Extension manual on monosex tilapia production and management

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WorldFish

TAAT
Technologies for African Agricultural Transformation

Extension manual on monosex tilapia production and management

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Overview

Guide for users

The material in this guide has been put together to assist extension workers and other trainers in facilitating and delivering improved technologies to tilapia breeders for profitable ventures. The content uses plain language for easy understanding.

In the modules, learning objectives, activities, materials and facilitation methods have all been highlighted, along with other key components, including instruments for pre- and post-course evaluations. Output evaluations, outcome evaluations and feedback mechanisms have been provided for periodic improvement of the manual. To achieve the learning objectives, activities must be properly scheduled and executed. The learning materials have been packaged for different hatchery and nursery staff to acquaint themselves with the knowledge and skills necessary to run a successful hatchery operation.

This manual is for instruction only. Trainers should adjust the modules as needed depending on the knowledge and experience of the trainees. The training methodologies and techniques for each module have been described in detail and carefully planned. Sticking to the methodologies will ensure that trainees actively participate and will help trainers achieve the expected outcomes. The modules have been arranged in order with a set time in which to discuss the information. If necessary, trainers, in light of their own experience, can change or modify the modules while maintaining the topic. However, starting and ending the session on time is important for both trainers and trainees. Assessing the success of the program is necessary for everyone involved, so trainees need to be evaluated during and after the modules to assess how much they have learned. Instruments for evaluation assist trainers in assessing how well the set targets have been met, while feedback from trainees enables assessment of the progress toward achieving the overall objectives.

Targeted audience

The manual is aimed at mainly tilapia breeders—both women (30%) and men (70%) as well as youths (25%)—according to their level of involvement along the aquaculture value chain. Any tilapia breeder within 15 to 60 years of age is considered a prospective learner.

FISH CRP

The CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish is developing the better management practice (BMP) guidelines at the global level and contextualized BMP resources at the country level to support sustainable farming of genetically improved farmed tilapia (GIFT) in WorldFish focal and scaling countries. This BMP manual, produced as part of this approach, aims to enhance the capacity of tilapia fish breeders, grow-out fish farmers and extension service providers in Africa to support scaling of tilapia production.

Background

Technologies for African Agricultural Transformation (TAAT) is a framework developed by the African Development Bank as part of its efforts for agriculture development on the continent. It aims to enhance the use of proven agricultural technologies among stakeholders to foster the changes needed through farm-level productivity and value chain development. Aquaculture is one of the nine commodity compacts with proven technologies that have the potential to increase yields and benefits for upscaling in 12 countries in Africa: Benin, Burundi, Cameroon, Cote d'Ivoire, Democratic Republic of Congo, Ghana, Kenya, Malawi, Nigeria, Tanzania, Togo and Zambia. Led by WorldFish, the TAAT Aquaculture Compact has been training aquaculture subject matter specialists and youth agripreneurs as facilitators under capacity development and technology outreach.

There are three specific objectives of the Aquaculture Compact:

1. to create an enabling environment for aquaculture technology adoption by value chain actors
2. to effectively deliver technologies to fish farmers and other actors along the aquaculture value chain
3. to increase aquaculture production and productivity by identifying and disseminating quality tilapia and tilapia seed, producing low-cost fish feed and through value addition.

Tilapia *(Oreochromis niloticus)* is a good candidate species for culture to boost fish production in both domestic and global markets. This will contribute to fish nutrition and security in Africa. However, the early sexual maturity and the prolific nature of tilapia often results in stunted growth, which is a major obstacle to realizing the full potential of tilapia farming. This, of course, is unattractive to markets. The purpose of this manual is to distribute methods that will expose extension workers to better practices in monosex tilapia production and facilitation techniques. This will enable them to spread these skills to other fish breeders in their respective areas, which will increase the production of high-quality fingerlings for fish farmers to buy.

Rationale

The TAAT Aquaculture compact has noted that fish breeders and fish farmers in Africa are confronted with many challenges in producing tilapia. These include a lack of access to quality fish seed, low skills of fish breeders in BMPs, high fry and fingerling mortality and the lack of knowledge on fish health management in hatcheries. This manual has been put together to assist extension workers and other trainers in facilitating and delivering improved technologies to tilapia breeders to produce fast-growing and healthy fingerlings for profitable ventures.

Development objectives

i. to enhance the productivity of tilapia
ii. to increase farmers' income
iii. to improve food (fish) security and nutrition.

Learning objectives

i. to enhance knowledge on broodstock selection, management and artificial breeding methods
ii. to acquire experience of BMPs in a hatchery for increased productivity
iii. to build entrepreneurial skills in business plan development for a sustainable hatchery venture
iv. to learn skills on how to share knowledge with other hatchery operators and fish farmers in their respective areas for increased tilapia production.

Module instructions

Trainers should refer to the following instructions for how to begin and end modules 1 through 6.

How to start each module

Before beginning each module, trainers must prepare prompting questions for the participants. The purpose of the questions is to encourage participants to share their knowledge about the intended contents of the module. Next, trainers must then conduct a pre-evaluation by soliciting feedback from the participants. The purpose of the pre-evaluation is to assess the knowledge, skills and attitude of the participants before they start learning. After the pre-evaluation is complete, trainers can begin the module.

Each module begins with a set of questions about the content. This helps the trainers assess how much the participants know before the module begins.

How to end each module

Before ending each module, trainers must carry out a learning activity that leads to discussion, memory retention and action. Methods that trainers can use include lecturing with audio-visuals, brainstorming on issues raised, role playing on key issues, and group discussion and feedback. For learning materials, trainers can either write narrations or draw further illustrations about the content of the module and indicate or attach further reading material related to the content.

Each module also ends with a set of questions about the content. This helps trainers assess how much the participants learned during the module.

Partners of the TAAT Aquaculture Compact stock tilapia fingerlings in a fishpond at the Mukasa Agro Solution Farm in Kabwe, Zambia.

Module 1: Introduction

Pre-evaluation questions

1. Which of the following is not an advantage of tilapia culture?
   a) Monosex tilapia is superior with respect to growth and yield per unit area and has great value and demand.
   b) They are often densely stocked, which saves space, and they can be cultured at a high stocking density, especially in cages.
   c) Tilapia is less stress tolerant compared with some indigenous cultured species, like catfish.
   d) They are able to feed on natural foods in the pond and thrive equally well on supplementary feeds.

2. Which of the following is not a disadvantage of tilapia culture?
   a) The growth rate of individual fish is usually affected by high stocking densities.
   b) They reach market size faster than mixed sex tilapia at harvest, if properly fed.
   c) It is challenging and difficult to maintain good water quality.
   d) Densely stocked systems are prone to poor fish health.

3. Tilapia is a very prolific species. True or false?

4. Why is tilapia referred to as the "aquatic chicken"?

5. Why is monosex tilapia culture preferable to mixed sex culture?

1.1. Origin of tilapia, the "aquatic chicken"

After carp, tilapia is one of the world's most important farmed fish. It is a good fish for warm water aquaculture. "Tilapia," the common name, is broadly applied to a group of cichlid fish species that originated in Africa, the Middle East and the Mediterranean. Together, they are some of the oldest fish to be cultured. Tilapia can be produced in either an extensive (in earthen ponds) or intensive (in cages and tanks) system and in either freshwater or saltwater in tropical and subtropical climates.

The most commonly cultured tilapia species, and the most dominant worldwide, is the Nile tilapia *(O. niloticus)*. Tilapia tolerates a wide range of environmental conditions and is a suitable polyculture candidate with carps and catfish.

Tilapia's white flesh has a mild flavor to it. It is usually called aquatic chicken because it breeds easily and can be mass produced. It is a perfect factory fish since it has no bones in the muscles, making it suitable for filleting and for feeding children. Tilapia eats pellets made from plant sources (largely corn and soy) and this results in rapid weight gain. It easily converts diets that resemble cheap chicken feed into low-cost animal protein. Like chicken, tilapia can be farmed in simple backyard systems or high-tech, large-scale or intensive systems.

In 1994, ICLARM, now known as WorldFish, introduced the GIFT strain to improve tilapia productivity and marketing. GIFT *(O. niloticus)* grows bigger, making it more acceptable to consumers. Its international market size ranges from 450 to 550 g. Culturing GIFT is widely gaining popularity in developing countries and is now popular among farmers in Africa. Recently, many tilapia hatcheries have been established in African countries, where they produce fry and fingerlings of monosex tilapia.

1.2. Rationale for monosex tilapia production

Tilapia is a very prolific species. However, it has a low conversion ratio of feed to flesh, which prevents optimal growth. In female tilapia especially, metabolic energy is directed toward reproduction. This makes male tilapia more economically attractive because their metabolic energy is channeled toward growth, which makes them grow faster. As a result, it is better to adopt monosex culture. Monosex tilapia (all-male production) can be obtained using manual sexing, hormones, GIFT, YY male technology, or hybrids.

Although producing mixed sex is technically easy, the yield is always poor. At harvest, weights are low and the sizes are mixed. Monosex culture is more technical, but it is easier to produce all male tilapia fingerlings in any production cycle—as high as 98%. Using hapas in fish seed production allows for a higher survival rate and mass production of tilapia.

1.3. Advantages of monosex tilapia

The following are advantages of using monosex tilapia:

- Monosex tilapia is superior with respect to growth and yield per unit area and has great value and demand.
- They are often densely stocked, which saves space, and they can be cultured at high stocking densities, especially in cages.
- They possess the ability to feed on natural foods in the pond and thrive equally well on supplementary feeds.
- Three crops are possible in perennial ponds.
- They can be profitably cultured in seasonal ponds and small ditches or canals close to the homestead.
- They are highly resistant to disease and tolerant of adverse weather, wide temperature fluctuations (12ºC–40ºC) and saline water (12–15 ppt).
- If fed properly, they reach market size faster with uniform sizes at harvest.

1.4. Disadvantages of monosex tilapia

The following are disadvantages of using monosex tilapia:

- The growth rate of individual fish is slower due to high stocking densities.
- It is challenging and difficult to maintain good water quality.
- Densely stocked systems are prone to ill health.
- Tilapia is less stress tolerant compared with some indigenous cultured species, like catfish.
- The use of hormones on human health has a perceived negative effect.

Post-evaluation questions

1. Which of the following is a disadvantage of tilapia culture?
   a) Monosex tilapia is superior with respect to growth and yield per unit area and has great value and demand.
   b) They are often densely stocked, which saves space, and they can be cultured at high stocking densities, especially in cages.
   c) Three crops are possible in perennial ponds.
   d) There is a perceived negative effect of the use of hormones in tilapia on human health.

2. Which of the following is not a disadvantage of tilapia culture?
   a) The growth rate of individual fish is usually affected by high stocking densities.
   b) Tilapia can survive in adverse weather, wide temperature fluctuations (12ºC–40ºC) and saline water (12–15 ppt).
   c) It is challenging and difficult to maintain good water quality.
   d) Densely stocked systems are prone to ill health.

3. Which of the following is not a method of obtaining monosex tilapia?
   a) manual sexing
   b) hormones
   c) YY male technology
   d) laceration

4. Which of the following is a benefit of using hapas in tilapia culture?
   a) management flexibility, as is seen in the use of collapsible/foldable tanks
   b) fast growth
   c) regular water replacement
   d) for killing female tilapia and leaving only males

5. Why are male tilapia preferred over females?
   a) They eat faster than females, which eat only a tiny portion compared to males.
   b) They are immune to infections, while females have no immunity against infections.
   c) Males grow bigger because their metabolic energy is channeled toward growth.

6. Tilapia is a very prolific species. True or false?

7. Why is tilapia referred to as the "aquatic chicken"?

8. Why is monosex tilapia culture preferable to mixed sex culture?

9. Why is the yield much lower for mixed sex tilapia than monosex tilapia?

10. Is tilapia suitable for polyculture?

11. Tilapia can only be grown in countries with warm weather. True or false?

Module 2: Site selection, pond construction and management

Pre-evaluation questions

1. Which of the following is a factor to be considered when siting for pond construction?
   a) topography
   b) soil quality
   c) availability of water
   d) all of the above

2. What are the disadvantages of having large ponds?

3. What are the advantages of having small ponds?

4. What are the disadvantages of siting ponds in places prone to flooding?

5. What is the need for security plans in a fish farm?

2.1. Site selection

The following are the most important BMPs in site selection:

- Local topography:
  - Topography goes a long way in determining the type and size.
  - Ensure the site is where water drainage is possible by gravity.
  - Find a site with the least possible earth movement.

- Availability of water:
  - Find out about other users (current or potential) of land, water and other natural resources that could directly or indirectly impact the water quality, such as an existing factory or a planned development of a quarry site.
  - The availability of good quality water is important to the success of a farm.

- Soil quality:
  - Do not use a site that has a gravel bed, deeply rooted stumps, rock outcrops, limestone, etc.
  - Clay loam, sandy clay and silty clay loam are preferred.
  - Do not site the pond in a place that has sandy soil due to porosity or somewhere with termite mounds or termite activity, which can create leaks in the pond.

Other important BMPs include the following:

- Size of market: The enterprise has a higher chance to succeed if it is near a large market.
- Security: Poachers are a big problem in aquaculture and are capable of ruining a business.
- Vegetation cover: Heavy canopy trees and dense vegetation will cost more to clear.
- Accessibility: The site should be accessible by road to buy inputs and sell products.
- Nearness to home: It is important that the ponds are close to the fish farmer's home for easier management and monitoring as well as for security against poaching.
- Nearness to market: Freshness is important in determining the value of fish. Fresh fish is therefore sold as soon as possible with the lowest transportation cost.

Other BMPs for site selection include the following:

- Do not make a pond on a spring or water source. Rather, use a spring as an inlet water source or collect the water in a reservoir then channel it into the ponds.
- Make sure that the site is protected from flooding so as not to incur losses.

2.2. Pond construction

The following procedure outlines the steps required for building a pond:

- The size and shape of ponds depend on the purpose and intensity of production and the cost of construction. Rectangular ponds are the most common, because the shape is the most practical to build and manage. However, the bigger the pond size, the more flexible it can be with shape. Pond size can vary widely from as small as 50 m^2 to 1 ha.
- Pond water depth should be about 0.8 m at the shallow end and increase gradually to about 1.2 m at the deep end, with 0.3–0.5 m of freeboard (Figure 1).

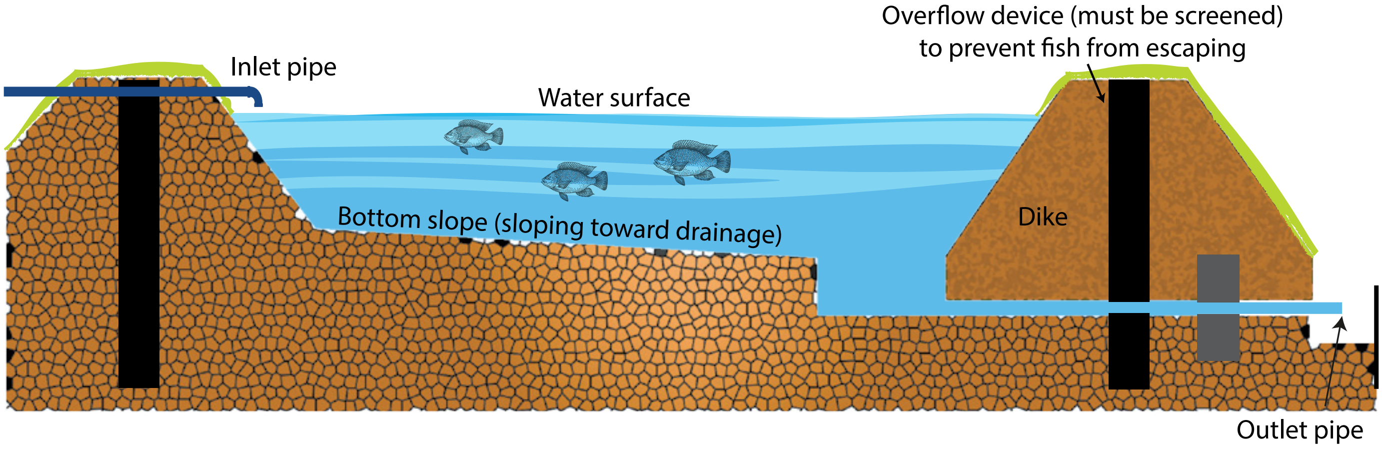

Figure 1. Profile and features of a well-constructed pond.

- Make sure the pond dike is above ground so that it can prevent floodwater from running into the water and entering the pond. Ensure dikes are wide enough between the ponds to avoid the risk of breaking or failing and to provide ample workspace. Dikes can vary in width depending on what will be going over it, such as people, vehicles and machinery, but they should be at least 1 m wide.
- The inner and outer sides of the dike should be sloped between 1.5:1 and 2:1 to prevent the dike from collapsing or failing due to water reaction, especially on the inner side of the dike (Figure 2).

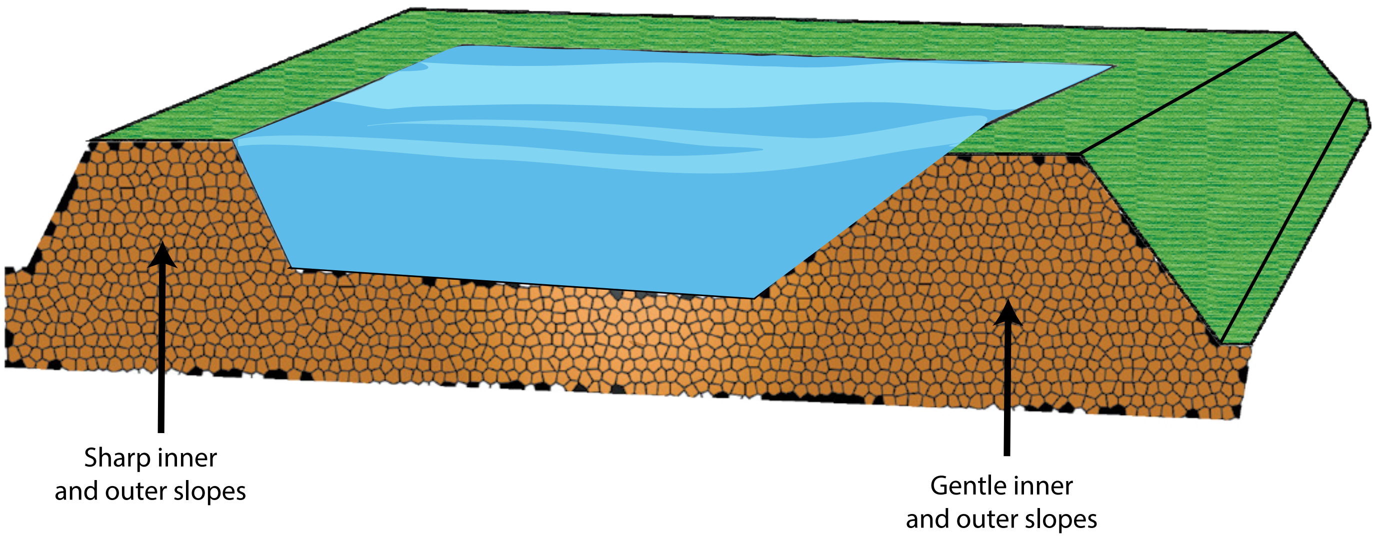

Figure 2. Profile of a sharp-sloped dike and a gentle-sloped dike.

- To avoid leaks, make sure the soil used for the dike does not contain large amounts of rocks, sand, wood or plants.
- Separate the inlet and outlet canals. To avoid management-related issues, do not allow waterflow from one pond to another, especially during a disease outbreak.
- Treat inlet water in a reservoir or use filtration, if need be. The flow of water into each pond must have individual valves for control (Figure 3). Put a screen over the inlet to keep out wild fish, twigs, leaves and other trash.

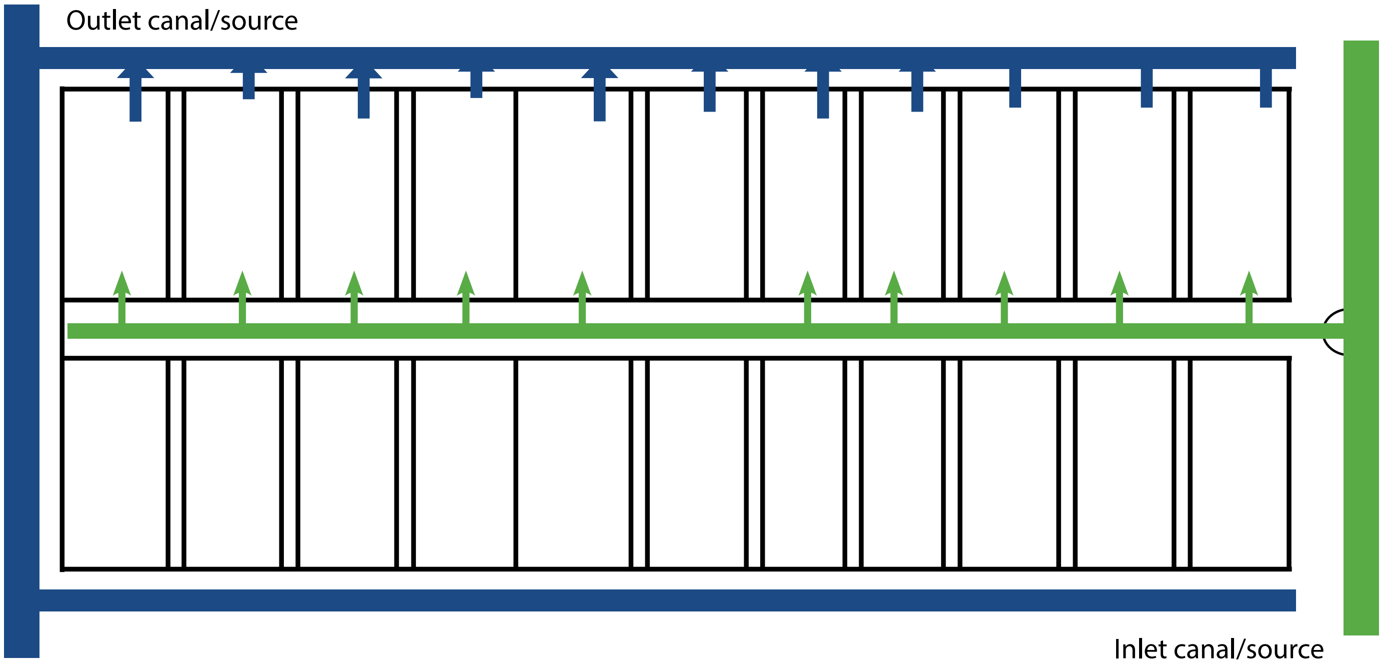

Figure 3. Fish farm layout with inlet and outlet structures.

- Make sure the outlet is at the deepest end of the pond so that all the water can be drained out of the pond by gravity.
- The inlet and overflow pipes should be at least 20 cm above the water surface to prevent fish from escaping.
- Wastewater should go through a sedimentation pond or canal to avoid polluting the natural environment. Put a screen over the outlet to avoid the release of dead fish or other waste into the surrounding environment.
- To aid harvesting, dig a small ditch in the lowest area of the pond bottom toward the drain outlet at a width of 2 m (Figure 4).

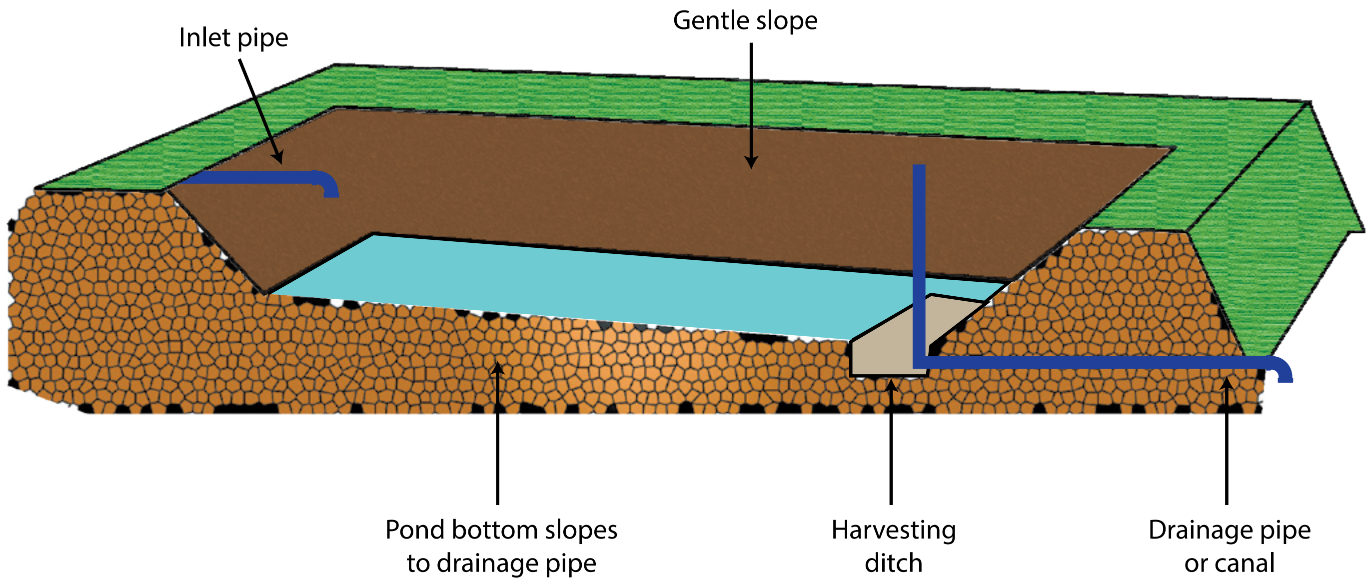

Figure 4. Pond layout with inlet, outlet and harvesting ditch structures.

2.3. Pond maintenance

The following procedure outlines the steps required for maintaining a pond:

- When a pond has been drained, leave it to dry until the base cracks. To increase soil pH, apply agricultural lime for a minimum of 10 days before beginning another cycle or batch. This helps improve soil properties and dispose of organic wastes, kill small and harmful organisms. Use quick lime as follows: 2000 kg/ha for highly acidic soil or ponds, 1200 kg/ha for acidic soil or ponds, 1000 kg/ha for slightly acidic soil or ponds, 400 kg/ha for neutral soil or ponds.
- BACTOSAFE S pond soil treatment is a specially formulated biological and biochemical system designed to accelerate the biological decomposition of highly fouled aquaculture pond soil. It is a natural microbial ecosystem to inoculate the soil wastes and start the bioremediation process. It also is fortified with unique accelerants to speed the microbial action. Steps on how to use the BACTOSAFE S are stated below.
- To avoid blockage, regularly clean the mesh on the overflow pipe in undrainable ponds where water flows continuously.
- Always maintain grasses on the dike. Check dikes for holes and fix them. Maintain the ditch by lifting mud onto the dikes. Check the inlet and outlet canals and maintain their depth to ensure waterflow.

BACTOSAFE S Application

Step 1: Ensure earthen pond is already emptied.

Step 2: Determine the quantity of BACTOSAFE S using the size of pond in which BACTOSAFE S is to be applied.
- Suggested dosage – 500 gram for a 40 m x 60 m (common size pond)

Step 3: Get a carbon source like molasses for activation (bacteria becomes active and multiply).
- Recommended dosage doubles the amount of BACTOSAFE S required.
- i.e. 500 gram BACTOSAFE S will require 1 kg Molasses.
- i.e. 1 kg BACTOSAFE H will require 2 kg molasses.

Step 4: Get warm water of about 5 liters in a clean bucket, mix required BACTOSAFE S quantity with equivalent carbon source (molasses) in warm water or clean pond water of 100 liters and aerate for 30 minutes. Allow mixture stand without covering for maximum of 4 hours, after which mixture is evenly broadcasted on pond surface. Shovel can be used to tilt and mix pond bottom efficient colonization.

NB: apply preferably before 10 am in the morning, to prevent denaturing of bacteria by hot sun.

Step 5: To allow activated positive bacteria colonize pond soil effectively, allow evenly broadcasted pond stay for 24 hours before filling in water.

Step 6: For better result, repeat the entire process in 30 days time, after stocking pond with water and fish in the system.

Post-evaluation questions

1. A colleague has acquired land for fish farming that has a year-round source of river water and is close to a large market but has a pesticide factory upstream a short distance away. What would be your advice?
2. What would happen if the outlet is not at the deepest end of the pond?
3. Why should wastewater go through a sedimentation pond or canal before being released into the natural environment?
4. What is the purpose of an overflow pipe in a pond?
5. What could happen if the soil used for the dike contains large amounts of rocks, sand, wood or plants?
6. A pond without an inner or outside slope tends to be stronger. True or false? Give a reason for your answer.
7. What is the importance of liming a pond before starting a new batch of production?
8. What are the disadvantages of having small ponds?
9. What are the advantages of having large ponds?
10. Which of the following is not part of a pond?
    a) outlet
    b) dike
    c) slope
    d) topography

Module 3: Reproduction and incubation

Pre-evaluation questions

1. What is the most common stocking ratio for tilapia?
   a) 2–3 females to 1 male
   b) 20 females to 1 male
   c) 1 female to 10 males
   d) none of the above

2. What is the optimal pH for tilapia?
   a) 6.5–7.5
   b) 1–2
   c) <4.5
   d) >8.5

3. Which of the following characteristics would you want broodstock to have if you were involved in the selection process?
   a) presence of wounds
   b) absence of wounds and parasites
   c) presence of deformities on the body and/or fins
   d) all of the above

4. Approximately how many eggs are in one batch?
   a) 100–2000
   b) 50–100
   c) 600,000–1,000,000
   d) 340,000–450,000

5. What age does tilapia reach first maturity?

3.1. Reproduction in tilapia: Sexual dimorphism

In tilapia production, males are preferred for grow-out. Males grow bigger and are more profitable because they are more efficient with time and energy, while females tend to waste energy and time because of reproduction.

Sexual dimorphism is a condition where two sexes of the same species exhibit different characteristics apart from the differences in their sexual organs. Such differences may be in color, shape and size, which makes males distinct from females. Generally, female tilapia can be distinguished by looking at the genital papillae behind the anus. It has a rounded shape with a triangular indentation in the center (Plate 1). In males, the genital papilla is tapered in shape, while females have a separate opening for eggs and urine (urinary opening and oviduct). Females have three apertures: anus, urinary and genital. The urinogenital aperture is smaller. Males have the same opening for sperm and urine (urogenital opening). There are two apertures on the ventral side of the belly: the urinogenital aperture and the anus. The former is smaller.

Plate 1. Male (L) and female tilapia (R).

In nature, males are bigger and grow larger under culture conditions. Their age at maturity for commercial production is one year, and mature fish spawn 6–12 times a year. Males are polygamous, so the stocking density is commonly 2–3 females to 1 male. The number of eggs in one batch ranges from 100 to 2000 depending on the size of the female.

3.2. BMPs in broodstock selection and care

Successful farming requires fish breeders to select broodstock for increased production in quality and quantity of fish seeds. Broodstock is a good predictor of fecundity and can be used to select fish of higher seed production.

When selecting broodstock, farmers should look for following:

- Younger brooders should be between 6 months and 1 year old.
- It is preferable for brooders to weigh 250–300 g on average.
- Highly vigorous, well-fed brooders must be selected. Avoid feeble or diseased brooders.
- The fish should have no wounds or parasites.
- There should not be any deformities on the body and/or fins.
- There should be evidence of healthy and moderate fish growth—neither too fat nor too thin. The body should possess the required shape, conformations and proportions.

Broodstock can be kept in different types of facilities: concrete tanks, hapa net cages installed in ponds or a lake, and earthen ponds. The following lists the steps required to build a facility that is suitable for tilapia broodstock:

Concrete tanks: Construct tanks that are $4 \times 5 \times 1$ m^3. Design each compartment with a catch basin occupying about 15%–20% of the floor area with a depth of about 10–12 cm. The catch basin serves to collect both breeders and fry during harvest. Water is drained through a removable polyvinylchloride standpipe about 7 cm in diameter with perforations 50–75 cm high to maintain the water level. It also serves as an overflow device and prevents fish from escaping. Concrete-based hatcheries are relatively expensive.

Hapas: Construct hapa net cages that are $3 \times 3 \times 1.2$ m^3 with a mesh of 0.5 mm. Suspend the cages in the pond or lake from fixed bamboo posts. Submerge them at a depth of at least 1–1.5 m, leaving 0.5–1 m of the net above the water surface. Cover the cages to prevent predators from entering.

For constructing rectangular earthen ponds, these can have an area of 100–320 m^2 (10×10 or 16×20) per compartment. Each compartment should have a water inlet and outlet that are protected by a net. Maintain a water depth in the pond of at least 0.7 m.

Six months to one-year-old tilapia weighing 250–300 g is suitable for breeding. The stocking density varies according to rearing facility. In hapas, stock the broodstock at a density of 5 females per m^2. In concrete tanks, stock 4 females per m^2 without aeration and 6 females per m^2 with aeration. In earthen ponds, stock 2 females per m^2. Separate and eventually pair the fish at a ratio of 1:3 (male: female) per m^2. This will increase the output by more than 50% and the growth rate of the fry by 25%.

The following procedures are the steps required for breeding between 6 months and 1 year old tilapia:

- The sex ratio of males to females for all types of breeding facilities ranges from 1:2–3 (male: female) per m^2. However, the most economical ratio for fry production is to stock one male for every three females.
- Remove the premaxilla of the male fish by clipping it with scissors to prevent injury or the death of females during courtship.
- Spawning is so stressful to the female fish. Therefore, balanced feeds are needed to improve reproductive capacity and to produce highly viable fry, free from malformations.
- Floating feeds are currently used to reduce feed loss and maintain water quality.
- Loss of appetite is considered indicative of the number of brooders carrying eggs in each unit.
- Feed broodstock daily with formulated dry pellets that contain 30%–35% dietary crude protein.
- Feed them twice daily at feeding rate of 1%–2% of their weight.
- Remove the eggs to prevent the females from incubating their eggs orally. This allows better control of hatching and permits the female produce another batch of eggs. Collecting swim-up fry is a better method than incubating eggs. This requires skilled personnel and facilities to ensure stable water flow and temperature at all times.

- In hatcheries, the sizes of tilapia broodstock range between 250 and 300 g.
- Female *O. niloticus* broodfish are usually smaller (<200 g) than male broodfish (>300 g).

3.3. Seed collection and egg incubation

Tilapia show a high degree of parental care for their eggs and fry. Nile tilapia *(O. niloticus)* and three-spotted tilapia *(O. andersonii)* are mouth brooders. They incubate the eggs in their mouth until they are fully hatched (Plates 2 and 3). This kind of fry collection system is easy for smallholder hatchery farmers. Collecting fry collection from ponds usually occurs every 7–21 days. The system is cheap and easy, though survival is low. The major disadvantage is that fry are not uniform in size, which promotes cannibalism at stocking.

The method used to rear tilapia eggs varies with species. Female broodstock must be checked regularly for eggs. If they carry eggs in their mouths, they must be collected and transferred into the hatchery. Harvested eggs and yolk sac larvae are transferred to the hatchery section where they are cleaned and washed with clean water first. They are then disinfected with potassium permanganate (2 ppm which is 2 mg in 1 liter of clean water) for 30 minutes and then washed in clean water again during incubation to control bacterial or fungal infections. They are weighed and put into the incubator jars containing water that is passed through a recirculating system. The eggs must be kept in gentle motion in order to mimic the entrance of fresh water into the mouth and out through the opercula opening for mouthbrooders.

Plate 2. Collecting eggs from a mouth brooder at the TAAT Aquaculture Compact tilapia cage culture system demonstration center of IITA in Ibadan, Nigeria.

Plate 4. Collecting fry from hapas at the TAAT Aquaculture Compact tilapia cage culture system demonstration center of IITA in Ibadan, Nigeria.

Plate 3. Fertilized eggs in the mouth of a female brooder (three-spotted tilapia) at the TAAT Aquaculture Compact tilapia cage culture system demonstration center of IITA in Ibadan, Nigeria.

Plate 5. Hapas set up for breeding tilapia at the WorldFish facility in Abbassa, Egypt.

Jar hatching is also a good way of hatching larger numbers with little supervision. Tray hatching can be a more effective method for creating optimal health conditions of fry and for better control. However, it is very labor intensive, so it not the most cost-effective technique. Using hapas is a convenient means of collecting and rearing tilapia fry (Plates 4 and 5). During egg development, a lot of ammonia and carbon dioxide can be produced, which need to be flushed away by continuous flow-through. If ammonia concentration exceeds 5 mg/L, it can inhibit the growth of the fry and damage the developing gills. It is important to maintain a pH level between 6.5 and 7.5 to ensure healthy development. A pH below 4.5 or above 8.5 will result in high egg and fry mortalities. High pH and low water hardness can weaken the eggshells, causing prematurely hatched eggs and weak fry. The eggs are mouth-brooded at 28°C and hatch within 96 hours.

3.4. Egg and yolk sac collection and larval rearing

Inspect broodstock regularly at 5-day intervals. Collected seeds usually have eggs at various stages of development: hatchlings, pre-swim-up and swim-up fry. To maintain higher yields in frequent harvesting, the eggs need to be incubated artificially.

In big hatchery operations, eggs are collected every 5–7 days from the mouth of the females. This guarantees that better quality and a higher percentage of all-male sex-reversed fingerlings are produced. However, collecting eggs every 7 days means it is likely to have hatchlings in the mouth of broodstock mixed with eggs. To collect breeders, gather fish at one end of the hapa nets. Use two nets to collect the breeders and use water to flush the eggs out of the mouths of the brooders. This method ensures higher quality fry and a better rate of success for sex reversal (98% minimum). Eggs and yolk sacs are separated into stages 1 to 5. Some stages can be combined if they are not too distinct. Fry can be removed by using scoop net and stock into other hapas or rearing pond after accounting. Brooders can also be carefully caught in a hapa by a wide net and fry collected to stock into another hapa.

Well-oxygenated, clean water must be maintained for good results. Poor seed management will result in poor overall production. The larvae of all tilapia species have bulky yolks, which make it difficult for the fish to swim or causes them to sink. Because of this, it is important that they are kept in constant slow-moving water, which also keeps the system oxygenated. They rely on their superficial blood vessels in the tail and body for their oxygen supply because of the absence of functional mouths or gills.

The larvae of mouth-brooding species should be reared in the incubators until they become free-swimming. In hatching jars, the swim-up fry follow the flow of water out of the jar. The outflow can be channeled into the rearing tanks to minimize handling.

3.5. Biosecurity measures for egg and yolk sac collection and larval rearing

The following are the biosecurity measures for egg and yolk sac collection and larval rearing:

- Handle parent fish and their eggs with care.
- Use well-oxygenated, clean water in flow-through.
- Control the entrance of visitors, staff and other disease vectors to prevent transfer of infection.
- Hatchery operators must ensure optimal physical and chemical conditions of the water. Use reliable instruments to take measurements so that the fish are not unduly stressed and predisposed to opportunistic bacterial infection.
- Clean and disinfect all hatchery equipment regularly and allow to dry.

Post-evaluation questions

1. What does an incubator mimic in tilapia broodstock?

2. How do a high pH and low water hardness affect the eggs?

3. What are some examples of physical biosecurity measures?

4. What are some examples of chemical biosecurity measures?

5. If two males are stocked in a hapa, how many females should be in the same hapa?
   a) 6 females
   b) 10 females
   c) 1 female
   d) none of the above

6. What is the optimal pH for tilapia?
    a) 6.5–7.5
    b) 1–2
    c) <4.5
    d) >8.5

7. Which of the following characteristics would you look for if you were involved in a broodstock selection process?
    a) presence of wounds
    b) absence of wounds and parasites
    c) presence of deformations on the body and/or fins
    d) all of the above

8. Approximately how many eggs are in one batch?
    a) 100–2000
    b) 50–100
    c) 600,000–1,000,000
    d) 340,000–450,000

9. Which of the following chemical treatments can be administered during egg incubation to prevent fungal and bacterial infection?
    a) potassium permanganate
    b) oxytetracycline
    c) methyl testosterone
    d) vitamin premix

10. Which of the following is not an important reason for biosecurity?
    a) minimizes the risk of project failure
    b) reduces viability and leads to eventual loss
    c) lowers the chance of disease outbreak
    d) decreases the chance of economic losses from fish loss

Photo credit: Mr. Remi Ahmed/Choice Fisheries Consults Ltd

Fish breeders from 15 states participated in a step-by-step monosex tilapia training session by the TAAT Aquaculture Compact team in Nigeria at Choice Fisheries Farm in Odan NLA village of the Ado-Odo/Ota Local Government Area, Ogun State.

Module 4: Feed preparation and management practices

Pre-evaluation questions

1. What is a Secchi disk used for?

2. What is the difference between physical biosecurity and chemical biosecurity?

3. What factor encourages the recirculatory system?
   a) strict environmental regulations
   b) scarce water source
   c) higher cost of land
   d) all of the above

4. What factor encourages cage system?
   a) abundant water bodies
   b) good oxygen level in the water bodies
   c) no predator infestation in most of the water bodies
   d) good market price

5. Which of the following is not a technique for sex reversal?
   a) hormonal sex reversal
   b) hybridization
   c) visual selection
   d) yolk sac vibration

4.1. Techniques for sex reversal feed preparation

4.1.1. Fry nursery

Larvae hatch in their first phase, carrying yolk sacs on which they feed for 2–3 days according to ambient temperature. After complete consumption of yolk sacs, fry are stocked into the treatment units at a rate of 2000–3000 fry per square meter. The holding capacity of each unit is completed within 1 day to avoid discrepancy in fry sizes after treatment. Treatment period is calculated from the day following stocking the nursery unit. Any increase over the density could reduce the effectiveness of the hormonal treatment.

There are four methods for monosex tilapia production: hormonal sex reversal, hybridization, visual selection and genetic manipulation.

Hormonal sex reversal is the most common of the four. The method is practiced in many countries, though it is very sensitive. In India, for example, stocking only monosex tilapia is allowed only in line with national guidelines. This manual is not advocating the use of methyl or ethyl testosterone hormone. Its purpose is to teach the most commonly used and available techniques. Newly hatched larvae are fed with hormone feed for 21–23 days. Feeding for sex reversal begins on the 10th day after hatching, when the gonad of the fry still remains in an undifferentiated stage. The most common sex reversal hormone is either 17 alpha methyl testosterone or 17 alpha ethyl testosterone.

It must be noted that hybridization is not a recommended practice because it leads to mixing strains and the loss of a pure genetic strain in the area or region.

4.2. Using methyl testosterone or ethyl testosterone in hatcheries

The following are guidelines for better aquaculture practices (BAPs) when using methyl testosterone or ethyl testosterone in hatcheries:

- Maintain records of hormone applications whenever hormones are used to produce monosex fry.
- Train workers how to use methyl testosterone, ethyl testosterone or other sex reversal hormones.
- Require workers to wear protective clothing and masks with an air filter.
- Make sure the facility has a protocol for managing water used for sex reversal. Do not release hormone-treated water directly into the environment. Always comply with government standards, where these exist.

4.3. Using methyl testosterone or ethyl testosterone on farms

The following are guidelines for BAPs when using methyl testosterone or ethyl testosterone on farms:

- Using methyl testosterone for sex reversal of fry is permissible, provided it is not banned by the importing country.

- Instruct workers to wear protective clothing and a mask with an air filter when working with a hormone.
- Maintain records whenever a hormone is used.
- Minimum hold time is 48 hours before any water in which fish have been treated or fed with feed containing methyl or ethyl testosterone can be released into the environment.

4.4. Principles of sex reversal

This process raises the level of male steroid in the bloodstream of sexually undifferentiated fry. This occurs before they have physically become male or female, usually between 21 and 28 days after hatching.

The following is the procedure required for mixing the ingredients:

- Prepare the ground and sieve the dry feed ingredients.
- Mix the hormone stock solution with the alcohol.
- Add the solution slowly and mix it with the dry feed ingredients.
- Allow the alcohol to evaporate at room temperature with no direct sunlight by spreading out the mixture to a maximum thickness of 3–5 cm. Mix lightly by hand two or three times.
- Treated feeds can be packed once the mixture feels dry to the touch and all the odor of the alcohol has disappeared. This ensures that at least 98% of the stock will be male.

Two synthetic androgens are used in sex reversal of tilapia fry into males: ethyl testosterone and methyl testosterone.

The hormones are used for a very short time. Several studies have shown that it is cost-effective and testosterone levels in adult fish that have been hormonally sex reversed are actually very low.

Prepare the alcohol-hormone stock solution as follows:

- Dissolve exactly 4–5 g of methyl testosterone in exactly 1 L of 95% ethyl alcohol. (This quantity is sufficient to treat approximately 300,000 fry.)
- Store stock solution at 4^{0}C.

Calculate the feed adjustments as follows:

- Determine the initial total weight of the fish stock (in this case, 10 g for 300,000 fry).
- Initial amount of feed = total weight of fry stock x feeding rate (in this case, 9 g x 0.20 = 1.8 g/day).
- After 1 week, make some feeding adjustments. This can be done by computing the total weight of surviving fry through sampling and multiplying it with the feeding rate.

The following are the materials needed to produce 1 kg of sex reversal feed:

- 1 kg of 0.2 mm feed (with at least 40% protein)
- 4–5 g of 17 alpha methyl testosterone hormone
- 1 L of 95% ethyl alcohol (WorldFish Abbassa recommendation)

The following are important factors for ensuring good and efficient sex reversal:

- Fry must not be more than 17 days old.
- The correct hormone dose is 4–5 mg.
- Feed must have high palatability (25%–45% protein).
- Feed tilapia between three and six times daily.
- Make sure the fish do not show any signs of disease.
- Maintain an optimal temperature <32^{0}C.
- Ensure fry are of uniform size to prevent cannibalism.
- Control the level of natural food.
- Store hormones and hormone-treated feed at a temperature of 4^{0}C.
- The optimal fry density is 1000/m^2 or 12 fry/L.
- Treatment duration should take a minimum of 25–28 days for more reliable sex reversed success.
- After treatment, there should be few fry under 14 mm in size. However, if more than 5% of the fry are 13 mm or smaller, remove those fry because 25% of them could be females.

Fry rearing during hormone treatment

Fry are fed with the ration previously prepared to which the hormone has been added. They are fed six times a day until the end of the treatment or the primary nursery period. Feed must be spread on the water surface of the rearing unit to give all fry equal access to the hormone-treated feed. Feeding continues for 21 days to ensure successful sexual inversion where the male ratio reaches 98%.

Fry harvest (after nursery)

Fry are harvested at the end of the nursing period. They are either moved to clean basins as a preliminary step before sale or to rearing units for growth into the fingerlings phase. When selling the fry directly from the nursing units, the hatchery's operator must make sure that no waste or precipitates ever exist in the nursery units.

The following conditions must be noted at fry harvesting:

- Avoid harvesting/handling the fry at noon or at high temperatures.
- Grade the fry at harvest to accurately determine their numbers before sale or transportation. Avoid size discrepancies that may occur at the rearing units.
- Move the fry to the storage units in barrels or plastic basins and avoid overcrowding to reduce stress or loss of part of the harvest during transfer.
- The size of the counting scoop net at sale varies with the size of the fry. Count a scoop sample before packaging the fry at sales.
- The number of fry per bag varies according to fry size and distance traveled.

The recommended feeding schedule for tilapia is shown in Table 1.

4.5. Water quality management

Water quality affects fish health and survival in extreme conditions. Tilapia does well in high quality water and the following physico-chemical properties:

- A 60 cm Secchi disk reading is considered good.
- Tilapia thrive in temperatures between 27^{0}C and 31^{0}C. Stop feeding the fish at times of the day when temperatures are lower than this range. Tilapia can survive at temperatures of 20^{0}C–40^{0}C, but below 10^{0}C could be lethal.
- Uneaten feed and fecal deposits leave a lot of dirt in the water, resulting in a high ammonia level.
- A dissolved oxygen level of 5–8 mg/L and a pH of 7–9 are suitable parameters for enhanced growth of tilapia. Incorporate aeration if the dissolved oxygen level is low.
- Tilapia is a freshwater fish that can tolerate brackish water up to 12–15 ppt.
- Ammonia levels in ponds depend on the quality of feed, feeding rate, temperature and size of fish. Maintain concentrations below 0.1 mg/L. Since ammonia can be related to pH, higher levels of ammonia can be safe in water with a pH of 7 but not in a pH above 9.
- Nitrite is toxic to fish. It is produced by bacteria during the breakdown of ammonia through the process of nitrification. Tilapia start to die at a nitrite concentration of 5 mg/L, and high levels of it can cause brown blood disease.
- Regularly flushing pond water helps reduce the accumulation of pollutants in the system. Add salt to disinfect pond water at 1 g/10 L of water.

Other precautions in water quality management for rearing tilapia include the following:

- Wash out non-ingested food and fecal deposits daily by removing and replacing 10%–20% of the water.
- Scrub the walls of the troughs once every 6–8 weeks to remove algae growth.
- Without aerators, a flow-through rate of 23–46 L per minute is needed for an adequate dissolved oxygen level for 45.4 kg of tilapia.
- In cases where no water quality test kit is available, check to make sure that the fish are eating the feed. If they are not, this could be an indication of poor water quality.
- Avoid overfeeding. The daily feeding rate should be 15%–20% of the weight of the fry until they reach an average length of 15 mm (0.01 g). At that stage, drop the daily feeding rate to 10% of their weight until the end of the treatment.

4.6. Tilapia culture facilities

There are three types of culture facilities for tilapia: earthen ponds, cage facilities and recirculatory systems. Production costs can be 25%–40% higher in cages than earthen ponds and as much as 80%–120% higher in recirculatory systems than in earthen ponds.

4.6.1. Earthen ponds

The following are optimal characteristics of earthen pond culture:

- Temperature is suitable.
- Land is abundant and cheap.
- Environmental regulations are not too strict.

Days	Weight	Log_w	Specific growth rate	Weight gain
1	0.03	-1.52288	0	0
29	0.8	-0.09691	5.092745	0.77
34	1.7	0.230449	6.547179	1.67
36	1.8	0.255273	1.241179	1.77
59	8.2	0.913814	2.863223	8.17
62	13	1.113943	6.670983	12.97
64	17	1.230449	5.825278	16.97
65	21	1.322219	9.177037	20.97
80	30.3	1.481443	1.061489	30.27
87	37	1.568202	1.239416	36.97
90	43.5	1.638489	2.342918	43.47
97	47.48	1.676511	0.543164	47.45
105	59.5	1.774517	1.225078	59.47
112	62.6	1.796574	0.315105	62.57

Source: Choice Fisheries Farm in Odan NLA village, Ado-Odo/Ota Local Government Area, Ogun State.

Table 1. Weekly feeding schedule for tilapia.

- There are abundant and suitable water sources (Plate 6).
- Cost of fish is not too high.
- Technical labor is not required.

Plate 6. Tilapia cage culture system at the TAAT Aquaculture Compact tilapia cage culture system demonstration center of IITA in Ibadan, Nigeria.

4.6.2. Cage facilities

The following are optimal characteristics of cage culture:

- Temperature is suitable.
- Abundant water bodies.
- Sufficient oxygen in the water bodies.
- No predator infestation in most of the water bodies.
- Market prices are good.
- No source of pollution exists close to the water bodies.

4.6.3. Recirculatory systems

The following are optimal characteristics of using recirculatory systems:

- Environmental regulations are strict.
- Water sources are scarce.
- The cost of land is high.
- Temperatures are low.
- Project located in urban areas.
- Fish command higher selling prices.
- There is a continuous electricity supply at an affordable price.
- Qualified staff or labor are available.

4.7. Routine management practices

Good management practices involve routine or regular checking and monitoring of fishponds, including water quality and depth, as well as inlets and outlets of production facilities. It is important to monitor and check the following on a daily basis:

- Check main water intakes. Feeder canals and pond inlets must supply adequate water to the ponds and hatchery.
- Check and confirm that all pond structures are functioning well.

- Check water quality using a test kit or by visual assessment. The latter requires experience and can be done by observing the behavior of the fish as well as checking the turbidity from the plankton and making sure that the color of the water color is greenish.
- Feed fish regularly.
- Keep detailed records daily.

Weekly tasks or longer intervals include the following:

- Check dikes and structures for possible leaks when draining is complete.
- Remove any mud at the bottom of the ponds.
- Control aquatic weed and pests.
- Conduct routine water quality checks.
- Assess the stock through test cropping. This helps determine the efficiency of feeding, adjustments to daily feeding ration (which saves feeding cost), the quality of fish growth, the stocking rate and the general health of the stock. If the stocking rate is too high, crop out the bigger fish.
- Maintain detailed recordkeeping for resource use efficiency and stock inventory.
- Calculate various parameters for managerial decision-making, including the feed conversion ratio (FCR) and daily growth rate (g/day)

Fish farmers should stock only the highest quality fingerlings. It is important to grade hatchlings and fingerlings as many times as possible to lessen the use of chemicals and antibiotics in fish health management. Use more probiotics if the technology is available. Ensure all fishing gears are sanitized.

Other precautions include the following:

- Restrict movement into the hatchery.
- Keep new incoming stock in a quarantine tank.
- Store feed in a cool and dry environment and use within 3 months of receiving it.
- Avoid stocking the lowest grade (smallest fingerlings) of a production batch.

4.8. Using hapas and probiotics

A hapa is a cage-like, rectangular or square net impoundment made of fine mesh netting material. They are placed in a pond to hold fish for various purposes and can be disinfected, washed and preserved longer by soaking with urea for an average of 4–5 days. Hapas are used for rearing tilapia fry to fingerlings to increase the survival rate at harvest. About 90% of commercial hatcheries in Egypt use hapas.

4.8.1. Use of probiotics

Many fish farmers depend on Smart Choice Probiotics marketed as Defence. It is customised Direct Fed Microbial Privately (DFM). It is privately cultured in USA Laboratory. It is heat stable product. Contains a source of live (viable) naturally occurring microorganisms.

Guaranteed analysis: Minimum 1.0 x 1011 (100 billion) CFU kilogram. Per Kilogram.

- Lactobacillus acidophilus.
- Lactobacillus casel.
- Bifidobacterium casel.
- Enterococcus faecium.

Direction for use:

- For non-high-pressure feed 0.5kg/ton
- For extruded feed with high temperature 1kg/ton
- For fry: 5 -10gm /kg feed
- External use in water: 3 -5gm/cubic meter of water. It can be fed directly at the same rate.

Other commonly used probiotics in Africa are:

- Shandong Baolai Leelai – China.
- Sanzyme Biologics (p) Ltd. India.

Benefits of Probiotics:

1. Balance the intestinal micro flora.
2. Increase feed conversion rate.
3. Promote growth, especially when it is used with good enzyme like 10 strength enzymes produced by Smart Choice Eggriculture, USA. In a trial using the above combination, a batch of Tilapia attains weight 1.8 gm weight at 5 weeks and the escapees attained average of 3.7 gm. This is by every standard higher than breeders' expectation.
4. Improve immunity.
5. No side effect, no residue and no drug resistant bacteria.
6. Not healthy harmful and ecologically friendly.

BACTOSAFE H is a concentrated complex of live bacteria selected specifically to enhance the health of fish and shrimp in hatcheries. It is a natural microbial ecosystem with added stabilizers and growth stimulants for detoxifying aquaculture hatchery water. It eliminates water-fouling waste products such as ammonia, nitrites and hydrogen sulfide, thereby lowering stress and providing a healthier environment for aquatic animal growth. It also improves animal health and disease resistance by creating a probiotic environment.

BACTOSAFE H Application

Step 1: Determine the stage of fish in need of BACTOSAFE H. It must be in the hatchery.

Step 2: Determine the quantity of BACTOSAFE H based on volume of water in the fish tank or overhead GEEPEE tank. It should be noted that recommended quantity vary with stage of fish (yolk sac, fingerlings and juveniles).

Suggested dosages to 1000 liters of water per day are;
- Yolk sac (before feeding starts i.e., after 3 days of hatching) – 4 mg/1000L
- Fingerlings – 6 mg/1000L
- Juveniles – 8 mg/1000L
- For extreme ammonia situations in any of the stages – 10 mg/1000 L

NB: Each of these dosages can be shared to be us 2 or 3 times per day or used just once for the day.

Step 3: Following this, will be activation (bacteria comes alive and multiply) of BACTOSAFE H in NON – CHLORINATED fresh water of about 5 liters in a clean bucket. Measure any of the suggested dosages above depending on the situation, Pour and stir (to prevent coagulation) in the non – chlorinated 5 liters of freshwater. Cover (anaerobic) stirred solution for maximum of 4 hours, after which it is introduced into the either the fish tank (suitable in RAS – Recirculatory Aquaculture System) or overhead GEEPEE tank (for flow-through system).

Step 4: Leave solution to digest available ammonia in the system. For recirculatory aquaculture system,

Leave solution for as long as 24 hours to digest ammonia in the system, before flushing out water. In case of flow through system, leave for 3 hours before flushing out then allow fresh activated water flow in form the overhead GEEPEE tank.

NB: In extreme ammonia situations, local adaptions must be made to suit the condition.

4.9. Biosecurity

Biosecurity is a set of preventive measures put in place to reduce the chance or risk of transmitting infectious diseases from outbreaks or pathogens, such as viruses, fungi, bacteria and parasites. It is also designed to reduce the access of vectors, including wild fish, predators, pests, rodents, domestic animals, livestock and people.

The main goal of implementing biosecurity measures is to protect the farm and the surrounding environment from the introduction or spread of pathogens. These can come from the water source, seed source, feeds, equipment, personnel or waste.

There are two different types of biosecurity: physical and chemical. Physical biosecurity measures are those that aim at preventing the intrusion of disease-carrying vectors into the farm site. These include physical barriers, water treatment and quarantine. Chemical measures are those used to treat materials before they enter the facility. Other elements of biosecurity are to minimize the impacts of invasive alien species on the environment and avoiding health risks that can arise from eating fish.

4.9.1. BMPs for farm biosecurity

The following precautions and measures are considered for BMPs:
- Make sure seed are healthy and free of disease. Animals entering the farm can present a significant disease risk, especially if their health status is unknown, so it is important to buy seed from reputable hatcheries. If possible, quarantine fry before stocking them in the ponds. This can be done through isolation in a hapa or in a small pond with no other fish.
- Limit entry points into the farm. This will make it easier to monitor compliance with biosecurity measures.
- Ensure wash-down with a broad-spectrum disinfectant on vehicles. Otherwise, make sure the vehicles are parked away from the facilities.
- Wash hands at the farm entrance, before and after farm activities.
- Install a footbath at the entrance to the farm.
- Avoid contact with sick animals.
- Avoid touching eyes, mouth and ears.
- Maintain social distancing among workers and between workers and customers. Disinfect farm tools regularly.

4.9.2. Quality assurance

- Brooders must be secured from a trusted source. It is, however, advisable to procure brooders from a multiplication center for genetically improved strains.
- Replace brooders with new ones of the same species every 3 years.

- Increase the effective size of the brooder population to minimize inbreeding.
- Keep records for each batch of broodstock.
- Procure hormone from a reliable source and keep it in a refrigerator.
- Use pure alcohol in preparing the standard solution for solubility of hormone.
- Feed brooders high protein to produce highly viable fry.
- Feed fry during the nursing/treatment period on specialized high quality artificial feeds of proper size to safeguard the production of highly viable fry.
- Prepare fry feeds (as described in section 4.4) and keep them in the fridge until they are used to feed the fry.
- Abide by hormone concentration (60 mg/kg of feed) to produce a monosex fry population (98% males). Note that higher concentrations of hormone could reduce sexual reversal efficiency.
- Start fry feeding immediately after consumption of yolk sacs with hormone treated feed. Delaying feeding could entice fry to feed on natural food, thus reducing the potential success of sex reversal process.
- Feed fry on the hormone-treated feed for a period of not less than 21 days and not more than 28 days.

4.9.3. Facility entrance

Indiscriminate entrance into the facility heightens the chance of contamination and transfer of pathogens.

- Control or restrict the entrance of vehicles, visitors, staff and other disease vectors to prevent transferring infections.
- Install a hand-wash and footbath at the entrance.
- Disinfect the wheels of vehicles as they enter.
- Change the disinfectant regularly.

4.9.4. Water management

Water quality is the most important factor in ensuring fish health.

- Hatchery operators must ensure optimal physical and chemical conditions of the water, using reliable instruments to take measurements so that fish are not unduly stressed and predisposed to opportunistic bacterial infections.
- Use chlorine, ozone, UV, ultrafiltration or another treatment to kill pathogens in water used for production.

4.9.5. Disinfecting equipment

Clean and disinfect all hatchery equipment after use and before any production cycle.

- Maintain a clean work environment. Do not take hatchery equipment outside the facility or use it in other places.
- Disinfect all hatchery equipment regularly and dry thoroughly.
- Flush sand filters and remove the sand to dry under the sun.
- Keep nets and other equipment off the floor.

4.9.6. Quarantine incoming fish

Incoming broodstock, fingerlings or juveniles from other farms are potential vectors of disease into the facility. Carry out a prophylactic treatment to rid the fish of parasites and bacteria before introducing them into the hatchery.

- Prophylactic treatment includes medicated baths in potassium permanganate, oxytetracycline, etc.
- Repeat these treatments three to four times within a week.
- Allow flow-through when treatment is not ongoing.
- Feed the fish when they are not undergoing treatment.
- Smooth inner surfaces in tanks allow for easy and complete cleaning.
- During quarantine, monitor fish closely.
- Apart from quarantine treatment, give broodstock regular prophylactic treatments with or without oxytetracycline at least once a month.

Post-evaluation questions

1. What instrument is used to check water clarity?

2. Why is it important to limit entry points into the farm?

3. Pathogens can come from water sources, seed sources, feeds, equipment, personnel or waste. True or false?

4. What is the difference between physical biosecurity and chemical biosecurity?

5. What factor encourages using a recirculatory system?
   a) project located in urban areas
   b) fish commands a higher selling price
   c) continuous power supply at an affordable price
   d) all of the above

6. When can sex reversal feeding of tilapia begin?
   a) Day 21
   b) Day 10
   c) Day 27
   d) none of the above

7. Which of the following is used as a treatment to kill pathogens in water used for production?
   a) chlorine
   b) ozone
   c) UV
   d) all the above

8. What factor encourages using the cage system?
   (a) no predator infestation in most of the water bodies
   b) good market price
   c) no source of pollution close to the water bodies
   d) all of the above

9. Which of the following is correct regarding sex reversal in tilapia?
   a) It raises the level of male steroid in the bloodstream of sexually undifferentiated fry.
   b) It raises the level of female steroid in the bloodstream of sexually undifferentiated fry.
   c) It suppresses the level of female steroid in the bloodstream of sexually undifferentiated fry.
   d) It suppresses the level of male steroid in the bloodstream of sexually undifferentiated fry.

10. Which of the following is not a technique of sex reversal?
   a) hormonal sex reversal
   b) hybridization
   c) visual selection
   d) yolk sac vibration

Representative of 10 African of countries' partners of the TAAT Aquaculture Compact participate in a practical training session in Abbassa, Egypt, in October 2018.

Module 5: Fish health and disease management

Pre-evaluation questions

1. Which of the following is not an external factor that affects fish health?
   a) geology
   b) industry sewage
   c) sewage
   d) excreted waste

2. Which of the following is not an internal factor that affects fish health?
   a) feed management
   b) soil
   c) water exchange
   d) maintenance

3. Which of the following is not a type of disease?
   a) parasites
   b) fungi
   c) bacteriophage
   d) virus

4. Which of the following is not a sign of sickness in fish?
   a) fish stop feeding
   b) ragged fins
   c) hyperactivity
   d) lethargy

5. Are fungi a primary or secondary problem?

5.1. Factors affecting fish health

Fish health management is a term used in aquaculture to describe management practices that are designed to prevent fish infections and diseases, and to control diseases when they occur. Once fish get sick, it can be challenging to rescue them (Figure 5). Successful fish health management begins with preventing diseases rather than treatment. Preventing fish disease is accomplished through good water quality management, nutrition and sanitation.

Observing fish behavior and feeding activity daily helps detect health problems early so that a diagnosis can be made before the majority of the population becomes sick. Treatments are successful if they are implemented early following the occurrence of a disease while the fish stock is not seriously infected.

Fish disease is significant in aquaculture because it leads to substantial economic loss and reduction in the market value of fish. Disease outbreaks increase production costs because of the loss of fish (mortality), cost of treatment and decreased growth during recovery. In nature, fish diseases are not obvious because sick animals are quickly removed from the population by predators. In addition, fish are less crowded in natural systems than in captivity or culture systems.

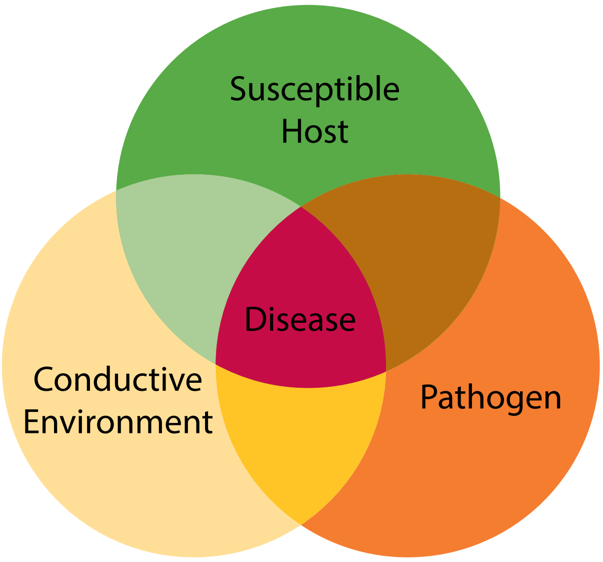

Figure 5. Classes of factors that affect fish health.

5.2. Types of fish diseases

There are two major categories of diseases: infectious and non-infectious.

5.2.1. Infectious diseases

Infectious diseases are caused by pathogenic organisms in the environment or carried by other fish species. They are contagious, and treatment might be necessary to control the outbreak. Infectious diseases are broadly categorized as parasitic, bacterial, viral or fungal (Figure 6).

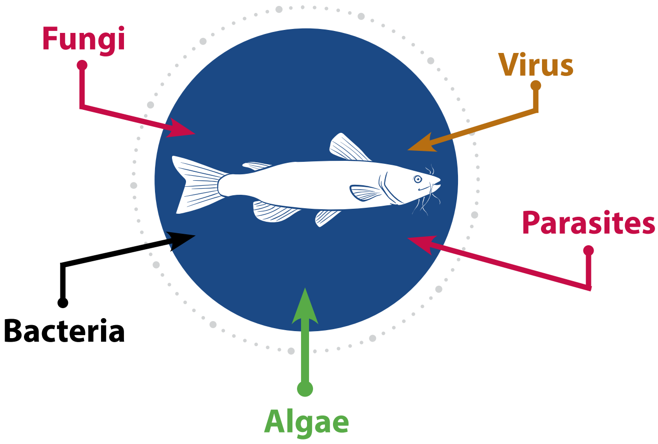

Figure 6. Biotic factors that affect fish health.

5.2.1.1. Parasitic diseases

Parasitic fish diseases are frequently caused by small microscopic organisms called protozoa, which live in the aquatic environment. There are several classes of protozoans. They target the gills, gut and skin, causing irritation, weight loss and even death. Standard fisheries chemicals, such as copper sulfate or potassium permanganate, can control most protozoan infections. There are broadly two types of parasites: ectoparasites and endoparasites.

5.2.1.1.1. Ectoparasites

Ectoparasites are organisms that live on the skin of another organism, called a host. They use the host for food and protection at the detriment of the host, sometimes even costing it its life. Examples of ectoparasites among tilapia include the Ich or fish louse *(Ichthyophthirius multifiliis)*, the salmon fluke *(Gyrodactylus)* and Trichodina species. Trichodina is a protozoan parasite that has severely affected production at many facilities. It can result in extremely high mortality rates, particularly in young fish.

These parasites heavily infest the gill and body surfaces of infected fish. Infected fish display flashing (swimming against the floors of tanks to scrape off the parasites), rapid breathing, weakness and uncoordinated swimming. These parasites attack the gills, rendering fish less efficient at absorbing oxygen, releasing carbon dioxide, excreting ammonia and maintaining chemical balance between their body and the environment.

Copper sulfate and salt can temporarily control Trichodina. However, treated fish remain carriers even after treatment, and much like Streptococcus. It is nearly impossible to eliminate Trichodina from a system once it has been introduced. Carefully examine any fish from outdoor ponds or other farms for Trichodina before letting them onto the premises.

5.2.1.1.2. Endoparasites

Endoparasites are organisms that live on the inside of a host, from which they derive their food. They exist in two forms: intercellular parasites and intracellular parasites. Intercellular parasites, such as nematodes, tapeworms and other Helminthes (which live in the gut of the host), inhabit spaces of the host body. Intracellular parasites, such as protozoan, live within the cells of the host.

5.2.1.2. Bacterial diseases

Bacterial diseases are often internal infections, but they can also be external, resulting in erosion of the skin and ulcerations. Columnaris is an example of an external bacterial infection and can be caused by rough handling. Opportunistic bacterial pathogens are microorganisms that cause diseases in hosts that are predisposed to environmental stressors or have reduced immune function. Stress factors like hypoxia, high concentrations of ammonia, abnormal pH and high population density make it possible for opportunistic pathogens to thrive. Typically, fish infected with a bacterial disease will have hemorrhagic spots or ulcers along the body wall, around the eyes and mouth. They might also have an enlarged, fluid-filled abdomen and protruding eyes. Most bacterial infections occur when fish immunity has been compromised or when a parasitic infection has opened the way. Bacteria in these cases are considered secondary infections.

5.2.1.3. Viral diseases

Viral diseases are difficult to distinguish from bacterial diseases without special laboratory tests. They are difficult to diagnose, and there are no specific medications available to cure viral fish infections. Consultation with an aquaculture or fish health specialist is recommended if you suspect a bacterial or viral disease is killing your fish.

5.2.1.4. Fungal diseases

Fungal spores exist freely in the aquatic environment, but only affect unhealthy fish. Healthy fish tend to be immune. When fish are infected with an external parasite, bacterial infection or are injured by handling, the fungi can colonize damaged tissue on the exterior of the fish. These areas appear to have a cotton-like growth or brown matted areas when the fish are removed from the water. Potassium permanganate are effective treatments for most fungal infections. Since fungi are usually a secondary problem, it is important to diagnose the original problem and correct it as well.

5.2.2. Non-infectious diseases

Non-infectious diseases are caused by environmental problems, nutritional deficiencies or genetic anomalies. They are not contagious and usually cannot be cured by medications. Environmental diseases are the most significant in commercial aquaculture. They include low dissolved oxygen, high ammonia, high nitrite and natural or human-made toxins in the aquatic environment. Proper techniques for managing water quality will enable producers to prevent most environmental diseases.

5.3. Signs of sick fish

These signs can be observed in fish seed as they grow from fingerlings to juveniles. The most obvious sign that something is wrong within the culture system is the presence of dead or dying fish. This is because a careful observer would notice a change in the behavior before mortalities begin (Table 2).

The following are easily detectable signs of sickness in fish:

- Fish stop feeding. Healthy fish eat actively if fed at regularly scheduled times.
- The entire stock or a few fish appear lethargic or sluggish.
- Fish hang lazily in shallow water, gasp at the surface or rub against objects. These behavioral abnormalities indicate that the fish are not feeling well or that something is irritating them.
- The presence of sores, such as ulcers or hemorrhages.
- Ragged fins.
- Abnormal body shape, such as a distended abdomen or "dropsy" and exophthalmia or "pop eye."

When any of these abnormalities occur, evaluate the fish for parasitic or bacterial infections.

5.4. What to do if fish are sick

If you suspect that your fish are getting sick, the first thing to do is check the water quality. Low oxygen is a frequent cause of fish mortality in ponds, especially in the summer. High levels of ammonia are also commonly associated with disease outbreaks when fish are crowded

Condition	Healthy fish	Sick fish
Escape reflex (determined in water)	Reactions to any external stimuli, like sounds or vibrations	Lose ability to react to any stimuli and are easily caught
Defensive reflex	Toss and flab about when laid on a table	Sluggish and motionless
Tail reflex	The caudal fin stretched in the shape of a fan	The caudal fin hangs vertically downward
Ocular reflex	Hard to keep eyeball in normal position	Loss of reflex

Table 2. Characterization and differentiation of sick and healthy fish.

in vats or tanks. In general, check the levels of dissolved oxygen, ammonia, nitrite and pH during a minimum water quality screening associated with a fish disease outbreak. The parameters of significance include total alkalinity, total hardness, nitrate (saltwater systems) and chlorine (if using city water).

Keeping daily records is important because it will be a reference point to trace what might have gone wrong and for general management. Records should include the dates fish were stocked, size at stocking, source, feeding rate, growth rate, daily mortality and water quality. Good records also include a description of behavioral and physical signs exhibited by sick fish and results of water quality tests. These will provide a complete case history for easy diagnosis and information about management and for preventing future cases.

5.5. Diseases from environmental deficiencies

5.5.1. Oxygen depletion

Oxygen depletion, or hypoxia, is a common effect of eutrophication in water. The direct effects of hypoxia include mortalities, especially in fish that need high levels of dissolved oxygen. Low dissolved oxygen can result in high mortality of fish seed and consequently serious financial problems for commercial fish operations.

Sometimes it is difficult for fish farmers to determine whether tilapia are coming to the surface due to low dissolved oxygen levels and when they are just swimming normally. When the water system is normal, tilapia dart back and forth across the surface, but when dissolved oxygen is low they tend to swim slower and look suspended in the water, as in a hanging position. Although fish can show such behavior when fully fed, it is important for farmers to distinguish between tilapia hanging because they are fully fed and those hanging from low dissolved oxygen. Fish gasping at the surface of the water are likely oxygen starved (Figure 7), while poorly oxygenated ponds, emit foul odors from decaying vegetation, excess fish waste and other organic matter.

Fish production can be greatly affected by excessively low or high pH. Extreme pH values can kill fish and also reduce the growth of natural food organisms. Critical pH values vary according to the fish species, the size of fish and other environmental conditions. The purpose of measuring the level of un-ionized ammonia is to manage pond pH. If the pH level is above 8.5 at sunrise, use acid fertilizers. If it is below 6.5 at sunrise, use lime and alkaline fertilizers.

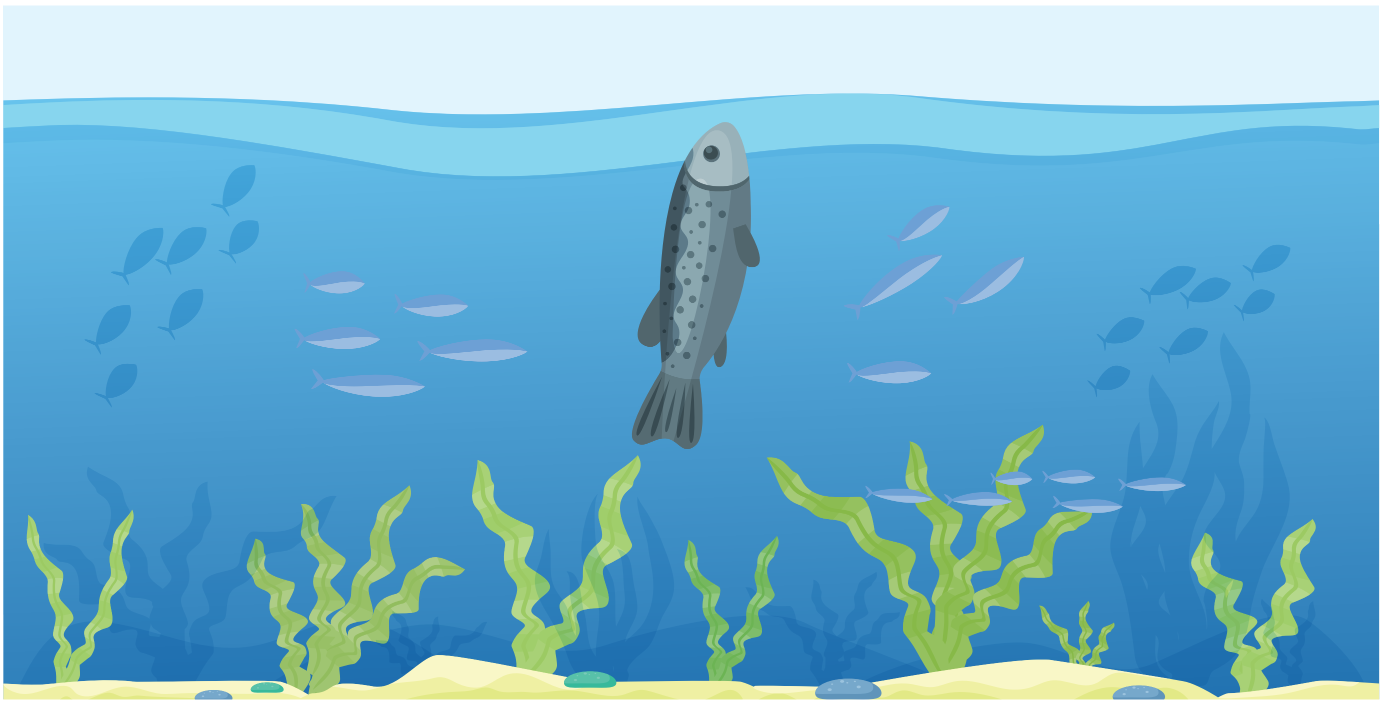

Figure 7. Fish gasping for air at the surface of the water.

Clay turbidity in pond water (muddy water) can be harmful to fish and limit pond productivity. Low phytoplankton density in ponds means less food and dissolved oxygen for the fish. On the other hand, too much phytoplankton (algal bloom) leads to minimized sunlight penetration, causing algal deaths. Less phytoplankton and decomposing plankton also lead to less food and dissolved oxygen for the fish. Good water quality requires maintaining an optimal plankton level. Visibility in a pond with the right plankton density should be about 30 cm (Plate 7).

5.6. Diseases from nutritional deficiencies

5.6.1. Dietary essential amino acid deficiency and toxicity

Excessive heat treatment of feed proteins during feed manufacture can lead to poor feed formulation if manufacturers use disproportionate amounts of feed proteins with natural specific deficiencies of dietary essential amino acids (EAAs). Nutritional pathologies also arise from consuming feed proteins containing toxic amino acids. Some feed proteins contain toxic amino acids that affect fish growth and efficiency and can even lead to death. Symptoms of toxicity include scoliosis, deformed opercula, scale deformities, scale loss, and spongiosis of epidermal cells. These occur when the dietary content of leucine is higher than 13.4%. Some general symptoms of protein deficiency are dorsal or caudal fin erosion, cataract, decreased carcass lipid content and renal calcinosis.

5.6.2. Dietary essential fatty acid deficiency and toxicity

When fish are given feed deficient in essential fatty acids (EFAs), they tend to display reduced growth and poor feed efficiency. This can be due to poor feed formulation or from the use of live food organisms that are deficient in EFA. Dietary excess of EFA can exert a negative effect on fish growth and feed efficiency. Cyclopropenoic is a toxic fatty acid found in the lipid fraction of cottonseed products. It can be toxic to fish. This toxic fatty acid can reduce growth rate, cause extreme liver damage, increase glycogen deposition, decrease protein content, and lower the activity of several key enzymes.

5.6.3. Hypervitaminosis and hypovitaminosis

Hypervitaminosis is a condition that occurs when fish have accumulated too much of a vitamin in their body. It is caused by fat-soluble vitamins, such as vitamins A and D, because they are stored in the body longer than the water-soluble vitamins. Under certain conditions, the amounts are so high that they become toxic. Most recorded cases of hypervitaminosis in fish have occurred under experimental conditions, so they are fortunately rare under normal tilapia culture conditions.

Plate 7. Monitoring pond turbidity.

Hypovitaminosis, on the other hand, is vitamin deficiency that can be caused by numerous factors: (a) inadequacies in nutrients, (b) malabsorption of nutrients from feed, (c) the presence of dietary anti-vitamin factors, (d) dietary antibiotic addition, (e) effects of pharmacological agents, and (f) abnormalities of vitamin metabolism or use in the metabolic pathways, feed processing and storage. Fish with a vitamin deficiency show symptoms such as scoliosis, lordosis, reduced growth, poor healing, internal/external hemorrhage, caudal fin erosion, exophthalmia, anemia and reduced egg hatchability.

5.6.4. Dietary essential mineral deficiency and toxicity

Macro minerals are required in large quantities. Although they are equally important in the diet, microminerals are only needed in minute quantities. A mineral deficiency in fish can lead to physiological functions. Symptoms include skeletal deformity, abnormal calcification of bones, cranial deformity, reduced growth, poor feed efficiency, bone demineralization, low carcass ash, calcium and phosphorus, anemia, anorexia, sluggishness and muscle flaccidity. Mineral toxicity in fish is usually associated with the use of unconventional dietary feed ingredients that could have heavy metal contaminants, including copper, cadmium, mercury, arsenic and lead.

Post-evaluation questions

1. Which of the following is not an internal factor that affects fish health?
   a) cleaning
   b) geology
   c) water exchange
   d) maintenance

2. Which of the following is not a type of disease?
   e) fungi
   f) symbiosis
   g) bacteriophage
   h) virus

3. Which of the following is not a sign of sickness in fish?
   a) voracious feeding
   b) gasping at the surface
   c) abnormal body confirmation
   d) lethargy

4. Are parasites considered a primary or secondary problem?

5. What would you recommend to a fish farmer with a pH problem reading above 9 in the morning?

6. What are the effects of diseases in fish?

7. What is the remedy for a water pH reading below 6.5?

8. Is the following statement correct or incorrect? "Some fish diseases are infectious while others are not."

9. Which of the following is not an external factor that affects fish health?
   a) geology
   b) sewage
   c) soil
   d) virus

10. Potassium permanganate can be used to control water turbidity. True or false?

Harvesting tilapia fingerling from the hapa at TIGOI Fish farm Vihiga, Kenya.

Module 6: Business plan development

Pre-evaluation questions

1. Is a business plan important? Give one reason why.

2. Which of the following is not part of a business profile?
   a) shirt color
   b) business name
   c) head office address
   d) company status

3. Would you classify fish farming as capital intensive or otherwise? Give at least one reason why.

4. Is return on investment considered a market analysis or financial analysis?

5. Which of the following is not part of a market analysis?
   a) market need
   b) demographics and segmentation
   c) competition
   d) profit margin

6.1. Purpose of a business plan

A business plan is a step-by-step blueprint of how a business owner will operate their business. It provides direction for every decision. A business plan has two main purposes. First, it is used to run a business with a clear and consistent vision. Second, it is required to gain access to funding, such as loans and grants for businesses.

A business plan is used to manage a business by stating the goals, how they will be achieved and when. The plan also summarizes what the business is about, why it exists and where it will go. It serves as a point of reference for partners, investors, employees and management to assess progress with reference to its objectives.

6.2. Business profile

A business profile is a list of basic details about a company. It highlights the strength of the company to prospective clients and customers. It is a form of a résumé that communicates a company's values, objectives, services, products and current status. A simple business profile format includes the name of the business, the address of the head office, phone number, website, company status and the contact information of the person in charge (name, phone number and email address).

6.3. Organization and products

Business organization details include the date of registration and the start of business, main areas of business activity, main product lines, services and the principal customer in industries and across geographical boundaries. Another important part is business capacity, which covers labor, finance and technical ability. These details include the business organization and number of employees, the financial circumstances of the business (optional) and the company's capacity for projects in terms of staff qualifications and certification. It also covers references to success stories in a similar project.

6.4. Description of management team

The management team is the group of individuals that organize the business strategy and ensure the business objectives are met. They operate at a high level of an organization and are responsible for day-to-day managing of other teams or individuals. A description of a management team helps third parties recognize what sets the business apart from others.

6.5. Market analysis

A market analysis is a qualitative and quantitative assessment of a market's attractiveness and its dynamics. These includes market size (volume and value), buying patterns or preferences of customers, degree of competition, economic environment (including demand and supply forces) and various customer segments. A market analysis helps gain insight and understanding of potential customers and competitors. It is useful in identifying a niche for a business or in developing a marketing strategy. The process of a market analysis involves several factors: demographics and segmentation, target market, a market need assessment, and competition.

6.5.1. Demographics and segmentation

Demographics and segmentation are the division of the market according to age, race, gender, family size, religion, ethnicity, education and income. All of these give direct information on market size. They point to the target market and market need. The first step in the process of a market analysis is measuring the market size. Market size refers to the maximum total quantity of sales or number of customers a business has or the total potential number of customer or quantity of sales in a given year. There are two approaches for measuring market size: volume and value. Volume deals with the number of customers while value is the estimated monetary worth of the proposed business. The number of customers available to buy fish in an area can be compared with the value they attach to fish in that area.

Consider this example: Two areas have potential customers in the form of small-scale tilapia farms that are willing and capable of buying tilapia fingerlings. The first area has 100 farms, which are able to pay USD 0.05 per fingerling. The second area has two farms, which are able to pay USD 0.08 per fingerling. It might be better to establish in the first area where there is a larger volume, even though it has lower value and higher competition. The market appears stable and accessible.

6.5.2. Target market

A target market is the group of potential customers a company wants to sell its products or services to. No small business can effectively target every potential customer, so it is wise for small businesses to target a niche market that enables them to compete with large established ones.

6.5.3. Market need assessment

A market need assessment deals with why customers buy the product. Some customers might buy tilapia fingerlings because they grow fast, while others might buy them because of the taste, price, health factors or resistance to disease.

6.5.4. Competition

Competition between companies selling similar products and services is a daily occurrence in business. A quick way to do a market analysis is to compare your competitors with your business using a simple table containing important drivers of demand (Table 3). This will give a reasonable view of businesses you are competing with and will enable you to determine their weaknesses, which your company can use to better position itself in the market.

Barriers to entry are obstacles or hindrances that make it difficult for a new company to enter an existing market. An analysis of barriers will answer two main questions:

1. What prevents new entrants from coming in and taking a good percentage of your customers?
2. What makes you think you will be able to break the barriers and successfully enter the market?

Company	Competitor 1 (tilapia mixed sex fingerlings)	Competitor 2 (tilapia monosex fingerlings)	Competitor 3 (tilapia monosex fingerlings)	My company (tilapia monosex fingerlings)
Revenues	USD 272	USD 408	USD 1902	USD 326 (first year target)
Employees	2	5	7	4
Size	1 farm sales	1 farm	1 farm	1 farm
Price	Low	High	Low	Average
Quality	Average	Low	Low	Superior
Delivery	Free	No	USD 2.72	Discounted

Table 3. Hypothetical analysis of competitors.

There are many barriers to entry. The following are barriers that fish seed production businesses, specifically, could face:

- Cost of investment: Investment in fish seed production is capital intensive.
- Location: The inability to secure a suitable location for fish seed production and other geographical factors will determine a successful enterprise.
- Brand loyalty: This covers consumer attachment to existing fish seed producers or their products.
- Brand cost: The marketing cost is high for a business to reach a certain level of recognition.
- Economies of scale: Existing fish seed producers benefit from a lower average cost due to the scale (size) of production. Inputs can be acquired in bulk, resulting in a lower appreciable cost of production.
- Being "the first mover": Some companies earn a strong position because they are the first to enter and dominate a market.
- Regulations: These are rules and guidelines made by governing bodies to control production activity or processes. A fish seed producer is expected to comply with these regulations, which can affect production activities. Regulations vary from one country to another.

6.6. Financial analysis

A financial analysis is the evaluation of the viability, stability and profitability to merit investment in the business or project. It is used to build a long-term plan to draw business activities. There are several methods of financial analysis. This module focuses on cost-benefits analysis (CBA), profit margin, and return on investment (ROI), as shown in Table 4.

6.6.1. Cost-benefits analysis

The CBA is a process by which organizations can analyze decisions, systems or projects, or determine a value for intangibles. The model is built by identifying the benefits of an action as well as the associated costs and then subtracting the costs from benefits. This is often used in capital budgeting to analyze the overall value of money for undertaking a new project. The CBA produces a ratio called the benefit-cost ratio (BCR), which is an indicator of the relationship between the relative costs and benefits of a proposed project. It can be expressed in either monetary or qualitative terms.

The CBA process covers a detailed or exhaustive list of all the costs and benefits associated with the project. It includes both direct and indirect costs. Direct costs cover labor involved on the farm, equipment and machinery, seed, feed and all forms of farm inputs. Indirect costs concern electricity, overhead from management, rent and utilities.

If a project has a BCR greater than 1.0, this means that benefits outweigh costs. It implies that the business is feasible and worth investing in. For example, a BCR of 1.20 means that for every dollar spent in costs there is a financial gain of an additional USD 0.20.

Net present value (NPV) is the difference in the sums of discounted benefits and discounted costs. A positive NPV means the project is feasible while a negative one means it is not worth investing in and should not be considered.

The following are two rules guiding the use of an NPV or CBR:

- If separate, unrelated projects are being assessed and the budget for funding the projects *is not limited*, use an NPV or BCR.
- If separate, unrelated projects are being assessed and the budget for funding the projects *is limited*, the projects should be ranked with a BCR, not an NPV.

For businesses that have small to mid-level capital expenditures and a short to intermediate time to completion, an in-depth CBA could be dependable for a making sensible decisions. For large businesses with a long-term time horizon, a CBA helps calculate the current value of money through discounting. The BCR is computed as a ratio of the discounted benefit stream divided by the discounted stream of costs. Inflation is accounted for by deflating prices using price indices.

6.6.2. Profit margin

Profit margin is the amount by which revenue from sales exceeds costs in a business. There are four levels of profit margins: gross profit, operating profit, pre-tax profit and net profit.

Profit Margin = Net Profit/Revenue

Quantity of broodstock stocked	Size of broodstock stocked	Mortality rate @1%	Qty remaining after mortality	Cost of feed	Other production cost (USD)
2694	200	27	2667	1481	4523
Total production cost					**6004**

Breakdown of feed grade and amount (BRANDED AND COMPOUNDED) to produce 5,000,000 fingerlings						
Feed grade	**Brand name**	**Unit price (kg)**	**Unit price (bag)**	**Bag size**	**Quantity of feed in kg required**	**Total cost of feed (USD)**
0.2 mm	Novatek	USD 1.10	USD 3.30	3	99	109
0.5 mm	Novatek	USD 1.10	USD 16.70	15	225	248
1.0 mm	Novatek	USD1.10	USD 16.70	15	375	413
4.0 mm	Novatek (Broodstock)	USD 1.10	USD 16.70	25	647	712
						1481

Revenue and profit	
Items	**Amount (USD)**
Average weight	2 g
Expected yield	350,000
Selling price/kg	USD 0.03
Revenue	USD 10,500
Profit	USD 4496
Return on investment (ROI)	74.895063
Cost benefit analysis (CBA)	1.74895063

Breakdown of other production cost	
Items	**Amount (USD)**
Labor (14 staff)	2.570
Water	453
Transport	500
Unexpected costs	1000
Total	**4.523**

Table 4. Financial analysis of tilapia *(O. andersonii)* fingerling production in Zambia.

A company takes in sales revenue, which covers the direct costs of the products or services. The gross profit margin is what is left over after the cost of the product or service is subtracted from sales revenue. Next, advertising, which is an indirect cost, is also subtracted, leaving the operating profit margin. Interest on debt and any unusual charges or inflows unrelated to the company's main business are then subtracted, which leaves the pre-tax profit margin. The net margin, also known as net income, is what is left over after taxes are paid. This is considered the company's bottom line.

The profit margin covers the following:

- It measures the degree to which a company or a business activity makes money, by dividing income by revenue.
- It is expressed as a percentage and indicates how much profit has been generated for each dollar of sales.
- The most significant and commonly used margin is net profit margin, which is a company's bottom line after all expenses, including taxes and other costs, have been subtracted from revenue.
- Profit margin is used by creditors, investors and businesses as an indicator of a company's financial health, management skill and growth potential.

6.6.3. Return on investment

This is a financial metric of profitability used extensively to measure the profit or gain an investment can realize. The ROI is a simple ratio of the gain from an investment relative to its cost. It is useful in evaluating the potential return from a stand-alone investment. It can also be used to compare returns from several investments.

The ROI can be positive or negative. A positive ROI means that net returns are good because total returns exceed total costs. A negative ROI means that the investment produces a loss because total costs exceed total returns. Calculating an accurate ROI requires including total returns and total costs. It is better to express ROI as a percentage because it is easier to understand and make deductions from.

The following are the steps involved in calculating ROI:

- Calculate all costs and all income.
- Add all the costs to generate the total cost of production.
- Add all income to generate the total income.
- To calculate net income, subtract the total cost of production from the total income.
- To calculate the ROI, divide the net income by the total cost of production and multiply it by 100.
- To prevent omissions, it is important to know which factors to consider when calculating the cost.

6.7. Sourcing capital/grants

A capital-intensive project or business-like tilapia seed production is usually difficult to start. This is a significant barrier to entry, so potential business owners must consider this challenge. If business owners do not have the funds to start or improve an existing business, the other available options are to look for a grant or get a loan.

There are many ways to secure the funds required to complete a project:

- Personal fundraising: The first investor in a business should be the business owner. This can be in the form of cash, in-kind, or collateral on assets. This signifies to potential investors that you have a long-term commitment for the project you are embarking on.
- Partnerships: This is an agreement between two or more parties to advance their mutual interest (sharing management and profits). The partners can be individuals, nongovernmental organizations, businesses and community-based organizations. Check if there are other organizations, either not-for-profit or commercial, that could partner with you in sharing the capital costs of the project. Depending on the agreement and arrangement, they could join in management (sharing or dividing responsibilities) or be passive. It is advantageous when the partners are trained and equipped in different fields, because it increases the chance of success.

- Government or public funding: This depends on the country and agricultural policies. Government grants and subsidies could be available for low-interest loans expected to boost agricultural production. Check the lists of available government grants or loans either online or at government offices in charge of such funding.

Post-evaluation questions

1. What is the difference between a loan and a grant?

2. Is competition an advantage to a fish feed business?

3. What are the advantages of branding?

4. What are barriers to entry?

5. What are the safest forms of sourcing funds?

6. What are the challenges of sourcing personal funds?

7. What is the advantage of partnership funding?

8. What is the disadvantage of partnership funding?

9. Which of the following is not considered a direct cost?
   a) seed
   b) equipment and machinery
   c) feed
   d) rent

10. Which of the following is not considered an indirect cost?
    a) seed
    b) overhead from management
    c) electricity
    d) rent

Partners from 12 countries participated in training conducted by the TAAT Aquaculture Compact at the WorldFish facility in Abbassa, Egypt, in 2019.

Conclusion

Tilapia farming is growing faster than expected in many countries, especially in the developing world. As the aquatic chicken, tilapia is likely to solve the problem of food security as a cheap source of fish protein. Therefore, more quality broodstock is required to produce the billions of high-quality fry necessary to achieve increased fish production.

Key terms

Term	Meaning
Algae	Photosynthetic organisms that possess photosynthetic pigments, such as chlorophyll. However, they lack true roots, stems and leaves that are characteristic of vascular plants.
Artificial breeding	A process in which some stimulants, hormones or pituitary extracts are injected into broodfish (which do not spawn in captivity) to cause them to spawn.
Better management practice (BMP)	Any program, procedural technique, method of operation, skill, measurement or device that maximizes the health and well-being of cultured species, minimizes environmental effects and promotes an efficient and economic aquaculture operation.
Broodstock/breeders	A group of mature individual fish used in aquaculture for breeding purposes.
Cost-benefit analysis (CBA)	A process by which organizations analyze decisions, systems or projects, or determine a value for intangibles.
Cost-benefit ratio (CBR)	An indicator that shows the relationship between the relative costs and benefits of a proposed project.
Dissolved oxygen	The amount of gaseous oxygen dissolved in the water. Oxygen enters the water through direct absorption from the atmosphere, from rapid movement or as a waste product of plant photosynthesis. Dissolved oxygen levels below 5 mg/L can cause stress to aquatic life.
Feed conversion ratio (FCR)	Amount of dry feed required to grow 1 kg of fish. For example, if 2 kg of feed are required to grow 1 kg of fish, the FCR would be 2. This means that when a feed has a low FCR, it takes less feed to produce 1 kg of fish than it would if the FCR was higher. The lower the FCR, the better the feed performance and vice versa.
Fertilization	The fusion of haploid gametes, egg and sperm to form the diploid zygote. During the spawning season, the male fish seek out the nests of fish eggs that the females have laid. When they find one, they swim over the nest and fertilize the eggs with their semen. This allows conception to take place, and immediately the eggs start to become fish.
Fingerlings	Fish eggs that hatch into larvae and grow up to the size of a finger. Usually, they are no more than 8 weeks old.
Fry	Freshly hatched fish not more than 4 weeks old.

Term	Meaning
Fungi	A group of living organisms that are classified in their own kingdom. This means they are not animals, plants or bacteria. Unlike bacteria, which have simple cells, fungi have complex cells, like animals and plants.
Genetically improved farm tilapia (GIFT)	Selective breeding to develop a faster-growing strain of Nile tilapia *(Oreochromis niloticus)* suitable for small-scale and commercial aquaculture for increased fish production.
Genital papilla	A small, fleshy tube behind the anus in some fish from which sperm or eggs are released.
Gonad	A mixed gland that produces the gametes (sex cells) and sex hormones of an organism. In female fish, the reproductive cells are the egg cells, and in the males the reproductive cells are the sperm.
Gonadal maturity	Both male and female fish gonads undergo marked cyclic morphological and histological changes before reaching full maturity and becoming ripe.
Gravid	Female fish full of eggs that are laid and fertilized externally.
Hatchery	An indoor or outdoor structure built for fish reproduction. A hatchery provides sanctuary for fish seed production and rearing before transferring them to nursery ponds or selling them.
Hatchlings/larvae	Freshly hatched fish not more than 5 days old. Fish larvae eat smaller plankton, while fish eggs carry their own food supply. Both eggs and larvae are eaten by larger animals.
Hormone	A regulatory (chemical) substance produced in an organism and transported through tissue fluids such as blood or sap to stimulate specific cells or tissues into action. Hormones can be natural (e.g., African catfish pituitary) or synthetic (e.g., Ovaprim).
Hybridization	The mating of genetically differentiated fish species either as individuals or groups and can involve crossing individuals within a species (also known as line crossing or strain crossing) or crossing individuals between separate species.
Incubation of fish eggs	The maintenance of fertilized fish eggs in a body of water or in a fish breeding apparatus until the fry hatch. The fertilized eggs are incubated in a body of water (non-plant method) or in fish breeding plants (plant method).
Incubation trough	Containers used for hatching fish eggs in a hatchery.
Juveniles	Hatched fish not more than 12 weeks old. Typically, they are between 25 and 50 mm long.
Monosex	Same sex population of fish.
Optimum temperature	The temperature at which a procedure is best carried out, such as the culture of a given organism or the action of an enzyme.
Ovulation	The release of eggs from the ovary.
Parasites	Disease-causing organisms in fisheries that are of public health importance. Examples include roundworms (nematodes), flatworms or flukes (trematodes) and tapeworms (cestodes).
Pathogens	Infectious agents that cause fish disease. They are always present in an aquaculture system, but not always at sufficient levels to cause a disease.

Term	Meaning
pH	Power or potential of hydrogen ranging from 1 (highly acidic) to 14 (highly alkaline).
Physio-chemical parameters	Parameters that measure water quality, such as temperature, pH, dissolved oxygen, conductivity, salinity, Secchi disk depth, nitrate, nitrite, sulfate, chloride, total hardness, calcium and magnesium.
Pituitary gland	The major endocrine gland. It is a pea-sized body attached to the base of the brain that is important in controlling the growth, development and functioning of the other endocrine glands.
Productivity	Total fish biomass in a production system.
Profit margin	Amount by which sales revenue exceeds costs in a business.
Prophylactic treatment	A medication or treatment designed and used to prevent a disease from occurring.
Return on investment (ROI)	A performance measure used to evaluate the efficiency of an investment or compare the efficiency of a number of different investments. To calculate ROI, divide the benefit (or return) of an investment by the cost of the investment.
Saline solution	A mixture of salt and water. A normal saline solution contains 0.9% sodium chloride (salt), which is similar to the sodium concentration in blood and tears. Saline solution is usually called normal saline.
Sex reversal	A process in tilapia that involves treating/administering recently hatched fry with a male steroid so that the undifferentiated gonadal tissue of generic females develops testicular tissue, thus functioning reproductively as males.
Sexual dimorphism	A condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs.
Siphoning	To draw off or convey water by means of a tube in a hatchery operation. This can be done manually (mouth siphoning) or mechanically (pressure tube operation).
Spawning	The deposition of eggs and sperm so that they can unite.
Stock	Subpopulations of a particular species of fish.
Stocking density	The number of fish kept in a given unit of area. In a monoculture pond, the stocking rate is the same as the stocking density because there is only one kind of fish.
Stunted growth	Reduced growth rate. Fish of this sort constitute 18%–22% of a freshly hatched fish population and should be sorted and disposed.
Water quality management	The systematic collection of physical, chemical and biological information, and the analysis, interpretation and reporting of those measurements in comparison with the expected maximum fish yield in aquaculture.
Wild/natural water bodies	Naturally occurring waterbodies, such as rivers, streams, lakes and lagoons.
Yolk sac	A membranous sac containing a yolk attached to the embryos of reptiles and birds and the larvae of some fish.
Zooplankton	Microscopic animal organisms drifting in oceans, seas and bodies of freshwater.

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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 decision-making on the critical issues of our times.

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