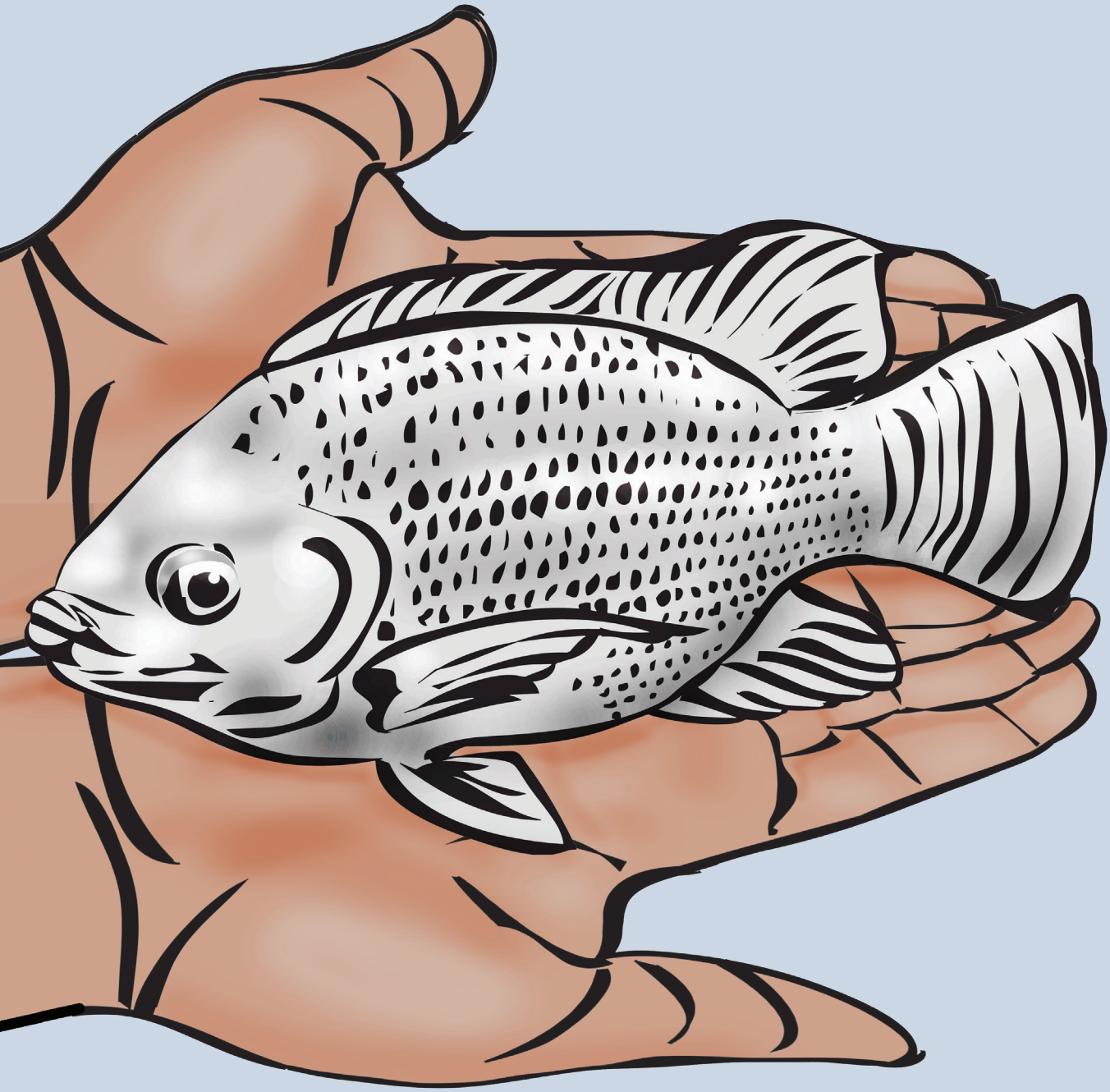

Illustrations: Derrick Nasando and Nicholas Mukupa

Better management guidelines for smallholder fish farmers in Malawi

WorldFish

Funded by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In partnership with
Norad
CGIAR RESEARCH PROGRAM ON Fish
Led by WorldFish

Better management guidelines for smallholder fish farmers in Malawi

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Citation

This publication should be cited as: Mudege NN, Lundeba M, Mark P, Chungu P, Peter Allen P, Chisusu D, Maluwa A and Komugisha RB. 2021. Better Management Guidelines for smallholder fish farmers in Malawi. Penang, Malaysia: WorldFish. Manual.

About WorldFish

WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decisionmaking on the critical issues of our times.

WorldFish is part of One CGIAR, the world's largest agricultural innovation network.

The Fish Innovation Lab supports the United States Agency for International Development's agricultural research and capacity building work under Feed the Future, the U.S. Government's global hunger and food security initiative. Mississippi State University is the program's management entity. The University of Rhode Island, Texas State University, Washington University in St. Louis, and RTI International serve as management partners.

Acknowledgments

WorldFish and the Feed, the Future Innovation Lab for Fish, collaborated to develop this Better Management Practices Manual. The work by WorldFish was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) project - Piloting Inclusive Business and Entrepreneurial Models for Smallholder Fish

Farmers and Poor Value Chain Actors in Zambia and Malawi. This work was undertaken under CGIAR Research Program on FishAgri-Food Systems (FISH) and supported by the CGIAR Trust Fund contributors: https://www.cgiar.org/funders/. The team would like to acknowledge the work done by the WorldFish Zambia team under Norad funded Aquaculture Technical, Vocational, and Entrepreneurship Training for Improved Private Sector and Smallholder Skills Project (AQ TEVET) because this work provided most of the materials for developing this smallholder farmer manual. For the same reason, the team would like to acknowledge The Malawi Gold. Standard Aquaculture Production System document developed by the Malawi Department of Fisheries and its partners. We also thank Vishnumurthy Mohan Chadag, Kelvin Mashisia Shikuku and Ahmed Nasr-Allah, for their unwavering support and review of the draft manual. We would also like to acknowledge the following experts from the Government of Malawi's Department of Fisheries for their support and review comments on the draft manual. Sincere thanks go to Nicholas Mukupa and Derrick Nasando of Kalahari Media & Office solutions, who developed the artwork and formatted the manual.

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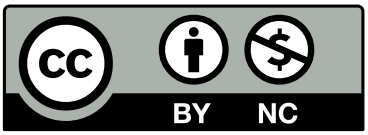

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1. Introduction to aquaculture:

Aquaculture is the farming of aquatic animals and plants. It can be either e land-based or open-water production. In Malawi, the principal form of aquaculture is fish farming, which is the practice of culturing fish in enclosed facilities such as ponds, tanks and cages.

1.1. Aquaculture in Malawi

Fish farming in Malawi started in 1906 with the introduction of rainbow trout *(Onchorhynchus mykiss)* for angling. Today, the country produces 5% of cultured fish in the region of the Southern African Development Community (SADC). Recently, Malawi has experienced growth in its aquaculture sector. Annual fish production under aquaculture increased from about 800 t in 2005 to about 4900 t in 2015 and 7672 in 2016 (CASA Malawi 2020). Malawi's Department of Fisheries estimates that the country has 15,465 smallholder aquaculture farmers.

1.2. What are the constraints related to fish farming among smallholder farmers in Malawi?

- There is a lack of availability of quality seed and feed close to smallholder farmers.
- Complete feeds are expensive to buy.
- Farmers have limited access to extension support and services.
- There is also a lack of financial support and access to high value markets.
- Infrastructure is inadequate.
- Use of poor farm management practices is widespread.
- Farmers do not have access to fast-growing fish species.

1.3. What are the benefits of aquaculture (fish farming)?

- Aquaculture contributes to food security and helps smallholder farmers diversify their diets.
- Fish is an important source of micronutrients, such as vitamin A (small fish), which has a lot of health benefits.
- Fish is an important source of animal protein.
- Some types of fish are rich in omega-3 fatty acids, which are healthy and can lower inflammation and blood triglycerides (bad fats).
- Aquaculture makes fish available in areas where there are no capture fisheries.
- It provides employment and entrepreneurship opportunities.
- When aquaculture uses land unsuitable for crop production, it improves natural resource management.
- It is a source of income for both male and female smallholder farmers and generates substantial income spillover for rural non-farm households.

2. Tilapia species cultured in Malawi

(This section is adapted from Nagoli J, Pulaizi A, Unyolo S, Phiri YL, Kanthenga H, Chemula D, Mbamba D, Thidza I and Sainani H. 2020. Fish farming trainers' guide: Pond aquaculture. Manual. Malawi: WorldFish.)

2.1. Where are tilapia found?

Tilapia, which thrives in small ponds, is now being raised in warm countries throughout Africa, Asia and the Americas. In Africa alone, there are more than 100 different types of tilapia. Each type looks and behaves slightly differently.

2.1.1. Chambo *(Oreochromis karongae)*

Chambo, also called chejumo, is gray and has vertical lines on its body. As a maternal mouth brooder, it incubates and broods its young in the female's mouth. This species is considered the best option for fish farmers in Malawi. Chambo breeds successfully in ponds and grows faster than either makumba or chilinguni. It takes a while for chambo to reach sexual maturity, which means that it spends a lot of energy on growing rather than breeding. It usually becomes sexually mature when it reaches about 70 g in weight. That makes chambo ideal for the Malawi Gold Standard system, in which large fish are needed at harvest. Chambo is omnivorous. It mainly feeds on plants that naturally grow in fertilized pond water (plankton), protein-based feeds including soya and sunflower, and plant-waste products like maize and rice bran.

2.1.3. Chilunguni *(Coptodon rendalli, formerly called tilapia rendalli)*

Chilunguni is indigenous to Malawi and is well adapted to all water bodies in the country, though it is not widely distributed among farmers. This fish is commonly called the red-breasted tilapia, but in Malawi it is known by several local names, including chilunguni, nyungusale, katakuzi, nyakalua, mgoma mbungu and many others. Chilunguni is a substrate spawner. It is a brightly colored fish with five to seven olive vertical bars, a bright red spot on the throat and breast, and a distinct black spot on the soft dorsal rays called "the tilapia spot." Chilunguni is herbivorous in nature (marophagous), feeding mostly on large plants.

Young and adult chilunguni are plant feeders that live in areas with plenty of vegetation. Their ability to digest aquatic plants make chilunguni especially important in combination with other tilapia species. Some of the vegetation that chilunguni feed upon includes sweet potato, cassava and papaya leaves, black jack/chisoso and elephant/napier grass. It has a high reproduction rate and produces about 5000–7000 fry per brooder and breeds about eight times each year. Chilunguni has a better growth rate than makumba because it starts breeding at a slightly older age. However, since its eggs are laid in shallow areas, the number that hatch and survive is low because many eggs and hatchlings die from high temperatures and predators.

2.2. What are the main characteristics of tilapia species cultured in Malawi?

Local name *(scientific name)*	**Chambo** *(Oreochromis karongae)*	**Makumba** *(Oreochromis shiranus)*	**Chilinguni** *(Coptodon rendalli)* *red-breasted tilapia*
Other local names	Omnivorous	-	Nyungusale, katakuzi, nyakalua, mgoma mbungu
Classification	Impende Iyakashika (Bemba) Pende (Nyanja) Mbufu	Omnivorous but changes to a more phytoplankton-/diatom-based diet at about 100 mm standard length	Herbivorous
Growth	Fast growth	Slower growth	Better growth rate than makumba
Reproduction subject to management conditions under culture	Matures in 4–6 months; spawns every month if temperature is below 24°C	Matures in 3–6 months; spawns every month if temperature is below 24°C	Matures in 7 months; spawns every 4–8 weeks if temperature is below 24°C
Temperature tolerance	24°C–36°C	19°C–36°C	24°C–36°C
Optimum temperature	27°C–29°C	24°C–32°C	Tolerates cold
Natural occurrence	Lake Malawi and Lake Malombe	Lake Malawi and the Upper Shire River but widely distributed in Malawi among aquaculture farmers	Indigenous to Malawi

Table 1. Main characteristics of indigenous fish species cultured in Malawi.

2.3. What other fish species are cultured in Malawi?

2.3.1. Mlamba (catfish)

Mlamba can be grown successfully in combination with makumba. Combining these two species can improve the growth of each species, because the cannibalistic nature of mlamba controls the makumba population. However, mlamba is not widely accepted in Malawi for cultural and religious reasons. Mlamba is characterized by a large, flat, armored head, with no spine in the dorsal fin, and it has a long base with no scales. One of the most unique features of mlamba is its ability to breathe air, which enables it to live in extremely high population densities and produce greater yields in various culture systems.

Species	Mlamba (catfish)
Origin	Indigenous
Local names	Mlamba
Classification	Carnivorous
Growth	Faster growth
Reproduction	Matures in 6 months and begins laying eggs after 9 months from November to February when daytime temperatures range from 27°C to 32°C
Temperature tolerance	18°C–36°C
Optimal temperature	24°C–30°C
Natural occurrence	Indigenous in Malawi; found in Lake Malawi, Lake Chilwa, Lake Chiuta and Upper Shire River

Table 2. Characteristics of mlamba in Malawi.

The growth rate of mlamba is better than any tilapia species; however, it does not spawn easily in ponds and tanks. Because of the cannibalistic nature of the species, fry will have low fry survival rates if the pond is not well managed.

3. Distribution of species allowed in Malawi

The Fisheries Conservation and Management Act (1997) outlines how fisheries and aquaculture are governed in Malawi. The act restricts the use of exotic species in aquaculture in order to protect Malawi's fish biodiversity. All exotic species, including O. niloticus, are prohibited in the Lake Malawi Catchment area. The common carp (another exotic fish species) was banned in 1992.

Species	Local name	Area
Oreochromis shiranus	Makumba	Widely cultured in Malawi
Oreochromis karongae	Chambo	Widely cultured in Malawi
Coptodon rendalli (red-breasted tilapia)	Chilinguni	Mostly in the Lower Shire River basin
Clarius gariepinus catfish)	Mlamba	-

Table 3. Fish that are commonly cultured in different parts Malawi.

3.1. Why am I not allowed to culture common carp or other exotic species?

There are many reasons for this. First, by law (The Fisheries Conservation and Management Act of 1997), farmers are only allowed to cultivate native species that are present in the receiving waters. Introducing exotic fish species in these water bodies can have unwanted and even dangerous consequences for the ecosystem. For example, the common carp digs up lake sediment, which could destroy tilapia breeding areas, thereby lowering tilapia reproduction by disrupted its nesting grounds (Chirwa et al. 2019).

Experience elsewhere in Africa has shown that when exotic tilapia species are introduced, this can lead to lower fish yields of the indigenous species that the local people depend on because of two reasons:

1. The exotic strains might compete with indigenous species for food, breeding sites and habitats.
2. Hybridization with closely related species might occur, threatening the genetic purity and integrity of indigenous species.

4.Site selection for earthen fishponds

4.1. How do I select a site for my fishpond?

4.1.1. Reliable water source

Make sure the water source is available year-round and free from contaminants. If possible, it should be slightly higher than the pond to reduce the energy costs of pumping water, since you can use gravity to fill the pond with water.

4.1.2. Water temperature

Make sure that the water temperature is suitable for optimal growth of the cultured species. For most tilapia species, the optimal temperature is between 24°C and 32°C. Tanganyika bream, for example, do not tolerate cold temperatures.

4.1.3. Warm area

Try to find the warmest area you can for building fishponds, and keep the area free from trees and shrubs. These limit the amount of sunlight that can penetrate the water, which lowers the temperature. Tilapia thrives in open, sunny locations where the water temperature is warm.

4.1.4. Pond maintenance

Follow these procedures to maintain your pond:

- Keep the pond water stagnant.
- Add fresh water only when the level drops 15 cm or more.
- On average, maintain the pond depth at 1 m. The deep end can be up to 1.2–1.3 m deep and the shallow end 0.6–0.8 m, depending on the size of the pond. Bigger ponds are constructed deeper with corresponding wider banks/dikes.
- Avoid building a shallow pond. Shallow water is more sensitive to changes in temperature. Shallow grow-out ponds are also susceptible to invasion from big birds, like Marabou storks, which can wade through the ponds and eat the fish. A moderate pond depth allows fish to escape in case of predators.
- For hatcheries, shallow depths could work well in pond-based hatchery systems. The shallower the depth, the warmer the water temperature, and warmth is good for fish reproduction. For hapa-based hatchery systems, **DO NOT** use shallow ponds. When properly set up, hapas should not sit at the bottom of the pond. Set hapas 10–15 cm from the bottom. Deeper ponds ensure that hapas have enough water and good depth.
- Where topography of the land permits, build a pond with inside slopes. The temperature of the water on the inside slopes will be warmer than the rest of the pond because the slope area is shallow.

4.1.5. Suitable soil type

The pond must have clay soil because clay soil can hold water. Sandy soil is not ideal because the pond banks will erode easily, and water will leak through the pond bottom.

4.1.6. Gentle slope

Build your pond on land with a gentle slope where it is possible to fill and drain the water using gravity instead

of pumping water in and out, which can be costly. Steep slopes can erode quickly and are not good for ponds.

4.1.7. Accessibility

Make sure the pond site is accessible to your home for security as well as easy management, such as feeding and checking on fish regularly. The pond should also be easily accessible by road to ensure easy links to fish markets and inputs.

4.1.8. Flooding

Choose areas that are not flood-prone. This helps reduce any long-term costs related to replacing escaped stock after floods. Avoiding flood-prone land also prevents pond water from seeping into groundwater supplies.

4.2. I am a new farmer and would like to take up fish farming. What should I do?

To avoid mistakes and future problems, visit your local DOF officers for advice on selecting a suitable area to build a pond. Farmers should not engage in aquaculture activities without consulting local authorities and DOF officers.

4.2.1. I want to take up fish farming, but my land is dambo. What should I do?

Please read section 5, which we have prepared to answer your question.

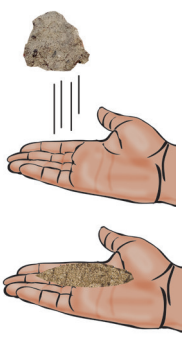
4.3. What is the easiest and cheapest method I can use to check if my soil type is appropriate for pond construction?

There are three methods that you can use:

1. **Squeeze the soil**
   a. Wet a handful of soil with just enough water to make it moist.
   b. Squeeze the soil by closing your hand firmly.
   c. If it holds its shape after opening your hand, the soil is good for pond construction.

2. **Throw the soil**
   a. Wet the soil and make a ball.
   b. Throw it in the air and catch it.
   c. If the ball holds together, the soil is good for pond construction.
   d. If it breaks or falls apart, the soil is not for pond construction.

3. **Water permeability test (for multi-day training)**
   a. Dig a hole 1 m deep in the ground. Fill the hole to the top with water. Cover the hole with leaves.
   b. The next day, the water level will be lower because the water has saturated the soil. Refill the hole to the top and cover with leaves.
   c. The next day, check the water level. If the level is still high, the soil is suitable for pond construction. If the water has disappeared, it is not suitable for fish farming.



5. Better management practices for dambo areas

5.1. Can I build a fishpond in a dambo area?

Building your pond in dambo areas has many disadvantages, such as the following:

- You will not be able to drain your pond for harvesting and cleaning. It is important to drain your pond completely to harvest all the fish, especially if you are doing fish farming as a business.
- You run the risk of losing your stock when it floods during the rainy season.
- Building a pond is difficult when there is too much water during the rainy season or if the water table is generally high.
- It is difficult to control water quality parameters, such as using fertilizer to grow plankton for natural food because of too much water from the ground.
- It posses environmental risks such as pond water seeping into the groundwater.

However, if you still want to construct your pond in such an area, there are two solutions to these common problems:

- Increase the height and width of the dikes (pond walls) to avoid flooding and breaking during the rainy season. Wide dikes also reduce seepage from one pond into the next.
- Use large overflow pipes to help remove excess water. If not removed, excess water can cause pond walls to break and collapse.

5.2. BMP guidelines for building and managing ponds in dambo areas

5.2.1. Make sure the site has limited flood risk in the rainy season

- Floods that exceed pond levees result in the loss of cultured animals, contamination of ponds with wild aquatic animals, and mixing of potentially poor quality floodwaters and pond waters. In dambo areas, the flood risk is high. You need to select a site where the flood risk is manageable. Consult other farmers and residents around the area on the history of the dambo in the previous 5 years in terms of flooding and water availability.

5.2.2. Do not build a pond on a spring (water source)

A spring is an underground water source that is commonly found in dambo areas. There are several reasons why you should not build a pond on a spring:

- Excess water will be difficult to control.
- Ponds can flood due to excess water.
- Flooding can result in a loss of fish.
- The results of fertilization (creation of natural food) will be difficult to attain because of the loss of nutrients from the water flowing out continuously.

Instead, use the spring as an inlet water source, and divert the water to the pond. In dambos with a water supply problem, make a reservoir pond near the source of water, such as a spring, from which water can be diverted into the fishpond.

5.2.3. Protect the site from flooding

Since flood risk is high, elevate the dikes, if necessary. Ponds should have high dikes and large overflows to accommodate high water levels. Instead of one spillway, ponds in flood-sensitive areas can have multiple spillways to allow for quick outflow of water.

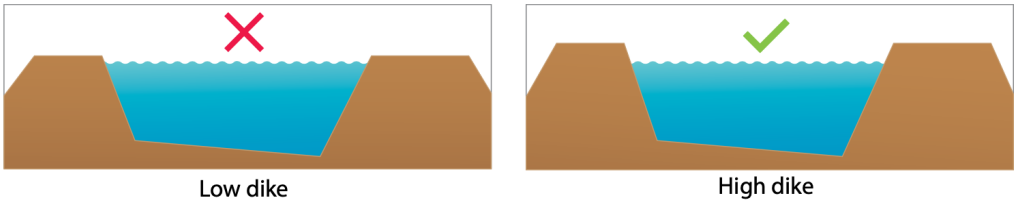


Figure 3. Side view of low-dike versus high-dike pond systems.

5.2.4. Do not develop fishponds in ecologically sensitive wetlands

Aquatic ecosystems cover 20% of the total land area on Malawi (Government of Malawi, 2015). Aquatic ecosystems in Malawi comprise lakes, rivers, wetlands and other small water bodies. Some wetlands of international importance, such as lake Chilwa wetland, 'which was declared a Ramsar site and a Man and Biosphere Reserve (MAB)' has been affected by human activities and climate change, affecting the livelihoods of the thousands of people (Government of Malawi, 2015). Aquaculture activities should not disturb these areas unnecessarily. For example, biosecurity measures should be put in place to maintain the integrity of biodiversity in the natural water bodies. Some measures include the following:

- Build sedimentation or treatment ponds to hold water coming from the ponds to contain pollutants or pathogens.
- Use native fish species, which cannot disrupt the ecosystem.
- Avoid using chemicals, which can pollute the water bodies.

6. Pond layout and construction

It is very important to consider the layout of the ponds in relation to the type of land, water source and drainage. Fishponds should be designed in a way that makes them easy to fill and drain completely.

6.1. How do I arrange my ponds?

- Arrange your ponds parallel to each other.
- Ensure your ponds have two bypasses to allow for independent supply and removal of water. This arrangement allows each pond to have an independent inlet and outlet channel.
- Do not allow the ponds to feed water into each other. This will reduce the risk of contamination and also maximize the results of fertilization in each pond.
- Make sure the ponds have a common source of water, such as a spring, stream, etc. (Figure 4)

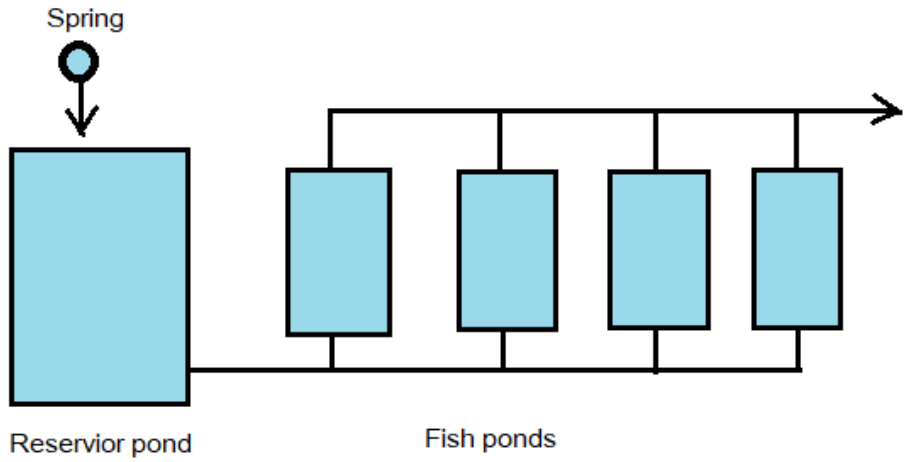


Figure 4. Parallel arrangement of ponds each having independent water supply and outlet channels with a common source.

- Construct dikes (also known as walls or banks) around the pond to ensure that water collects and remains in the pond.
- Plant grass on top of the walls to make them strong and to avoid soil erosion during the rainy season.
- Maintain the grass and keep it low.
- Maintain the right water level in the pond to regulate the temperature, inhibit the growth of underwater plants and keep dissolved oxygen at sufficient levels.

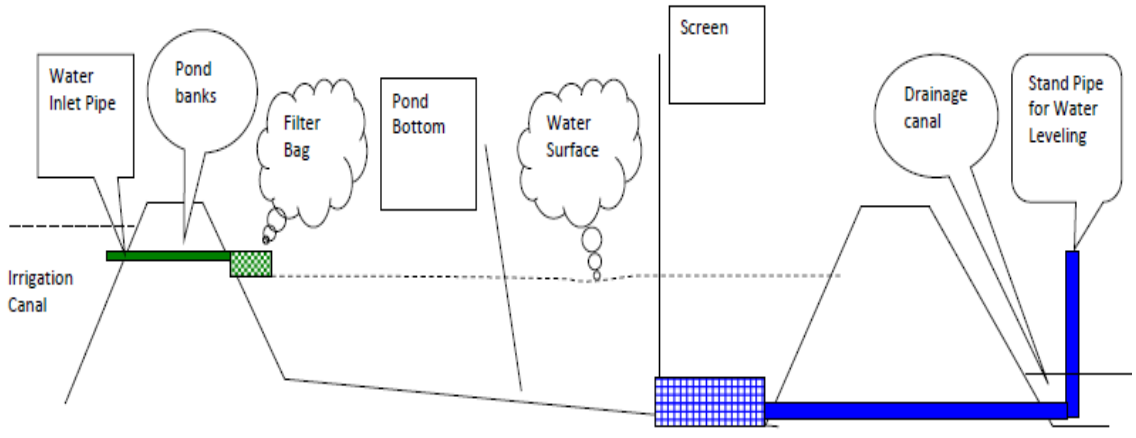


Figure 5. Vertical side view of a good pond with all basic features.

- Ensure your pond has inlet, outlet and overflow pipes.
- Place a screen/filter bag or a sieve over the inlet, outlet and overflow pipes to stop unwanted organisms from entering and prevent fish from escaping. You can use other materials such as a clay pot with holes punched in it, wire mesh, a piece of metal with holes punched in it, a loosely woven grass mat, or a basket that allows water but not small fish to pass through. Clean the screen regularly to remove debris and unclog it, preferably on a daily basis.
- Ensure your pond has a slanting bottom toward the outlet for easier water drainage.

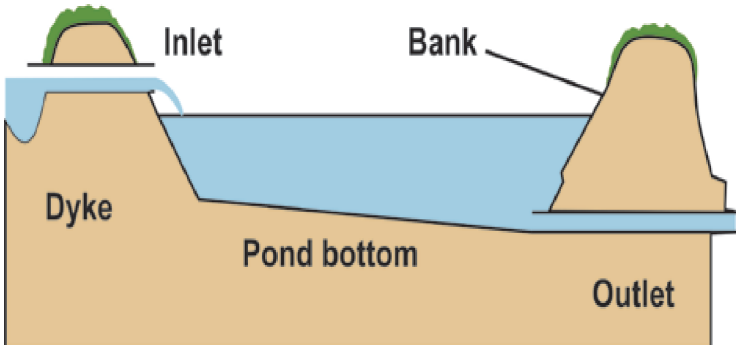


Figure 6. Side view of pond with slanting bottom.

- If your pond drains into a furrow, the furrow could become dirty and overgrown with grass. You may need to schedule a cleaning of the furrow.
- Having the water enter above the surface helps with aeration.

6.2. What are the best management practices for pond construction and preparation?

6.2.1. Build a pond that has a suitable size and shape

The best size and shape for ponds depend on production purpose, production intensity, market schedule, harvest methods and construction cost. Rectangular ponds are the most practical to build and manage. From both a management point of view and profitability, it is recommended that smallholders in Malawi build fishponds at least 1000 m^2 in size. Farmers can reach that level in one of two ways: (1) build two ponds 500 m2 each or (2) build five ponds 200 m^2 each. A farmer can decide on the size of their pond depending on the financial resources and labor that are available, as well as markets.

6.2.2. Use the right pond depth

Make sure the water depth is 60–80 cm in the shallow end (about knee high) and 1.2 to 1.3 m in the deep end (about waist high). The shallow end will allow you to skim fry easily into the nursery hapa. Your pond can be deeper than this if you need to use it as a water reservoir in the dry season. Just be sure that all the water can be completely drained for harvest. It is important to smooth out the pond bottom after reaching the proper depth. This will make it easier to use nets for harvesting fish, as they will slide easily over the pond bottom. Shallow ponds can be used for pond-based hatchery systems but not for grow-out.

6.2.4. Make sure dikes have the right height and slope

Elevate the pond dike at such a level that floodwater cannot enter the pond. The best slope for the pond walls is 1 m in height for every 2 m in length. You can easily make a triangle to help build the slope at this angle. The walls should be about 30 cm above the water level. Do not go beyond this height. If the pond walls are too high, they become unstable, and high walls make it hard to work around the pond. To avoid leaks, make sure that the soil used for the dike does not contain large amounts of rocks, sand, wood or plants.

Build the dikes wide enough between ponds to avoid the risk of breaking and to provide workspace. Compact the soil often as you build the wall. After adding 30 cm of loose soil, trample on it by foot or use a rammer. You can pound it with your hoe, a heavy log or a piece of wood attached to the end of a pole. This will make the dam strong. If you do not compact the soil, it will remain loose, the wall will not be strong and the pond will not hold water.

6.2.5. Ensure that each pond has its own individual water supply and outlet

Separate inlet and outlet canals; no water flow should
be allowed from one pond to another. If necessary, treat inlet water in a reservoir or use filtration. Control the flow of water into each pond using valves or shut gates, and screen inlet water to keep out wild fish, twigs, leaves and other trash. Make sure the outlet is at the deepest end of the pond so that all the water can be drained using only gravity. The inlet and overflow pipes should be at least 15 cm above the water surface to prevent fish from escaping. To avoid blockages, regularly clean the mesh over the overflow pipe in undrainable ponds where water flows continuously. Breaking the dike instead of installing an outlet is not a good practice, because this causes erosion, will weaken the dike and is labor intensive.

6.2.6. Settle and screen effluent water

For easier harvesting, make a ditch (2 m wide) in the lowest area of the pond bottom toward the drain outlet.

6.2.7. Dry the pond between batches

When using drainable ponds, drain the water from the ponds as much as possible and then dry the pond bottom until it cracks. This helps improve soil properties and dispose of organic waste.

6.2.8. Clean the pond between batches

Ponds that can be drained completely can be sundried to kill all small organisms remaining in the pond. This should be done for a minimum of 10 days. Apply agricultural lime to increase soil pH and kill harmful organisms.

6.2.9. Maintain the pond

Check dikes for holes and fix them. Maintain the ditch by lifting mud onto them. Re-slope the dikes if necessary. Also, check the inlet and outlet canals and maintain their depth to ensure water flow.

7. Biosecurity

7.1. What is biosecurity?

Biosecurity consists of practices that

- reduce the risk of introducing infectious diseases and pathogens to your fish;
- help to minimize the risk of pathogens (via fomites or water) or diseased fish from escaping or leaving your farm and spreading into natural water bodies, other farms or susceptible species;
- reducing stress to animals, making them less susceptible to disease (Yanong and Erlacher-Reid 2012).

7.2. Animal management

- Make sure fish seed are healthy and free of disease. To do this, buy seeds from accredited hatcheries. If you do not know which hatcheries are accredited, please ask your DOF officer.
- To prevent the potential spread of diseases and pathogens, quarantine any newly bought seeds in a separate pond with no other fish species, and separate them from other animals.
- *"Quarantine is the procedure by which an individual or population is isolated, acclimated, observed and, if necessary, treated for specific diseases before its release onto the farm or for live market sale (e.g., for grow-out or for aquarium fish stores)" (Yanong and Erlacher-Reid 2012).*

7.2.1. Importance of quarantines

- They protect the fish you have on your farm from potential exposure to exogenous diseases and pathogens.
- They allow new fish enough time to acclimatize to their new water environment and feeding and management regime.
- They give fish time to recover from the stress of handling and transportation.

7.2.2. Quarantine protocol

When you buy new fish from another hatchery, do not add them to the hapa where you are already quarantining other fish. Use a new hapa. Do not mix different batches of fish in quarantine. When you quarantine the fish, look for abnormal behavior and loss of appetite. Either could be an early sign of disease.

The length of quarantine depends on factors such as the situation, species, purpose of moving the stock and accompanying risk assessments. About 15 days to 3 months is recommended, depending on the nature of movement and associated level of risk. The nature of movement is also important, whether it is within a farm, between farms, between provinces or between countries. The health status of the facilities from where the fish were taken and received also needs consideration.

7.2.3. Practice good husbandry

- Ensure that fish are not stressed. Reduce excessive handling that can damage the skin of the fish and their gills, as this could weaken their mucosal immune system. This means that you have to take some of the following measures to help prevent diseases. First, maintain good water quality. Second, use appropriate feeds and feed amounts for the species under consideration. Third, use the recommended stocking density, as high stocking densities could concentrate microorganisms and increase the susceptibility of your fish to diseases. Stocking densities differ according to farming intensity, whether extensive, semi-intensive, intensive or super-intensive. Generally, a maximum stocking density of three fish per square meter is recommended for smallholder farmers.

- Observe fish daily at feeding time, as changes in behavior and appetite could indicate disease.
- When using commercial feeds, do not use them past the expiry date. Poor storage can also result in nutrient breakdown and contamination from molds. Store feeds in a cool, dry place away from vectors that can contaminate it.
- You may need to vaccinate your fish against some diseases. Talk to your DOF officer for more information on vaccinations.

7.3. Pond management

7.3.1. Use clean equipment

Use a disinfectant (i.e. chlorine, Virukill) to clean fishnets, buckets, containers and other equipment before use and especially between use in different ponds. You can also use salt to clean small pieces of equipment, such as scoop nets and sieves. After cleaning, dry your equipment in the sun for some time.

Disinfectant	Dosage (exposure time*)		
	Dipping (30 seconds to 1 minute)	Water bath (up to 1 hour)	Indefinite
Salt**	3% (30 g/L)	1% (10 g/L)	0.02% (0.2 g/L)
Formalin**	400 mg/L	250 mg/L	15–25 mg/L
Potassium permanganate	1000 mg/L	20 mg/L	2 mg/L
Madeline blue	1000 mg/L	20 mg/L	2 mg/L
Copper sulphate	500 mg/L	4 mg/L	Alkalinity level/100

** Exposure time given is relative and not necessarily ideal in certain circumstances.*

*** Denotes commonly accessed and used disinfectants/chemicals in Malawi/Africa aquaculture.*

Table 3. Commonly used disinfectants and recommended exposure time.

7.3.3. Use clean water

- Ensure that water entering the ponds is clean.
- Do not transfer water between ponds.
- Make sure ponds have independent pipes and outflows to avoid cross-contamination.

7.3.4. Dry and clean ponds between production cycles

7.3.4.1. Drainable ponds

- Drain water from the pond.
- Dry the bottom of the pond until the soil cracks. Dry the pond for a minimum of 10 days. Drying the pond helps improve soil properties, remove organic waste and remove or reduce aquatic animals such as snails and reptiles, which can spread diseases in ponds.
- After the pond is dry and the bottom is cracked, apply agricultural lime to increase the pH of the soil and kill harmful organisms. Liming is done to reduce acidic conditions, to make fertilizer work more effectively and to disinfect the pond from parasites. In general, red soil and areas with high rainfall will have higher acidity than dark soil and areas with low rainfall.

Contact your DOF extension officer if you are not sure how much lime to apply.

- If you cannot ask your DOF or Department of Agriculture officer for advice, then try doing it yourself. According to the Food and Agriculture Organization, lime (CaC03) is applied depending on the nature of the soil. New ponds may require more lime than old ponds. Sandy soils may require 2000 kg/ha of lime and heavy clay soils may require up to 4000 kg/ha. Drained ponds may require less lime. 'About once a year, apply one-quarter of the total quantity of liming material you required for the complete new pond treatment. (FAO, nd)' Lime ponds at least 2 to 4 weeks before applying any fertilizers. Lime ponds at least 2 weeks before a new batch of fish arrives.
- Some specific advice for Malawi on liming include the following:

Fish farming area	Lime application rates (per 200 sq m)
High alkalinity areas (Low acidity): Chitipa, Rumphi, Mzimba, Namwera, Lilongwe, Zomba West	Lime = 4 buckets (1 liter size) Wood ash = 5 buckets (1 liter size)
Low alkalinity areas (High acidity): Nkhata Bay, Mulanje, Thyolo, Chiradzulu, Zomba east, other parts of Dedza	Lime = 25 buckets (1 liter size) Wood ash = 30 buckets (1 liter size)

Source: Malawi Gold Standard

7.3.3.2. Undrainable ponds

- Pump the water out using a water pump.
- If you do not have a pump, drain the water and much as you can and allow fresh water to come in.
- Apply lime to the pond.

7.3.3.3. Drying ponds

- *"Drying and plowing is another method that can provide some level of pond disinfection. This method may only be possible during the dry season, or may not be possible at all in areas with year-round high groundwater or heavy rainfall. The pond is first allowed to dry for a week or until the surface has cracked to a depth of 4 inches (10 cm). After this occurs, the soil should be broken up to a depth of approximately 8 inches (20 cm) with a plow or tiller and allowed to dry for an additional week, prior to preparation, refilling, and stocking. This process helps to disinfect through a combination of microbial degradation, sunlight /UV exposure, aeration, and desiccation" (Yanong 2013).*
- You can also apply wood ash after drying your pond. Wood ash also helps kill harmful organisms.
- Another alternative is to use your hands and also shovels to remove the soil once it becomes cracked, and then and use the cracked soil for gardening. Removing this soil reduces the number of harmful microorganisms in your pond.

7.3.5. Dispose of waste properly

- Dispose of waste such as domestic garbage, dead fish and expired feed in a proper manner to avoid the risk of contamination or attracting predators.
- Use a clean scoop net or bucket to remove sick and dead fish from the pond as soon as possible.
- Burn or bury dead fish at a safe distance from the ponds (at least 100 m).

7.3.6. Control weeds and dense vegetation near ponds

Aquatic weeds provide shelter for vectors and predators. Weeds on the pond dikes and dense vegetation near the pond provide hiding places for predators and other animals.

- Manually clear vegetation from the pond dikes.
- **DO NOT** use herbicides, as these can be toxic to fish.

7.3.7. Implement measures to control predators and pests

Pests and predators can carry diseases when entering a pond. Always keep animals like birds, snails, frogs and monitor lizards out of the pond. Monitor the pond for these animals, because they will eat the fish.

- Cover inlets with small mesh, build a fence around the pond, avoid large trees on dikes, regularly check for dike erosion and install lines above the ponds.
- Use a clean scoop net to remove frogs and frog eggs.

- Dry the pond between batches.
- Fertilized ponds reduce visibility for the birds.
- Ensure that ponds have a sufficient water depth to decrease the smell of the fish in the pond.
- Monitor your pond regularly and use decoys such as scarecrows.
- Manage predators and pests in an environmentally sustainable way. Do not poison, trap or shoot animals.

7.3.8. Do not let livestock and domestic animals enter the pond

- Erect barriers around your ponds to keep domestic animals and livestock away from the ponds. Livestock can carry disease and pathogens that can contaminate the water and infect the fish.

7.4. People management

- Make sure that anyone working on the farm or visiting is wearing clean clothes and footwear, as pathogens can be introduced through clothes and footwear.
- Do not allow visitors from farms that have disease or mortality problems.
- Make sure people working at the ponds wash their hands before work, after eating and after going to the toilet. Keep contact with the pond water to a minimum.
- When entering the pond, farmworkers should bathe and change clothes, especially if they are working with fish of different health statues. If using hired or casual labor, make sure workers follow this protocol because there is a danger of spreading pathogens and diseases from one farm to another.
- Have a foot and hand-wash facility for both farmworkers and people visiting the farm.

- You can have a chemical footbath at the entrance of your pond area so that everyone entering the farm can decontaminate their footwear before entry.

8. Nursery ponds

8.1. What are nursery ponds?

Nursery ponds are where fry are raised before stocking into fertilized production ponds. Hapas set in fertilized ponds can also be used to nurse fry. You can nurse your fry to your desired size before you move them to grow-out or production ponds. You can raise fry from 1–3 months or up to your desired size. Once fry grow to between 5 and 20 g, they are referred to as fingerlings. It is important to nurse fry to reduce the mortality of juvenile fish.

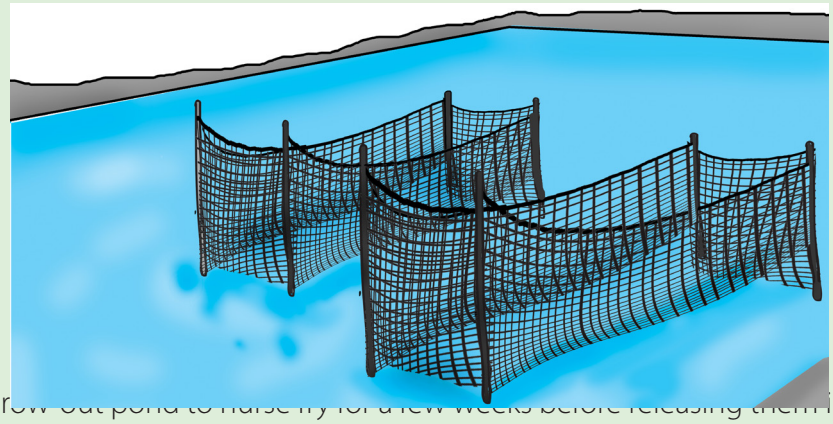
8.2. Why is it important to raise fry in fertilized ponds?

- The principal objective of rearing fry in fertilized ponds is to provide an environment in which fish can survive and grow rapidly.
- Fertilizing ponds helps maintain an appropriate size and abundance of food organisms (phytoplankton, zooplankton and macroinvertebrates) while simultaneously maintaining water quality suitable for survival and growth.
- It is important to time the preparation, filling and fertilization of nursery ponds so that they coincide with stocking fry. This will ensure that the pond has had sufficient time to develop suitable blooms of plankton when the fry are ready to be stocked. Timing the filling and fertilization of nursery ponds with stocking also helps ensure that the lag time between filling and fertilization and then stocking is not too long that it allows predatory insect populations to increase. In the same way, prepare the grow-out or production ponds to receive the juveniles from the nursery ponds. For steps on how to fertilize and fill ponds before stocking, refer to chapter 7 on fertilization and supplementary feeding.

8.3. BMPs for nursery ponds

8.3.1. Nursing fish without a nursing pond

If you do not have a nursery pond, you can use hapas to nurse your fish before releasing them into grow-out ponds.



Place hapas in your grow-out pond to nurse fry for a few weeks before releasing them into open pond water. One hapa of 5.4 m^2 (3.0 m x 1.8 m x 0.9 m) can accommodate 500 fry. The advantage of using hapas is that you can easily count the number of fingerlings. Clean your hapa with a brush every week. Hapas are often fouled by uneaten feed, fish feces and attached microbial growth, all of which can cause diseases.

8.3.2. Feed fry regularly

Feed the fry five times daily with high-quality powder feed (30% crude protein or more) at a feeding rate of 10% of fish weight. Be consistent regarding feeding times. If you do not have high-quality feed, you can use a homemade feed coupled with pond fertilization (section 9).

8.3.3. Grade fish regularly

For optimum survival, it is recommended that fry nursed in hapas are size graded and thinned out once a month. For grading, sieve the fish through netting, plastic mesh or parallel bars. Several sizes of graders will be necessary depending on the size of fish. After grading, the stocking density should be adjusted to size of the fish. The purpose of grading fry or fingerlings is to stock a uniform size in the nursery, grow-out or production ponds. For example, small and big fish are supposed to be stocked in separate ponds. Come harvest time, the fish will be the same size, which is good for the market. It also reduces competition for food as the fish are growing.

Size of Tilapia		**Recommended Stocking density**
Centimeters (cm)	Grams (gm)	No. fish.m2 (m^2)
25	0.2	750
3.8	0.5	440
5.1	1.0	255
6.4	2.0	143
7.6	5.0	63
9.0	100	35
10.0	20.0	20
11.4	50.0	10

Source: : (Tilapiathai.com/nam-sai-library cited in Hoevenaars K & Ng'ambi, 2019)

Table 4. Recommended nursery stocking densities for tilapia.

9. Stocking

9.1. What should I consider when looking for seed to stock my pond?

- Consider using a breeding center, commercial hatchery, government fish farm or well-trained local community hatchery operators.
- Ask the hatchery to condition or starve the seed before transporting them.
- If available in your area, stock all-male fish to avoid reproduction in ponds. If you have the expertise, you can also try creating monosex (all-male) tilapia when the fry weigh about 20–30 g. You can then stock the males only. Alternatively, you can consult with your DOF officer.
- Stock all male and uniform or same size tilapia, which will grow faster than mixed-sex tilapia. They also use feed more efficiently (for growth, not reproduction), which results in better productivity and profitability.
- Stock fish that are free from disease.
- Stock small fast-growing fish.
- Get your initial fingerlings from specialized fingerling producers to avoid stocking stunted young fish.
- Stock fish that look active (swimming, eating, vigorous).
- **DO NOT** buy seed from another farmer because of the risk of spreading disease or getting seed of poor quality.
- **DO NOT** take fish from the wild or natural waters if you are not sure of the cultivable species. Although cultivable species may be known, there is a risk of introducing and spreading disease from the wild. Taking fish from the wild can also deplete the wild stock.

9.2. How do I assess fry quality and other good characteristics?

- Ensure fingerlings weigh at least 1 g.
- Select healthy fingerlings free of disease and deformities. Check the color to make sure it is the natural color of the species. Loss of color is an indication that the fish is not in good health. Also, check the shape of the fish to make sure it is not distorted or deformed.
- Select active fry by observing their movements and response to feeding. Healthy fry move and feed actively. If they do not, it could be a sign that they are unhealthy.

9.3. What measures can I take to protect my seed during transportation?

Seed can suffer a lot of stress during transportation from hatchery to farm, and this stress can affect the performance of the seed. In some cases, it can even cause them to die.

- Locate a good quality hatchery close to your farm so that you reduce the transportation time and promote easy movement of seed.
- Make arrangements with the hatchery a few days before you pick up your seed, and prepare to travel between 18:00 and 10:00 when temperatures are still cool.
- Condition or starve the seed before transportation. Starvation allows the fish to empty their feces before being placed in containers or bags, which can contaminate water during transportation and kill the fish.
- Replace the water from the transportation containers or bags with clean water if necessary, especially if you see fish gasping or coming up to the surface. This is a sign that the fish are suffocating and trying to use atmospheric oxygen to breath.
- Wet your hands before handling the fish because dry hands can remove their protective covering that helps prevent disease. Keep the fish in water while sorting and counting.
- Adjust the water temperature slowly so that the fish are not exposed to sudden temperature changes. Take out some water from the transportation bags and slowly replace it with fresh water.

- Use cool water, about 20°C–23°C, if possible. In cool water, fish are less active, so they consume less oxygen and produce less ammonia and carbon dioxide, which can contaminate water and lead to oxygen depletion and even death.
- Avoid transporting fry in hot weather to avoid stressing the fish.
- Drive carefully (avoiding bumps if possible) so as not to stress the fish. The driving speed depends on the state of the roads. The earlier that the fish get to the destination, the better their survival. While traveling, check the fish every 15 to 20 minutes to see if they are gasping for air at the surface. If this happens, add some fresh water. If you cannot get fresh water, splash the water with your hands or add air with a bicycle pump.
- You can use any clean container for transporting fish, such as a bucket, gourd, 20 L tin or a drum. Be sure it is clean and does not have any traces of soap, oil or chemicals in it.

9.4. What else do I need to take into consideration during transportation?

Size (g)	LDensity (fish per L)	Transportation time (minutes)	Temperature (°C)
1–5	8	30	25
5–10	5	30	25
10–20	3	30	25
20-50	1	30	25

Source: Hoevenaars & Ng'ambi, 2019

Table 5. Ideal stocking rates and transportation time when using containers.

If the transportation time is longer than 30 minutes and the temperature is greater than 25°C, then change the water every 30 minutes. When transporting fish over longer distances and in large quantities, use oxygenated bags and transportation tanks. If necessary, seek advice from your DOF extension officer.

9.5. What are the best steps to take when stocking a fishpond?

- The fish must have enough space in a pond to grow well. If there are too many fish, they become overcrowded and stunted. To avoid this problem, stock three to six fingerlings per square meter, depending on the level of management. Skim young fish regularly, and grow them separately in hapas or ponds. Harvest market-size fish every 4 months during hot months and every 5-6 months in cold months.
- Seek advice from the DOF officer regarding the optimal stocking density of your pond. The optimal stocking rate for a pond results in the highest quantity and quality of fish production and thus the most profit.
- The stocking density (carrying capacity) differs depending on the size of your pond and management practices.

- When stocking fish into ponds, acclimatize them slowly acclimatize to their new environment to avoid stress.

9.6. How do I acclimatize my fish after transportation?

- Keep the seed bags floating on the pond for 20–30 minutes before releasing the fingerlings into the pond to acclimatize them to the temperature of the pond water.

- Start feeding the fish 1 or 2 days after stocking to allow them to recover from the stress of transportation.

9.7. What is the average stocking density for fingerlings?

- Consult your DOF officer first when deciding on stocking density.
- Stock fingerlings at a density of three to six fingerlings per square meter in a semi-intensive culture system, which is characterized by fertilization and supplemental feeding. Supplemental feeds can be either homemade or commercial feed.

9.8. What is the best time and place to stock seed?

- Stock seed during cool hours of the day when temperatures are still low: between 18:00 and 10:00. Stocking them early in the morning is best so that there is enough light for you to see what you are doing.
- Stock the seed around the inlet, where water drops into the pond, for maximum oxygenation of fish.

9.9. Important reminders for handling and stocking fingerlings

DO: Transport fish when the temperature is cool.
DO: Always use wet hands.
DO: Keep the fish in water while counting.
DO: Handle the fish gently.
DO: Fill transportation containers with pond water.
DO: Cover containers with leaves or cloths.
DO: Work fast and travel quickly.
DO: Always check the water temperature and temper fish, which can be done by slowly mixing the receiving pond water into the container that the fish are in.
DON'T: Muddy the pond while seining.
DON'T: Squeeze, drop or throw fish.
DON'T: Use dirty containers.
DON'T: Leave fish in containers for a long time.

DON'T: Let fish stand in the sunlight.
DON'T: Overcrowd the fish in the containers.
DON'T: Change the temperature of the water too quickly.

10. Feeds and feeding

A high-quality feed is essential for high productivity and good fish health. For optimal growth and profits, fish need a protein-based feed, because protein is good for growth. Commercial feeds offer several advantages over other feeds, including better feed conversion, consistent nutrition, faster fish growth, lower fish mortalities and improved water quality.

Although commercial feeds seem to be more expensive, they are actually much more efficient. They usually have a low feed conversion ratio (FCR)—the amount of food required to produce 1 kg of fish. For example, if fish in one pond are fed on a certain weight of commercial feed while fish in another pond are given the same weight of feed but made from locally available material, the fish fed from the commercial feed will grow bigger and faster than those on local feeds, which means they will have a lower FCR. Thus a lower FCR can lead to higher profits since the farmer will use less feed but produce more out of it.

	Maize (ground)	**Chakudya Chogula/ chakudya cha timibulu titalititali tochedwa ma peletsi muchingelezi**
Unit cost (ZMW) of feed/kg	189	1,040.00
FCR of the feed (kilograms of feed needed for 1 kg of flesh)	*20	2**
Total cost (ZMW) of feed used to produce 1 kg of fish	3,780	2,080

Source: modified from Isyagi et al. 2009.

Table 6. Cost efficiency of different types of feed.

10.1. How do I use feed effectively?

- Make sure the feed is well balanced and cost-effective.
- Ensure that it is consistently available and accessible.
- Buy feed from reputable manufacturers.
- Use feed formulated for the species under culture, such as tilapia or catfish feed.
- Follow the instructions from feed manufacturers.
- Base the feeding rates on the percentage of fish weight. This changes with the size of the fish. (Smaller fish require more feed as a percentage of their weight.)

10.2. How can I calculate the amount of feed to give to my fish?

Table 7 is an example of how you can calculate the amount of feed.

Explanation	Calculation
Use data from your records to get the average weight of 800 fish.	Average weight is 82 g.
Total weight of fish in the pond: weight x number of fish	82 g x 800 pieces = 65,600 g / 1000 = 65.6 kg
Total amount to feed your fish daily: weight of fish in the pond x daily feeding rate	3% weight = 3/100 = 0.03 65.6 kg x 0.03 = 1.968 kg = 2 kg
Two feeding portions or 2 times per day	Morning feed: 2 / 2 = 1 kg Afternoon feed: 2 / 2 = 1 kg

Source: Hoevenaars & Ng'ambi, 2019

Table 7. Feed calculation based on 3% of fish weight in a sample of 800 fish.

- Feed fish the right size feed, and adjust the feeding frequency to the size of the fish. Smaller fish require higher feeding frequencies than larger fish.
- Environmental factors, especially temperature, can affect the amount of feed required. For example, fish will eat less when the water temperature falls during the cold season and will eat more when the temperature rises. To avoid wasting feed during the cold season, reduce the amount of feed and frequency. Observe the feeding response as you feed the fish during the cold months.
- Observe fish behavior when feeding to make sure the fish are eating. If the fish have a low appetite, it could be a sign of distress or disease. Check the water quality (section 12), fish health (section 13) and stocking densities (Section 8.3).
- Avoid under or overfeeding. Excess (uneaten feed) can accumulate in the pond, causing the water quality and the quality of the pond bottom to deteriorate. Overfeeding wastes feed.

10.3. What can I use if commercial feed is not available in my area?

- Use farm or homemade feed.
- Some ingredients for homemade feed include soybeans, sunflower cakes, maize bran or whole maize, millet, cassava, trash fish (if available) and rice bran.
- To make a simple protein feed, mix 37.5 kg of ground soya and 62.5 kg of ground maize. This feed will provide about 30% crude protein, though even higher protein levels will improve growth. Farmers are encouraged to adapt new feed formulations as new research is released. Roast the soy well. Grind the ingredients into small particles for young fish (fry) and medium-size particles for larger fish. Feed the fish powdered feed during the first month and pellet feed during and after the second month.

Source: Chomba Chileshe, fish farmer.

Figure 7. Locally available ingredients for feed formulation.

- Consult your DOF officer on how to formulate homemade fish feed.
- Supplement any homemade feed with pond fertilization. Most homemade feeds do not provide the required balanced diet due to lack of some ingredients.

10.4. How do I store feed?

- Protect your feeds from contaminants such as pests and chemicals. Once the feed is contaminated, the quality goes down and can affect productivity. Feed can be contaminated through ingredients or due improper or long storage.
- Store feed in a cool, dry area that is protected from pests and potential sources of contamination.
- When receiving the feed, check its quality and date of expiry.

10.5. How do I calculate the FCR?

It is important to understand the FCR, because this has implications for the profitability of your fish farm. The FCR is the amount of food required to produce 1 kg of fish. It is an indicator for the performance of the feed, efficiency of the response to feeding, and the cost-effectiveness of the feed. For example, an FCR of 1.6 means that if you give your fish 1.6 kg of feed, you produce 1 kg of fish. The lower the FCR (less than 2), the better the feed.

Calculate FCR as follows: FCR = total amount of feed given (kg) / amount increase in fish biomass (kg)

Explanation	Calculation
Use data from sampling.	Previous weight of all fish in your pond was 40 kg. Current weight of all fish in your pond is 65.6 kg. The feed given to fish (from your records) is 2 bags of 20 kg = 40 kg in total.
Weight gain: current weight – previous weight	65.6 kg – 40 kg = 25.6 kg
FCR: kg of feed given in kg / weight gain in kg	40 kg/25.6 kg = 1.56 = 1.6

Source: Hoevenaars & Ng'ambi, 2019

Table 8. Example of how to calculate the FCR.

10.6. What is the optimal or ideal FCR?

- For Nile tilapia, the best FCR is approximately 0.8–1 for the fry to fingerling growth stage and approximately 1.4–1.8 for adult/grow-out.
- According AllerAqua, a private feed company in Zambia called AllerAqua, "Our achieved FCR ranges from 1.2–1.4 (cages) to 1.3–1.6 (ponds), depending on the management of the final size of the fish and the season within the respective operations."
- An FCR of 1 to 2 for grow-out fish (10 g to market size) is good in ponds, depending on the feed type and management of the farmer.
- For fry and fingerlings, 0.4 to 1 is what a farmer should aim for.

10.7. BMPs for feeding

i. Buy feed from a reputable manufacturer

- Since feed represents the largest part of production costs, buy the appropriate feed for the fish species.
- Use high-quality commercial feeds, and buy directly from a feed mill or trusted dealers.

- Buy floating pellets, which remain on the surface until consumed. This allows you to monitor feed response as fish are eating.

ii. Use only fresh, high-quality feed

- Ensure and maintain feed quality by checking labels, feed ingredients, expiry date, feeding rate, species of fish and other necessary information.
- Store feed in a cool, dry place that is free of contaminants and pests.
- Check the content of the feed before feeding to make sure it is dry and not moldy.
- Buy and use the feed before its expiry date.

iii. Use the right size feed

- Use the right size pellets for your fish at each life stage. If the pellets are too big, the fish cannot eat them, because fish swallow feed whole. If the pellets are too small, the fish have to expend more energy to eat enough. Using more energy to feed will decrease the growth rate of the fish.
- Use the feeding tables on the right pellet sizes for the right size of fish provided by the manufacturers.

iv. Feed fish consistently and regularly

- Be consistent with feeding times every day. Consistency is important for the growth of tilapia, because they adapt to their feeding times. Feed tilapia at the same time every day to maintain production efficiency.
- The number of daily feeding times varies according to fish size.
- Feed small fish up to 50 g 3–4 times daily.
- Feed large fish only 1 or 2 times per day. Make sure the total amount of feed does not exceed the calculated daily feeding rate for e*ach pond*.

Weight of fish (g)	Feeding rate (% of weight)	Daily feeding times
1–5	6–10	5–6
5–25	5	4
25–150	3	3
>150	2	2

Source: Hoevenaars & Ng'ambi, 2019

Table 9. Guide for feeding tilapia at 24°C–30 °C using a quality formulated feed.

v. Use feeding methods that reduce fish stress and have a lower environmental impact

- Follow the instructions of the manufacturer when using the feed.
- Maintain good water quality.
- Do not overfeed the fish, because the uneaten feed will go to waste and decrease the water quality.
- Do not underfeed the fish, because insufficient feeding will lead to poor growth.
- When using floating feeds, use a floating (feeding) hose ring or pipes to contain the feed and stop it from floating away to the pond margins, where it attracts birds and is harder for the fish to consume.

Source: Kafue Fisheries.

Plate 2. Feeding ring using floating pellets.

vi. Feed fish the right amount of feed

- Adjust feeding rates according to fish behavior. Fish should neither be overfed (no pellets should be left uneaten) nor underfed.
- Sample fish to get the average weight for calculating the right feed amount.
- In the absence of a weighing scale, it is hard to calculate feed quantities, so you can opt to feed your fish to satiation. Using floating feed allows you to monitor the fish during feeding. The feed should be consumed within 20 minutes of being offered to the fish. If fish do not eat all the pellets within 20 minutes, then reduce the quantity. If they do, then increase the amount.
- You can use the following guideline for feeding the soya and bran mixed feed. This is based on feeding a 500 sq m pond and a 1000 sq m for 4 months. (Source: Malawi Gold Standard).

Age of fish	500 sq m pond	1000 sq m pond
Month 1 Month 2 Month 3 Month 4	110 kgs (4 kgs per day) 183 kgs (6 kgs per day) 236 kgs (8 kgs per day) 270 kgs (9 kgs per day)	220 kgs (8 kgs per day) 365 kgs (12 kgs per day) 472 kgs (16 kgs per day) 540 kgs (18 kgs per day)
Total	800 kgs	1600 kgs

- These rates are based on a feed rate of 3% average body weight.

vii. Feed fish at the right time of day

- Feed your fish twice a day: once in the morning (08:00–10:00) and once in the afternoon (14:00–16:00) when the water is warm. This is when fish are active.
- Feed the fish at the same time every day, for example, at 09:00 and 15:00.
- Put the food in the same place every time so that the fish will know where the food will be and will not have to search for it.

viii. Store feed in a cool, dry place that is free of pests

- Store feed properly to maintain quality.
- Store feed in a cool, dry area to prevent spoilage, mold growth and contamination. To prevent pests from entering the storage area, make sure there are no gaps in the floor, walls or ceiling.
- Group feed bags according to feed type and size.
- Store feed bags elevated above the floor on pallets.
- Only open one bag at a time, and empty the feed in use in a container with a seal.
- Discard wet, old or moldy feed.

11. Fertilization and supplementary feeding

11.1. What is involved in pond fertilization?

- Fertilization is the application of either (a) organic fertilizer to a fishpond, such as chicken, goat, pig, cattle manure and compost, or (b) inorganic fertilizer, like chemical fertilizers.
- Chemical fertilizers are recommended for high production. Compost and animal manure are easier to obtain and less expensive, but they may not produce as many plants (plankton) to feed your fish.
- Please note that you need a minimum level of alkalinity to support a healthy phytoplankton bloom. Depending on the alkalinity of your water, you may need to lime your pond (20 mg/L) to improve the response to fertilization. Please see the section on water quality and the section on biosecurity for materials that can be used to increase alkalinity for pond. While many different liming products exist, the best material to use is finely crushed agricultural limestone. It is cost-effective and readily available. If your pond needs lime (consult your DOF if you are unsure), apply it at least 2–4 weeks before applying any fertilizer.

11.2. What is the purpose of fertilization?

- Fertilization creates a food chain that will increase the productivity of the pond.
- Nutrients (organic and inorganic fertilizer) added to ponds stimulate the production of plankton, which is a natural food for fish. Small fish will mainly feed on plankton in a fertilized pond. Plankton comes in two forms: plant form, called phytoplankton, and animal form, known as zooplankton.
- Natural food in the pond (phytoplankton and zooplankton) is very small and difficult to see.
- The color of the pond water determines the presence of this natural food. Usually, the water is green, brown, reddish or transparent.
- Green colors indicate plankton productivity. Green can range from brownish green to yellow green or bluish green. Brownish green suggests that the blooms have more zooplankton, while yellow and bluish green indicate the presence of phytoplankton. Some plankton turns red at certain periods of the day.
- If the water is brown, it is usually caused by suspended soil particles. This is often a sign that the pond is not fertile (the same is true when the water is transparent).

Green water is the best for tilapia production. If the water is dark green, though, it is a sign of overfertilization. **DO NOT** overfertilize your pond.

Plate 3. Overfertilized pond.

Plate 4. Well-fertilized ponds.

As an alternative to using solely commercial feeds, some feed companies have also developed special supplementary feeds that can be used in combination with fertilization. Small fish will feed on plankton in a fertilized pond, while larger fish can also be fed supplementary feeds with a lower protein content. This method can be used in both extensive and semi-intensive culture systems with a stocking density of less than 5 fish/m^2.

11.3. What can I do if I cannot access commercial supplementary feed?

- Fertilization alone cannot be enough to increase pond production. You may not have adequate manure to fertilize the pond. Most farmers do not have enough animals to produce enough manure, and it may be difficult to continually purchase chemical fertilizers to fertilize your ponds.
- It is important to complement fertilization with supplemental feeds.
- You can make a homemade feed with locally available ingredients, such as maize, millet, soybeans, sunflower cakes and cassava (section X).

11.4. How do I apply organic or inorganic fertilizer?

11.4.1. Organic fertilizer

- Before the pond is filled with water, spread the organic fertilizer on the dry pond bottom and fill the compost fences with a mixture of animal manure and dried grass until the pile is as high as the expected water level.
- After you fill the pond, stir the compost once or twice a week.
- Add more compost when the level drops.
- Two compost fences are enough for one growing cycle in a 200 m^2 pond.

If you are using animal manure, follow these practices:

- Spread the animal manure on the pond bottom before filling the pond with water. Spread a layer evenly. For each 10 x 10 m (100 m2), you will need two gunnysacks of cattle, chicken, sheep, goat or pig manure. Chicken manure is more effective, because it is high in nitrogen.
- Adding manure into the top 10–15 cm of soil will help stop the soil from leaking when the pond is filled with water. To easily collect animal manure, follow the recommendations of the Ministry of Fisheries and Livestock by putting your animals in standard raised kraals.

11.4.2. Inorganic fertilizer

- Only apply chemical fertilizers after filling your pond with water.
- Approximately 200 g of chemical fertilizer a week is enough to turn a 200 m^2 pond green.
- Do not add too much chemical fertilizer at once, because this may kill your fish.

11.5. BMPs on fertilization and supplementary feeds

- Apply BMPs for feeding when using supplementary feeds

i. Follow the instructions of the feed supplier for supplementary feed use

- Adopt the feeding regime recommended by the feed manufacturer for best results.
- Do not use compost cribs for fertilization. These do not fertilize the ponds effectively, and they reduce the productive surface area of the pond.

ii. Do not overfertilize the pond

- Adjust the fertilization rate and frequency to maintain light-green pond water, with a Secchi disk reading of 30 cm (see section 12.1.4
- If the water is green enough, **DO NOT** apply additional fertilizer.
- Overfertilization will deplete the dissolved oxygen in the pond and kill the fish.

iii. Make sure manure is free of chemicals, antibiotics and hormones

- When using chicken, cattle or pig manure, make sure it comes from a source where no hormones or antibiotics are fed to the animals.

iv. Prevent water exchange between fertilized ponds

- Do not exchange the water in fertilized ponds or reduce the exchange rate to the lowest level, unless it is an emergency.
- If water is not kept in the pond, the effectiveness of the fertilizer decreases.

v. Spread fertilizer evenly across the entire pond surface

- Ensure the fertilizer is spread evenly on the entire pond surface once a week.
- Dissolve chemical fertilizers in water before applying them to the pond.
- Never apply solid fertilizer to the pond because it will fall to the bottom and will not be available for the plankton.

vi. Fertilize ponds only on sunny days

- Fertilizers are generally less active if applied on a cloudy or rainy day.

vii. Remove aquatic plants from the pond

- Fertilizer activity drops if there are aquatic plants in the water, because these absorb more nutrients than phytoplankton.

viii. Wean fish on pellets

- Provide small amounts of feed into the ponds from the beginning of the seventh week to train fish to start eating feed.
- Follow the guidelines of the commercial feed you are using.

12. Water quality

Water quality is very important for fish growth and health. Poor water quality can negatively affect your fish farm and productivity.

12.1. Critical parameters

The following are important parameters in the pond environment in order of importance.

12.1.1. Dissolved oxygen

A dissolved oxygen level between 5 and 7.5 mg/L is recommended. Chronically low concentrations below 3.5 mg/L will affect the FCR for fish growth. In the morning, check for signs of low dissolved oxygen, such as gasping fish, fish at the water surface, low water transparency and fish swim sluggishly.

12.1.2. Temperature

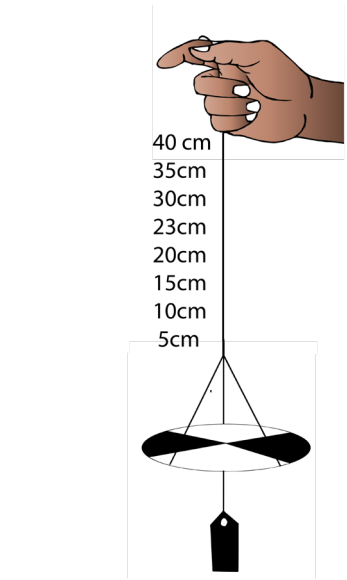
Optimal growth for most tilapia species is in water with a temperature of 24°C–30°C. Use a handheld thermometer to measure temperature.

12.1.3. pH

Tilapia can survive a wide range of pH, from 5 to 10, but are said to grow best at a pH of 6 to 8. The pH level can be measured using pH strips or a pH meter. A similar pH is important when transferring fish. Alkalinity is important for fish health and fertilization.

12.1.4. Transparency

Transparency is an indicator of water clarity and reveals the amount of suspended solids in the water. Measure transparency in the shadow, and aim for a reading of 25–60 cm. You can use a homemade Secchi disk to measure it.



12.1.5. Water color

- Light green, brown-green or greenish water is most suitable for fish culture. Dark brown and dark green are not good for fish.

12.1.6. Ammonia

- Ammonia exists in two forms: un-ionized NH3 (highly toxic) and ionized NH4 + (less toxic). Avoid concentrations of un-ionized ammonia greater than 0.1 mg/L. At a pH over 8, un-ionized ammonia increases. You need to maintain healthy parameters for un-ionized ammonia concentration, carbon dioxide, nitrite, alkalinity and suspended solids, which using organic manure fertilizers can help reduce. It is the interrelationship of all the parameters that influences the health and growth rate of the fish.

12.2. BMPs for monitoring water quality

- Monitor water quality every day and take measures when the parameters fall outside the optimal range

Observation	Measuring the parameter	Possible measures to mitigate problems
High temperature (>30°C)	Measure with a temperature meter. (These are expensive, so please consult your DOF to see if they have them.)	• Exchange water (water going in and out of the pond).
Low dissolved oxygen: < 3.5 ppm in the morning, <5 ppm in the afternoon	Measure with a dissolved oxygen meter in the early morning. (These are expensive, so please consult your DOF to see if they have them.)	• Increase water exchange (more water going in and out of the pond). • Stop feeding until corrected. • Watch for symptoms of parasites or disease. • Beat or stir water, moving water increases the level of dissolved oxygen. • Stop fertilizing your pond.
Low pH (<6)	Measure with a pH meter. (These are expensive, so please consult your DOF if they have them.)	• Add alkaline buffer (sodium bicarbonate, lime, ash). • Reduce the feeding rate. • Check the ammonia concentration.
High ammonia: TAN > 0.25 mg/L) or a pH higher than 9	Measure by chemical titration from the water test kit. (These are expensive, so please consult your DOF to see if they have them.)	• Exchange the water (water going in and out of the pond). • Reduce the feeding rate. • Watch for symptoms of parasites or disease. • Where total ammonia is higher than 8.3, apply products such as gypsum or CaSO4. • Please DO NOT apply lime under these conditions. If you apply some lime products (CaOH, CaO) the pH could increase suddenly, and pH increases of more NH4 will be converted into NH3 (toxic ammonia). Also, $CaCO_3$ is not soluble in water at a pH greater than 8.3.
Transparency too low: < 30 cm)	Either use a (a) Secchi disk or (b) your hand by submerging your arm into the water up to your elbow level and checking to see if your palm is visible.	• Exchange water (water going in and out of the pond). • Reduce the feeding rate. • Watch for symptoms of parasites or diseases. • Stop fertilizing.
Dark green or brown color (NOT GOOD)	For dark green water, use either a Secchi disk or the hand method. For brown water, observe the color.	• Exchange water (water going in and out). • Reduce the feeding rate. • Stop fertilizing.

Source: Hoevenaars & Ng'ambi, 2019

Table 10. Monitoring water quality.

13. Fish health

Diseases can result in devastating losses for farmers as they increase fish mortality and affect their growth rate. To reduce the risk of diseases and to minimize disease outbreaks on your farm follow BMPs. Disease prevention is important.

13.1. What are the most common clinical signs of fish stress?

- Changes in behavior, such as loss of appetite, could be the first sign that fish are stressed and diseased.
- Physical changes such as abnormal growths, lesions or discoloration on the body surface, loss of some scales, cloudiness of the eyes, eroded fins and clogged gills can be signs of diseases.

The following are common clinical signs of diseases and parasite infections in tilapia:

- lack of appetite
- lesions or hemorrhages (blood) on the body or in the eyes
- tail or fin rot
- pale and damaged gills
- cotton-like fungi on fish body
- white spots on the body and fins
- black-and-white spots or cysts on the gills
- reduced growth rate
- physical weakness, bent bodies and fatigued movement
- swimming in circles, losing balance, floating upside down
- reddish pigmentation around the anus or on the genital papilla
- cloudy and opaque eyes
- bloated belly or dropsy condition
- accumulated ascetic fluid in the body cavity
- swollen internal organs, such as the liver, kidney, gall bladder and spleen
- hemorrhages on internal organs
- white or black nodules or cysts on internal organs.

If a disease does occur, it is necessary to respond quickly and effectively. Quarantine the pond in which the disease occurred and adjust management. If needed, use chemicals or veterinary drugs for treatment. Always consult a fish health expert or a local veterinarian before resorting to any chemical treatment. Irresponsible and improper use of chemicals and drugs for the purposes of prevention or treatment could lead to several implications, including antibiotic residues in fish, antimicrobial resistance in bacteria, and food safety issues. Proper diagnosis is a must for making informed decisions on treatments. There is no treatment for viral diseases. Parasitic, bacterial and fungal diseases can be treated with approved therapeutic chemicals.

13.2. How can I tell if fish deaths are abnormal?

If more than 0.1% of your fish in a single production unit die within 24 hours, this is considered abnormal.

Tilapia major clinical signs

The purpose of this poster is to enhance the capacity of hatcheries, nurseries, grow-out farmers and extension service providers to recognize and report tilapia diseases. Prevention, early recognition, diagnosis and rapid intervention are the best steps to manage aquatic animal diseases. If you observe clinical signs, abnormal behaviour and unusual mortality, contact your local aquaculture health professionals to report and ask for support.

Fish lethargic at surface and notfeeding | Eye exophthalmia/popeye | Eye endopthalmia/eye shrinkage | Eye opacification

Skin erosions hemorrhagic lesion | Skin discoloration | Open wounds

Abdominal distension/swelling | Scale protrusion/detachment | Fish gasping air at the surface

Gill paleness (anemia) | Gill rot | Fin rot/tail rot | Swollen anus

This tilapia disease extension material and photographs were developed by the CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish. It was produced as part of the WorldFish better management practice (BMP) resources to support sustainable and responsible tilapia farming.

CGIAR RESEARCH PROGRAM ON Fish

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Figure 8. Poster of major clinical signs in tilapia.

BMP	Procedures
Do not stress fish	• Use the right stocking density to minimize stress. • Feed fish regularly. • Handle fish only when necessary and do so carefully. • Maintain good water quality.
Sample fish regularly	• Check a sample (20–40) of your fish for growth and health once or twice a month. • Sample fish in the morning, weigh them as soon as they are caught and the release them back promptly to the pond. • Use sampled fish to estimate the biomass in the pond and to calculate the FCR. • DO NOT feed fish before sampling.
Observe fish regularly	• Check fish regularly for signs of disease. • Healthy fish have a good appetite and are active swimmers.
Keep farm records	• Record any daily mortalities observed from the pond dike. • Record possible causes as well. • Contact authorities (DOF officers) as soon as possible in case of a disease outbreak or unusual mortalities on your farm.
Quarantine the pond immediately in case of a disease outbreak	• Make sure no people enter the pond area except authorized persons, if necessary. DO NOT move equipment out of the pond area.
Use appropriate veterinary drugs and chemicals properly	• Administer drugs according to the instructions of the manufacturer. • Use only chemicals and veterinary drugs approved by the Environmental Management Agency (Fisheries Act No. 22 of 2011 (Section 48)). • Only authorized personnel only should administer chemicals. • DO NOT harvest fish before the end of the withdrawal period (the time in which residues can be found in the edible parts of the fish) of the product, which can be found on the label of the medicine.
Properly dispose of dead fish	• Remove dead fish from the pond as soon as possible. • Dispose of dead fish far from the pond. • Bury dead fish far from the pond area, and add a cup of agricultural lime per medium fish to improve decomposition. • You can also incinerate dead fish. • If fish deaths are a result of normal mortalities, you can decide to use the dead fish for composting. However, cover the compost with soil to avoid odors.
Implement farm-level biosecurity protocols	• Make sure no animals, people or vehicles enter the farm/pond. • DO NOT use farm equipment from other farms without appropriate disinfection. • DO NOT introduce fish from unknown sources, including the wild.

Table 11. BMPs on fish health.

13.3. How do I calculate the biomass in my pond?

- Use the weight of the sampled fish to calculate the estimated biomass in the pond.
- Calculate the average body weight by dividing the total weight of sampled fish by the number of fish in the sample.
- Estimate the total fish biomass based on the average weight of sampled fish, and be sure to deduct the mortalities from the total number of fish stocked.
- A scale is necessary to weigh the fish.

Evaluation	Calculation
Data from your sampling	Number of fish caught: 54 Total weight: 521 g
Average bodyweight of one fish: Total weight/number of fish	521 g/54 fish= 9.65 g rounded to 10 g
Actual number of fish: Initial fish stocked minus mortalities	Initial number of fish stocked: 1100 Dead fish (get this from your records): 63 Actual bumber of fish in pond: 1100 (initial stcok)-63 (dead fish)= 1037 fish
Actual weight of all fish in your pond: Number of fish X average body weight; covert g to kg (divide by 1000)	1037 fish X 10 g=10,370 g 10,370/1000=10.37 kg

Source: Hoevenaars & Ng'ambi, 2019

Table 12. Example on how to calcutate fish biomass in the pond.

14. Harvesting

Carry out harvesting in an efficient and safe way. If harvesting for the market, emphasize the size and consumer demand of the fish. Faulty handling or using the wrong equipment can damage fish.

14.1. How do I choose which equipment to use during harvesting?

The choice of harvesting equipment depends on the size of the operation, available labor, frequency of use, available capital, preferred harvest method, and volume and sizes of fish harvested. However, using seine nets is the best method for smallholder farmers to use.

14.1.1. Seine nets

- Using seine nets for harvesting is the most recommended method because, unlike gill nets, they keep fish alive. This maintains the quality of fresh fish for sale. In mixed-sex ponds where reproduction occurs, seine nets can catch fingerlings either for restocking or for sale. Using seine nets can also catch fish in the shortest possible time.
- Seine nets work well in large, regular-shaped ponds with relatively flat, unobstructed bottoms.
- Seine nets can harvest ponds that are not drainable. However, the only reliable way to harvest all fish from a pond is to drain it completely.
- Do not use seine nets in very shallow water because it stirs up the mud and causes low dissolved oxygen levels and high toxic gas conditions, both of which can be extremely stressful to fish. Shallow water can also warm quickly in hot weather, which can greatly stress the fish.

Plate 5. Fish harvesting at a fish farming cooperative using a seine net.

14.1.2. Other methods of harvesting fish

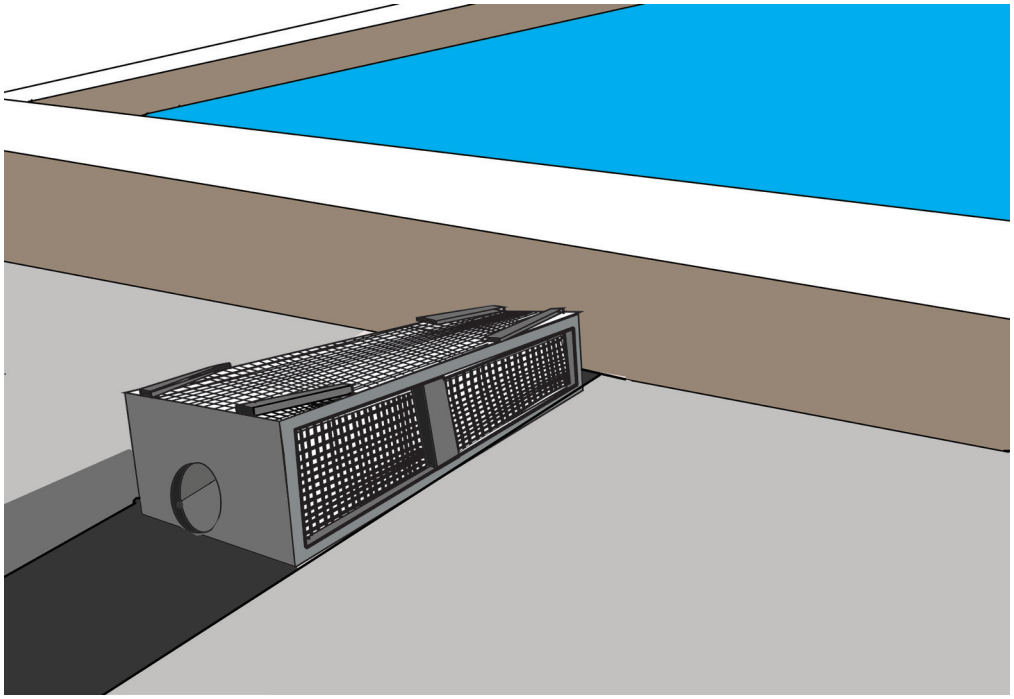
Although using seine nets is the best method and highly recommended, they are expensive and sometimes unavailable in rural areas. You can use the following alternative methods for harvesting your fish:

14.1.3. Gill nets

- They are relatively cheaper than seine nets.
- They are found in most rural communities, especially those near fishery areas.
- Gill nets allow a specific size of fish to be caught according to a pre-determined mesh size.
- A disadvantage of gill nets is that they hook around the fish gills, which kills fish before transportation, compromising the quality of fish.

14.1.4. Breaking the pond dike (wall)

- Partially break the wall on the outlet of the pond to allow water to drain down to a certain level.
- Once the water level is down, use baskets, scoop nets and other materials to collect the fish.
- You can also make a harvesting box and place it in the deeper end of the pond where fish congregate as the water drains out. Collect the fish from the box.



- One disadvantage of this method is that it weakens the pond wall, which can break before you are ready to harvest, which leads to loss of fish.

14.2. What materials and equipment do I need during harvesting?

You need a scale for weighing fish, as well as buckets, basins, etc., for holding fish while weighing them. You will also need hapas (if available) to hold fish inside the ponds before transportation or sale.

14.3. BMPs on harvesting

14.3.1. Ensure that prior arrangements are made for transportation and marketing before harvesting

- Plan your harvest well to avoid loss of fish due to transportation delays or a no-show of the buyer.
- Make clear agreements with the buyer in advance.
- Clean and prepare harvesting and sorting equipment before harvesting.
- Have enough labor and equipment.
- Harvest in the early morning when the water temperature is low and the heat is less intense.

14.3.2. Harvest only healthy fish of good size

- Grow fish and harvest only those weighing 200 g or more.
- **DO NOT** sell damaged or unhealthy fish.
- Sample fish before harvest to determine the health status, size and quality.

14.3.3. Stop feeding fish before harvesting

- Do not feed fish prior to harvest.
- Stop feeding the fish 1–2 days before harvesting, especially if they will be transported long distances. Fish may release fecal waste into the transportation tank and foul the water quality, which can stress the fish. Fish are also hardier and less stress occurs when their stomachs are empty.
- If fish have been fed medicated feed, be sure that the proper withdrawal time has passed before they are harvested for processing.

14.3.4. Ensure proper drainage

- Drain the pond halfway quickly before harvesting to make catching fish easier; it is difficult when the pond is full.
- Close the supply inlet before draining.
- Make sure the drain canal can accommodate water to completely drain the pond before harvesting.
- Cover the outlet with a net or any sieve material to prevent fish from escaping.

14.3.5. Grade fish

- Clean harvested fish with clean water to wash off dirt and mud.
- Add ice, if available, to keep the harvested fish fresh.

14.3.7. After harvest

- Check the fingerlings in the holding pond every day, and add plenty of fresh water. Do not add feed or fertilizer.
- Dry out the fishpond for 2 weeks.
- Check the pond, make repairs and add fertilizer.
- Fill the pond with water.
- Count the number of fingerlings you need from your holding pond and then grade them and put them in buckets. Check if there is a difference in the water temperature from the big pond, and temper the fish if needed. Then restock them into the pond.

15. Handling and transportation

How fish are handled during and after harvesting plays an important role in the quality of the final product. Appearance, odor, flavor, texture, nutritional value, consistency and food safety are the factors that determine fish quality, which is important for marketing purposes and food safety.

During harvest, keep your fish in water in a shaded area while you work. It is good to ice your fish if you are traveling long distances. Put your fish in cooler boxes or in boxes covered with wet hessian sacks.

15.1. How do I maintain fish quality during harvesting and post-harvest handling?

- Handle fish safely and practice good hygiene.
- Use clean equipment and operate in a clean and hygienic handling environment.
- Check fish quality during and after harvest.
- Make sure any personnel handling fish observe personal and food hygiene measures, such as wearing clean clothes, washing their hands and using clean equipment.
- Set proper time and temperature control. For food safety and quality, ensure a proper and uninterrupted cold chain (a series of storage and distribution activities that maintain a certain temperature range).
- Chill your fish as soon as possible after harvesting. Keep the temperature below 4°C since bacteria reproduce rapidly between 4°C and 60°C.
- Transport fish with care and minimum delay.
- Do not expose the fish to sun and wind.
- Depending on your target market and purpose, drying your fish is another way of preservation.

15.2. Why is it important to observe hygiene measures when handling fish?

- If fish are handled and prepared well, they can be stored longer while maintaining quality.
- Fish spoilage can lead to foodborne illness, which causes a danger to public health.

15.3. What are the signs that harvested fish are spoiling?

- Fish start decomposing as soon as you slaughter them. Signs of spoilage include changes in color or texture (eyes, gills), an unpleasant odor and an undesirable taste.

15.4. How long does it take for harvested fish to spoil?

- It depends on the storage mechanism and temperature.

Situation	*Temperature*	*Time it takes fish to spoil*
Kept in the sun	25 - 35	6 - 8 hours
Kept in shade	20 - 25	12 - 16 hours
Kept in cooler with ice	5 - 10	5 - 7 days
Kept in ice	0	14 - 20 days

Source: Hoevenaars and Ng'ambi, 2019

Table 13. Time to fish spoilage related to storage temperature.

15.5. How do I preserve fish?

If you have more fish than you want to sell by retail, you can use the following procedures for salting and drying to preserve your fish:

- Clean and scale the fish.
- Split the fish lengthwise and open it up.
- Salt the fish by soaking it in brine or packing it in a container between layers of salt.
- Hang the fish up in a shaded spot to let the excess drip out.
- Now dry the fish in the sun or in the smoke over a fire. For sun drying, put the fish on racks or hang them on lines in a sunny spot for 3 to 5 days until they are crisp. For smoking, lay the fish in a single layer on a wire rack and keep this above the fire for several days until dry.
- Store the dried fish in a container with a tight lid in a cool, dry spot.

15.6. BMPs for handling and transportation

15.6.1. Use easy to clean buckets, baskets or containers

- Use easy to clean buckets, baskets or containers to store and transport fish, and use smooth materials for storing and transporting harvested fish.
- Use plastic buckets, baskets or containers with a smooth surface to prevent damage to the fish.
- **DO NOT** use sacks, as these can damage the fish.
- Use transportation containers and equipment that are designed to minimize physical damage and allow for rapid handling of fish. Containers should allow melted ice water to drain.

15.6.2. Handle fish gently

- Handle fish with care to avoid physical damage, which can accelerate
- the spread of bacteria from the gut, gills and skin into muscle tissue.
- Clean the fish with clean water before storing or transportation.
- Place the fish in a box or container without bending the body.
- **DO NOT** overcrowd the fish in a single box or container.

15.6.3. Ensure personnel handling fish follow good hygienic practices

- Observe good hygiene when handling fish.
- Wash your hands, wear clean clothes and cover your hair.
- Wash your work tools.
- **DO NOT** eat, cough or spit onto the fish or near the fish.
- **DO NOT** wear jewelry.

15.6.4. Store fish products under conditions that prevent deterioration and spoilage

- Control temperature and humidity during storage.
- Keep fish in a clean place away from pests and any chemical, physical and microbiological hazards.
- Keep fish in a cool place shaded from direct sunlight until the fish are picked up by the buyer or put in a freezer.

15.6.5. Put fish on ice or in the freezer as soon as possible

- Transport fish in refrigerated trucks or in containers with ice or ice slurry (1:1 ratio of ice to fish) to ensure the temperature is below 4°C and close to the temperature of melting ice during the whole transportation period.
- Use the right quantity of quality ice for effective cooling, depending on the required temperature, type of containers, storage, transportation time and other factors.
- Buy flaked, tubed or crushed ice only from an approved supplier to avoid contamination. Ice should be manufactured with clean potable water (safe to drink).
- Arrange fish in layers with ice.
- Transport the fish at night or early in the morning to avoid the hottest hours of the day.
- Keep temperature records.

15.6.6. Ensure proper transportation conditions to avoid contamination from surroundings

- Use a closed truck or closed containers to protect the fish from bacteria and other contaminants coming from the air, soil, water, oil or chemicals.

16. Marketing

If culturing fish for commercial purposes, please ensure the following:

- Follow BMP guidelines to improve the productivity and quality of the fish.
- Respond to consumer preferences.
- Produce adequate volumes to sustain the target market.
- Price your fish competitively by identifying niche markets or establishing a reputation among your customers as someone who produces quality fish.

16.1. What are the possible fish markets I can target?

In Zambia, possible buyers of fresh tilapia are supermarkets, hotels, schools, churches, markets and fish traders.

16.2. BMPs for marketing

16.2.1. Pick a suitable market location

- Target local markets if you are unable to maintain a cold chain during transportation. Buyers should pick the fish up from a place close to the farm if you are unable to maintain a cold chain over long distance.
- Consider selling your fish at your farm with a pond-side market.
- Keep your fish alive in a hapa in the pond or in a large tank with water. Keeping the fish alive in the water avoids wastage in case you do not have a cold chain and all the fish for the day are not bought
- When buyers come, bring the fish from the pond to limit traffic to your pond.
- A hand-wash and foot bath where clients sanitize their hands and feet is required to keep your farm and pond free from disease.

16.2.2. Ensure market before harvesting

- Identify a buyer for the fish before it is time to harvest.
- You can also get a list of buyers and their orders so that you have an idea of how much fish you should harvest for sale for the day.
- Make the necessary arrangements with the buyer before harvesting to avoid unnecessary spoilage.

16.2.3. Produce a marketable product

- Sell fish that are the preferred size of the market. In Zambia, the size of the fish should be at least 200g, but ask buyers what size they prefer.
- Follow BMPs that we have discussed (refer to your BMP materials) to obtain good growth and quality.

16.2.4. Be part of outgrowing programs

- If you have limited access to the market or suffer from liquidity constraints, you may decide to participate in an out-grower program. These are programs in which the private sector provides seed and feed to farmers and buys the product from farmers at a set price.

- The disadvantage of out-grower programs is that the buyer could buy fish at a lower price to recoup the cost of seed and feed provided to farmers.
- Before joining an out-grower program, please consider the net gains you will get to determine whether it makes good sense for you to be part of the program.

16.2.5. Link with a private sector player that provides extension services

- There are several players from the private sector in Zambia that offer extension services to smallholders. These companies sell feed and seed and provide training to smallholders. They also help them find buyers for fish.
- Actively seek out these private sector players and engage with them in order to access all the relevant information and training you need.

16.2.6. Choose a specific day

- Choosing a specific day, especially if you engage in pond-side marketing, is a good practice for table-size fish, as well as for fingerling producers.
- Let potential buyers know which days you are selling, and also specify what fish you are selling. Advertise your product and days for sale using a signpost or a poster at the farm and other nearby street/road junctions, and use word of mouth around your community. For a poster, you can draw the fish or take a good photo of your fish from your last sampling

Figure 9. Example of a signpost.

This will help you make reasonable sales, as most clients will know and adhere to these set days to come and purchase fish or seed.

16.3. How do I attract customers to buy my fish?

There are four main ways to attract customers.

16.3.1. Quality

A good quality product will make customers come back and buy again.

16.3.2. Price

This is less important than you might think, as most people want the best value for money. Sometimes a low price will make people think that the quality of the product is low. Plan your production cycles to increase harvest during closed seasons when supply from natural waters is low. Fresh fish prices will increase during these periods. Producing species that are in demand by the market will ensure higher prices. Consider market preferences in terms of size and produce to meet these demands. The preferred size is likely to fetch higher prices.

16.3.3. Place of business

The distance from the business to the customer is important. How far is the buyer willing to travel to get your fish?

16.3.4. Promotion

How does the customer know about your product? You can advertise through posters put up in major towns and other public places and through newspapers and national and community radio stations before you harvest. Make sure advertisements are clear on the products available, date of harvest and quantities. Be sure to specify what fish you are selling to all your intended buyers. Advertise your product and days for sale through a signpost or a poster at your farm and other nearby street/road junctions. Please be sure to include your contact information so that they can call you to place or cancel orders.

17. Fish farming business: Business planning

17.1. What is a business plan?

- A business plan is a guide that shows the goals of the business, how they will be achieved and when.
- It is a tool to determine if profit can be made in the future to ensure that the farm is financially viable and that profits are reinvested from one production cycle to the next.
- It carefully considers strengths, weaknesses, opportunities and threats to the business.

17.2. Why is it important to develop a business plan?

- A business plan allows you to run your farm/business with a clear and more consistent vision.
- It enables you to closely monitor the financial health of the business.
- A well-written business plan can be used to access capital or further funding from a financial institution, such as microfinance or a funding agency.
- Like other businesses, aquaculture has risks. A business plan allows you to think ahead and be well informed and prepared.

17.3. Who needs a business plan?

- All fish farmers need to have a business plan, and it should be done before a business begins operation.
- Anyone involved in business, no matter how big or small, needs a business plan so that they can make informed decisions on how to run and grow their business.
- Even smallholder fish farmers do not farm fish only for food but also for sale. In this way, their fish farm is also a business enterprise. Therefore, smallholder farmers also need a business plan.
- Farmers can prepare their own business plan (if they are able to write one) or seek help writing one.

1. Ensure the business site/location is accessible and suitable for fish production. Identify and make sure that resources and inputs, such as water, fingerlings, feed and labor, can be obtained and the fish produced can be sold.

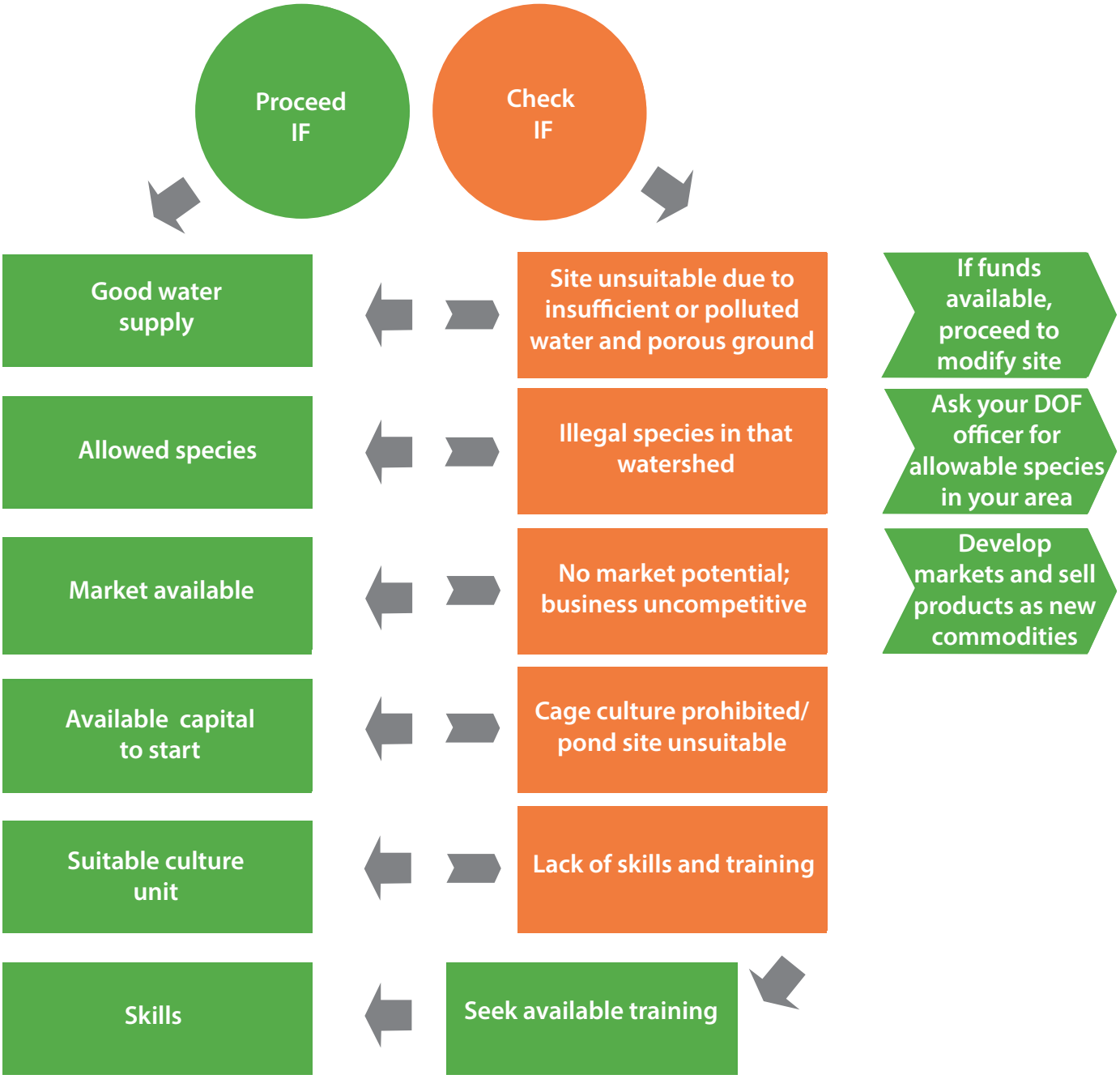
2. Plan to run the farm as a business and be willing to invest your skills, time and money. Take up available training opportunities in business and fish farming to improve your knowledge and skill.

3. Ensure you have access to capital and inputs required and make sure the farming business can make a profit. Avoid always relying on others for inputs. Plan ahead so that you have inputs available when you need them.

Figure 10. BMPs on business planning.

1. What product will my business provide? (selling good quality fish)
2. Who are my customers? (fish traders, hotels, supermarkets, schools)
3. Why would customers buy from me and no other famers? (good size, high quality fish)
4. What do buyers prefer, and will my product meet their preferences?
5. What strategies are my competitors (other farmers) using, and how does my strategy compare to those of others?
6. Are there government rules, regulations or policies that my business must adhere to?
7. Can I access the resources and inputs I need, like good water, fingerlings and feed?
8. Will I plan in days, weeks or months for the fingerlings, feed, labor and other inputs I need to grow the fish and take care of the farm?
9. What equipment and supplies will I need and what is the cost? (digging tools, feeds, seed)
10. Can I estimate my sales and expenses for each growing cycle of fish? What is the cost of my inputs, such as fingerlings, feed and labor, and how much will I sell my fish for?
11. How much money do I need to start the business, and where am I going to get this money from?
12. Do you have skills to run the business or do you need training, are you willing to take up the training?

Figure 11. Ask yourself the following questions when developing a business plan.



Source: Modified from WF BMPs Manual 2020.

Figure 12. BMPs for decision making during business planning.

17.4. Production planning

Production activities such as stocking, feeding and harvesting influence cash flow. If you have many ponds, stock them at different times to spread expenses and income over time. Note that activities such as buying fingerlings and harvesting will be more frequent, and costs such as transportation are higher. Therefore, look at your financial situation and the market to decide the most suitable production plan.

17.5. BMPs on production planning

17.5.1. Make the necessary calculation and preparations

- Find out the size of fish the market prefers and the price at which you can sell your fish.
- Based on your stocking density (the number of fish you will put per square meter) and estimated survival rate, calculate the number of fish you need and their cost (know the size of the fingerlings).
- Plan to stock fingerlings weighing at least 1 g for a higher survival rate, and ensure you know the FCR of the feed you want to use (10.4).
- Calculate the amount and cost of feed and other inputs required until your fish reach market size.
- Remember to calculate other costs, such as lime, labor, communication time and transportation. You can then use all this information to calculate your expenses and profit.

17.5.2. Ensure you have secured enough money to pay for all your production costs

- You need to have enough money to pay for all inputs and costs until your first harvest.
- Use earnings from harvest sales to cover production expenses for the next cycle, and treat only the remaining funds as profit.

17.5.3. Ensure there is a market available at the time of harvesting

- Look for a market before you start growing your fish.

	Factor	Guiding question	Answer	Example
1	Size of fish for market (g)	What size fish will you sell?		300 g
2	Growing period (months)	How many months will it take you to grow fish this size?		6 months
3	Number of ponds	How many ponds do you have?		2
4	Size of each pond	Total area of the pond (Pond 1)		600 m^2
	Pond 2: 30 m × 40 m (1200 m^2)	Total area of the pond (Pond 2)		1200 m^2
5	Number of fish per pond at a stocking density of four fish per square meter	Fish stocked in Pond 1 (600 m2 × 4 fish/m^2)		2400
		Fish stocked in Pond 2 (1200 m2 × 4 fish/m^2)		4800
6	Total number of fish	Total number of fish in both ponds		7200
7	Amount of fish harvested (kg)	Answer line 6 × answer line 1 divide by 1000		2160
8	Feed needed (kg)	Answer line 7 × the FCR (use 1.5 here)		3240
9	Money needed for fingerlings	Answer line 6 × the price of fingerlings		ZMW 7200 (ZMW 1 per piece)
10	Money needed for feed	Answer line 8 × price of feed/kg		ZMW 38,880 (ZMW 12/ kg)
11	Other costs (lime, transport, equipment, labor, pond construction etc.)	Will you spend any other money on your farm?		ZMW 5000
12	Total money needed	Answer line 9 + answers line 10 and 11		ZMW 51,080
13	Estimated mortality	Answer line 7 × 10% mortality		1944 kg
14	Potential fish sales	Answer line 13 × sales price		1944 kg × ZMW 30/ kg = ZMW 58,320
14	Potential profit	Answer line 14 – line 12		ZMW 7240

Table 14. Example 1: a production plan (insert your own responses in the answer column).

17.6. Finances

For any business, it is important to keep track of money—both money that is spent (expenses) and money that comes in (income). Income minus the expenses are the earnings of the farmer. Keep track of the money in your business by maintaining records in a book (cash journal). Write all your expenses and income in the cash journal so that you can calculate your balance. Update the journal for every transaction made for the farm.

You need to carefully consider all your costs to minimize the possibility of underestimating the costs and overestimating the profits.

17.7. BMPs for finances

17.7.1. Keep receipts of expenses and sales

Always get receipts when making any purchase and keep them. Also, give receipts for any sales that you make and keep the copies. These would be referred to when making an entry into your cash journal.

17.7.2. Keep a cash journal

Update this frequently, after every transaction, so nothing is forgotten. Write the date in the first column; in the second column describe the expenses or income received. For income, you write the amount in the third column (In), and for expenses in the fourth column (Out). To find out your balance (income minus expenses).

Date	Description	In (Income)	Out (Expenses)	Balance
1-1-2019	Savings	1000		1000
1-1-2019	Digging materials and pipes		350	650
12-2-2019	Fingerlings (200 pcs) 1 g		200	450
12-2-2019	Feed (3 bags x 15 kg)		300	150
16-4-2019	Feed (2 bags x 15 kg)		200	50
28-9-2019	Sales 36 kg	1116		1166

Table 15. Example 2: a cash journal.

17.8. Record keeping

Record keeping is important for a farm. Collect and record information correctly and keep it safely. Properly kept records are the best sources of information to manage a fish farm. Records keep track of farm activities and serve as a basis to make business decisions.

17.9. BMPs for record keeping

17.9.1. Keep records on all aspects of the farm

Maintain records on farm production and finances such as the following:

- the date of stocking and number of fish stocked per pond
- feeds and feeding records (amount, source and type of feed, response), which can be used for day-to-day management, adjusting feed ratios, estimating feed conversion efficiencies and growth rates
- feed storage and control records, such as expiry dates, date of purchase and number of feed bags used/ remaining
- disease and treatment records, which are necessary to track disease occurrence and treatment given.
- number and date of mortalities occurring in each pond
- management of chemicals and veterinary drugs, including records of the origin of chemicals and drugs, treatment start date, treatment stop date, compound used, diagnosis and symptoms, dosage, ponds where the drug was applied and harvest date for the treated ponds
- water quality parameters, such as dissolved oxygen and temperature, which are important to monitor water quality to detect problems well before they become a threat to the fish (see section 12.2 on how to measure water quality parameters).
- investments, input expenses, maintenance costs and sales, including prices of inputs and the fish sold as listed in the cash journal
- post-harvest management, including records of harvest date, type of harvest (partial or complete) and weight at harvest.

A complete set of records at end of a cycle will give you the following:

- how long (months) the fish took to grow to market size
- total number and weight (kg) of fish harvested
- how much feed was fed
- use the information from (b) and (c) to calculate the FCR
- temperature changes during the production cycle
- total number of mortalities and reasons.

17.10. Clusters

- As a farmer, you can benefit from being part of a cluster. A cluster could be a group of individual operators, farmer organizations, cooperatives federations and unions collectively coming together with common goals, needs or interests, interdependence and an overlapping field of work.
- Only join a cluster with good leadership, defined group activities, the capacity to provide services and benefits to its members, strong financial management and the ability to mobilize credit.
- Men and women should have equal chances and, ideally, representation within the cluster, such as positions of leadership.
- The group members should possess at least one fishpond per household.

17.10.1. Advantages of being part of a cluster

- Accessing inputs (fingerlings, feed), finance and services (market) becomes convenient.
- Sharing knowledge and providing technical support by extension officers becomes more efficient.
- Labor requirements become easier because there is a collective effort.
- You will also benefit by being part of a cluster that meets food quality and safety requirements, as this ensures a higher market penetration and sustainability.

Tables 16—20 are examples of types of records that a fish farmer should keep.

Date	Customer	Type of Transaction	Cash Received	Cash Paid Out

Table 16. Example of a sales journal.

Farm name _____ **Pond #**_____ **of** _____ **ponds**

Date	**Size of pond (m^2)**

Liming (first application)

Date	**kg**

Fertilization (first application)

Date	**kg**	**Type**

Stocking

Date	**Number of fish**	**Species**

Mortality

Date	Number of fish

Replacement

Date	Number of fish

Reproduction

Date fry observed	Number observed
Date skimmed	Number skimmed

Table 17. Example of a pond record sheet (Part 1).

Harvest

Consumed by farm (date)	number / estimated kg
Sold (date)	kg

Total Harvest (kg)

Table 18. Example of a pond record sheet (Part 2).

Date	Description (repairs, water quality changes, predator prevention, etc.)

Liming Record

Date	Kgs

Fertilization Records

Date	Kgs	Type

Restocking Records

Date	Number of fish	Species

Table 19. Example of a maintenance record.

Name of farm _____ Pond #_____ of _____ ponds Stocking date _____

(Fill in amount of feed (kgs) used for feeding)

Week # (since stocking)		1	2	3	4	5	6	7	8	9	10	11	12
Sunday	AM												
	PM												
Monday	AM												
	PM												
Tuesday	AM												
	PM												
Wednesday	AM												
	PM												
Thursday	AM												
	PM												
Friday	AM												
	PM												
Saturday	AM												
	PM												

Table 20. Example of a feeding record sheet.

18. Training

18.1. Preparation

- Prepare a training plan on the topics that you would like to cover.
- Decide whether you will invite participants to a central location to implement the training or whether you will visit individual farmers.
- Make sure you have all the resources you need to have a successful training session.
- Prepare a register so that participants who attend the training session/demonstration you are hosting are registered. Registration details should capture the name age, sex and location of the participant.
- Keep records if you also visit farmers at their home.
- Understand what the expectations and learning objectives of the participants are.
- Make sure the training includes a way for participants to practice the skills and techniques they learn.
- Mix theory and practice. Farmers learn better when they observe and practice.

18.2. Methods

- Invite both men and women farmers. If it is difficult to get women to attend, use women lead farmers and other traditional leaders to help you invite as many women as you can.
- Choose a training venue/demonstration site that is accessible to farmers.
- Carefully select a time when you are likely to get both men and women to attend.
- Encourage participants, especially women and young people, to share their experiences and to participate actively in the training.
- Invite no more than 25 farmers at a time to ensure interactions between you and the participants.
- Conduct the training in a language that participants easily understand.
- To finish all the sections in this booklet, you may need 3 to 5 days with a group of participants. If the training takes place in the community, split these days over a number of weeks.

18.3. Training plan

- Define topics you want to cover.
- Decide how much time you will need to cover these topics.
- Define the learning objectives: What should the participants be able to do after the topic has been discussed?
- Find out what the participants already know about the topics.
- Determine what the participants should know and what skills they need.
- Build on the knowledge and skills of the participants.

18.4. Teaching skills

- Be well prepared before each training session.
- Use good communication skills.
- Know the local language.
- Be respectful to others.
- Listen well and acknowledge the contributions of the participants.
- Encourage discussion.
- Encourage participation from all participants, especially women and young people, by asking them for their opinions or encouraging them to demonstrate certain things.
- Be honest when you do not know something.

18.5. Evaluating progress

- Assess the progress of the participants.
- If the participants are not making progress, adjust your training methods.
- Provide feedback to the participants.

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WorldFish

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WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decisionmaking on the critical issues of our times.

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