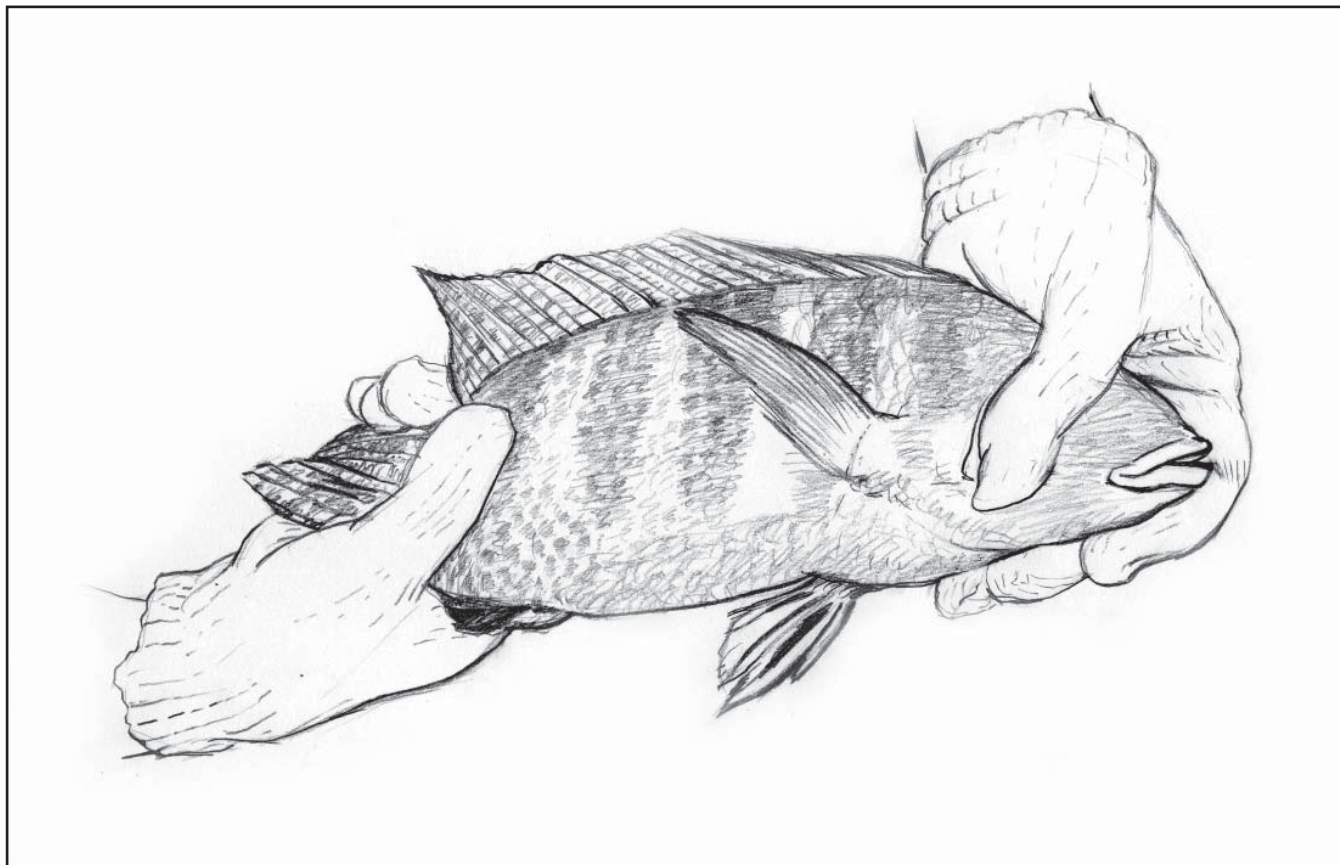


Fig. 19. When handling fish, wear cloth gloves to obtain better grip and cover the eyes so fish remain calm

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 flavour such as a muddy, earthy smell and taste are not preferred by consumers. Selling fish with an off-flavour could lead to a drop in the market acceptance of fish for a long period.

The cause of the off-flavour 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-flavour in tilapia can be controlled in two ways:

- Control of the algae in the pond
- Removal of the off-flavour 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-flavour and will “clean” them.

Selling fish with good flavour 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.

Fish marketing

In areas where tilapia farms are established for the first time there will be a need for promotion and market development, since tilapia will be a new fish to the consumers. To market tilapia through local retail outlets may be difficult unless some attempt is made to educate the consumers about tilapia. 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 (Fig. 20)
- Whole and fresh, sold soon after harvesting and sold by weight
- 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



Fig. 20. Marketing of live fish

The method chosen for selling the fish will be dependent on the locality and on the type of equipment that is available for handling the fish. In Fiji, for example, the most common method of selling fish is whole and live in tanks.

Be creative about marketing the fish so that people will want to buy the fish and be willing to pay a good price. For example, tilapia could be sold at the market or at fairs cooked as a parcel with cassava, onions, tomatoes and lemon. Plan to harvest at Christmas, special holidays or government pay-days when people want to buy fish. Display them with leaves and plants around the fish so they look attractive. Keep flies off them. Buy ice to keep them chilled. Keep the fish alive as long as possible. Fresh fish taste and look better than frozen fish, and live fish are best of all.

In villages, advertise the day of fish harvest so that people know in advance and come prepared to buy the fish. Ensure that people know where the fish will be sold. For example, put a sign on the main road. Inform nearby villages about fish sales before the harvest day. Take orders for fish. Consider buying a portable tank and an aerator so that live fish can be sold at the market.

Record keeping

A fish farm is a business; therefore all activities on the farm should be recorded. Proper record keeping is a valuable management tool. It is the means to measure the cash input and cash output, in order to evaluate and improve the farm performance and plan for future operations.

The records will assist in showing the farmer how much money can be made from the business (income), and how much money can be saved and spent on the running of business for the next pond cycle.

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

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

What should be recorded?

At the very least, record the number of fish and the total weight of fish harvested from the pond. This can be compared to the record of how many fish were stocked into the pond at the beginning of the pond cycle and used to estimate the percentage survival of fish.

For a more complete range of useful data and information, fill out the Pond Record Sheet form shown in Appendix 1. This will provide information useful not only to the business but also to the Fisheries Department in monitoring progress of the nation's fish farming industry. A Farm Logbook should also be maintained. Enter any daily observations such as dead fish, water temperature, water colour, water requirements, pond stocking dates, fish numbers stocked and their weight, daily feed rations, sampling dates, sampling data, harvesting dates, fish numbers harvested and their weight, total food requirements, and other relevant notes or data.

Keeping pond record sheets and a logbook will help answer questions such as the following:

- If a harvest is less compared to previous harvests, what change was made to make it worse?
- If one harvest is more compared to others, what improvements were made?
- Did a cold season affect the growth of the fish?
- How many fish and what size of fish can be available to sell at different times of the year?
- Could low percentage survival have been due to bad water quality, someone stealing the fish, or fish escaping?

Notes recorded in a logbook for a pond over a complete cycle can include:

FISH

Source of fingerlings
Number of fingerlings stocked
Date stocked
Total weight of fish stocked
Average weight of fish
Sample weight (every 2–3 weeks)
Gain in weight at each sample
Harvest weight
Value of harvest
% survival

WATER

Temperature
Dissolved oxygen
pH
Water colour and Secchi value
Volume of water exchanged

FOOD

Type of feed
Cost per kg of feed
Feeding rate used at each sampling
Daily feed ration (DFR) at each sampling
Total amount fed (kg)
Food conversion ratio (FCR)

SALES

Sales from farm
Sales at market
Price per kg



Further information

Books

Nandlal, S. and Pickering, T. (2004). Tilapia farming in Pacific Island countries. Volume one. Tilapia hatchery operation. Noumea, New Caledonia: Secretariat of the Pacific Community.

Pillay, T.V.R. (1990; 2nd edition 2005). Aquaculture principles and practices. Oxford: Blackwell, Fishing News Books, 575pp.

SPC (2003). Profiles of high interest aquaculture commodities for Pacific Island countries. Noumea, New Caledonia: Secretariat of the Pacific Community.

Software

SPC (no date) Economic models for aquaculture and agriculture commodities. Noumea, New Caledonia: Secretariat of the Pacific Community. Download from <http://www.spc.org.nc/aquaculture/site//home/index.asp>

Videos

An icy tale — chilling fish on-board. SPC Training Video no. 1. Noumea, New Caledonia: Secretariat of the Pacific Community

A visit to the fish market — better facilities for selling better seafood. SPC Training Video no. 7. Noumea, New Caledonia: Secretariat of the Pacific Community

Pond Record Sheet

Name of farm: _____ Pond No.: _____ Area: _____ m²

Fingerling source: _____ Stocking date: _____ No. stocked: _____

Stocking density: _____/m² Average body weight (ABW): _____ g Total wt: _____ kg

Feed supplier: _____ Type of feed: _____ Type fertilizer: _____

Daily feed ration (DFR): _____ kg Fertilizer (kg per week): _____

Fish sampling data:

Sampling date	Days from last sampling	ABW of fish (g)	New DFR (g)

Fish harvesting data:

Harvest date	No. days of grow-out	No. of fish	ABW of fish (g)	Weight harvested (kg)

Total fish harvested: _____ kg Selling price: _____ /kg Total sales: _____

Total feed used: _____ kg Feed price: _____ /kg Total feed cost: _____

FCR: _____

Total fertilizer used: _____ kg Fertilizer price: _____ /kg Total fert. cost: _____

Fish survival: _____ % Fish losses: _____ kg Fish given free: _____ kg

Market fee: _____ Transport cost: _____ Labour cost: _____

Other costs: _____



Useful formulae

Percentage survival:

$$\% \text{ survival} = \frac{\text{Number of fish harvested} \times 100}{\text{Number of fish stocked}}$$

For example:

If you put in 1000 fish and harvested 900, then % survival was $900/1000 \times 100 = 90\%$. A good survival rate is 90% or more.

Average body weight:

$$\text{ABW} = \frac{\text{Total weight of fish in a random sample}}{\text{Number of fish in sample}}$$

For example:

If you caught 500 fish and the weight of the fish was 75kg, then ABW was $75/500 = 0.150\text{kg}$, so ABW is 150g.

Daily feed ration:

$$\text{DFR} = \text{Feeding rate} \times \text{ABW} \times \text{Total number of fish}$$

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

Total feed requirement:

$$\text{TFR} = \text{DFR} \times \text{Feeding duration}$$

Food conversion ratio:

$$\text{FCR} = \frac{\text{Amount of food given}}{\text{Fish weight increase}}$$



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