AQUACULTURE EXTENSION MANUAL NO. 66

JULY 2020

TILAPIA CULTURE
THE BASICS

Maria Rowena R. Romana-Eguia
Ruel V. Eguia
Rolando V. Pakingking, Jr.

Aquaculture Department
Southeast Asian Fisheries Development Center
Iloilo, Philippines

Aquaculture Extension Manual No. 66

TILAPIA CULTURE: THE BASICS

Maria Rowena R. Romana-Eguia
Ruel V. Eguia
Rolando V. Pakingking, Jr.

Southeast Asian Fisheries Development Center
Aquaculture Department
Tigbauan, Iloilo 5021, Philippines
www.seafdec.org.ph

TILAPIA CULTURE: THE BASICS

July 2020

ISSN 0115-5369

Published and printed by:
Southeast Asian Fisheries Development Center
Aquaculture Department
Tigbauan, Iloilo, Philippines

Illustrations by Kevin Angelo R. Eguia

For comments and inquiries:
Training and Information Division
SEAFDEC Aquaculture Department
Tigbauan, Iloilo 5021, Philippines

(63-33) 330 7030
(63-33) 330 7031
devcom@seafdec.org.ph, aqdchief@seafdec.org.ph
www.seafdec.org.ph

SEAFDEC Aquaculture Department Library Cataloging-in-Publication Data

Romana-Eguia, Maria Rowena R.

Tilapia culture : the basics / Maria Rowena R. Romana-Eguia, Ruel V. Eguia, Rolando V. Pakingking, Jr. -- Tigbauan, Iloilo, Philippines : Aquaculture Dept., Southeast Asian Fisheries Development Center, 2020, ©2020.

[vii], 54 pages : illustrations (chiefly color). -- (Aquaculture extension manual, 0115-5369 ; no. 66).

Includes bibliographical references.

1. Tilapia -- Breeding -- Handbooks, manuals, etc. 2. Tilapia -- Feeding and feeds -- Handbooks, manuals, etc. 3. Tilapia -- Breeding -- Economic aspects -- Handbooks, manuals etc. 4. Tilapia -- Diseases -- Handbooks manuals, etc. 5. Fish culture -- Handbooks, manuals, etc. I. Eguia, Ruel V. II. Pakingking, Rolando, Jr. V. III. SEAFDEC. Aquaculture Department.

SH 167.T54 R66 2020 DLS2020-01

Foreword

The fast-growing and prolific tilapia is among the most important aquaculture commodities in the world. It grows fast, easily breeds in captivity, and is tolerant of various environments and culture systems. Propagating and farming this fish requires little input and the technology can be simple and easily adaptable by small-scale fish farmers. Investors also find tilapia farming to be profitable because of its fairly low investment cost and good feeding efficiency in lakes and ponds where natural food are available.

In the Philippines, tilapia is second only to milkfish in terms of fish production volume from aquaculture. Based on data from the Bureau of Fisheries and Aquatic Resources (BFAR), the country produced a total of 277,006 metric tons of tilapia in 2018. In that year, this comprised 33.5% of the volume of all non-seaweed production in Philippine aquaculture.

Realizing the potential of tilapia culture in achieving food security, SEAFDEC/AQD has been doing research on tilapia since the 1980s. The research center has published several papers on tilapia including the development of feed for Nile tilapia breeders and fry. It has also worked on a farm-based genetic selection scheme to give tilapia farmers a scientific guide in selecting and managing breeders.

SEAFDEC/AQD has also been disseminating science-based tilapia hatchery and grow-out technologies to its stakeholders through regular training courses on tilapia culture, extension work, and publication of manuals on tilapia culture.

To date, SEAFDEC/AQD has published three manuals in Filipino on tilapia hatchery (1996, with revised editions in 2001 and 2007), grow-out (1996, with revised editions in 2001 and 2007), and modular cage culture (2011). Three manuals in English on tilapia broodstock and hatchery management (2007), grow-out (2004), and net cage culture in dams and small farm reservoir (2000) were also published. SEAFDEC/AQD experts also contributed to the 2018 Philippines Recommends for Tilapia, a valuable resource published by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD).

This new aquaculture extension manual revisits the basics of tilapia culture with updated information on the grow-out technology in cages and ponds. Updated cost and return analyses were also included to guide farmers regarding the profitability of farming tilapia. A fresh chapter on tilapia health management is also included to promote the prevention of tilapia diseases.

We hope that this user-friendly manual can be a useful guide to fish farmers and to other stakeholders such as the academe and extension workers.

DAN D. BALIAO
SEAFDEC/AQD Chief

TABLE OF CONTENTS

Foreword *v*

Introduction 1

- Major Tilapia Production Areas in the Philippines 1
- Tilapia Species and Commercial Strains 2

Basic Tilapia Farming Concepts 7

- Environmental and Nutritional Requirements 7
- Farming in Net Cages 9
  - Choosing the right cage farming site 9
  - Cage module types 10
    - Fabricating net cages 12
    - Constructing the module 15
  - Seedstock procurement, transport and stocking 17
  - Feeding and feed management 20
  - Maintaining the net cages 21
  - Harvesting 22
  - Cost and return analysis 24
- Tilapia Pond Farming 26
  - Choosing the pond farming site 27
    - Farming intensity 28
    - Constructing and preparing the ponds 29
  - Stocking tilapia fingerlings 33
  - Water quality management 34
  - Maintaining the ponds 34
  - Harvesting 35
  - Cost and return analysis 37
- Other Methods 39
  - Monosex male tilapia culture 39
  - Rice-fish (tilapia) culture 41
  - Saltwater culture of tilapias 41
  - Aquaponics 41

Tilapia Health Management 42

- Infectious Diseases 42
- Noninfectious Diseases 44
- Disease Prevention and Control 44

Tilapia Processing 46

- Product Forms 46

Marketing 46

Suggested Readings 48

Acknowledgments 53

About the Authors 53

Introduction

Tilapias are originally from Africa, particularly Sub-Saharan Africa and the Middle East. The first species of tilapia brought into the Philippines in 1950 was the Mozambique tilapia (*Oreochromis mossambicus*) and this was introduced by way of a few pieces brought in by the Bureau of Fisheries Aquatic Resources from Java, Indonesia. Hence the common name Java tilapia was also meant to refer to the Mozambique tilapia. The Java tilapia is quite prolific as it can breed even at a small size provided that it has reached the mature age of 3 to 4 months. Farming the tilapia was shown to be relatively easy since it is a hardy fish that could grow in diverse types of environments. Although tilapia farming, particularly that of the Mozambique tilapia, have elicited some interest among fish culturists, early efforts to promote Mozambique tilapia culture in the Philippines was not as successful because this particular tilapia species does not grow to the preferred local market size. It was only in the early 1970's when another tilapia species (Nile tilapia or *Oreochromis niloticus*), was introduced, that tilapia farming in ponds and cages became popular among fish farmers.

Tilapia culture then flourished through the 1980's with the introduction of a hybrid species called the red tilapia (*Oreochromis* spp.). This species was known for its red-orange to pale red (pink) color which was more appealing to the local Filipino-Chinese market. Compared to the Nile tilapia, the red tilapias are more saline-tolerant and can therefore be farmed in rearing enclosures with varying water salinities, from brackish water to full strength seawater.

At present, most of the commercially valuable tilapias are grown in brackishwater ponds or in freshwater tanks, ponds and cages in many countries outside of its origin. Some of them now thrive in natural waters such as lakes and rivers where they were either unintentionally and/or purposely stocked. Tilapias once harvested, are marketed in many forms -- live, fresh, frozen, dried or processed. Since the tilapias are readily available, flavorful, not as bony as other fish species (e.g. milkfish), and inexpensive, it can be traded easily both locally and internationally.

Major Tilapia Production Areas in the Philippines

From the 2018 statistics, tilapias comprised 12% of the total aquaculture production in the Philippines at 277,006 metric tons (see BFAR On line information System, https://www.bfar.da.gov.ph/profile?id=19#post). It was noted as the third major species in terms of local aquaculture production next to seaweeds (1,478,301 MT) and milkfish (303,402 MT). Despite threats brought about by the incidence of diseases such as the tilapia lake virus, and the presence of common pathogens (bacteria etc.) that infect farmed tilapias, tilapia production targets have been steadily achieved with Regions III (133,358 MT), IV-A (81,491 MT) and I (16,830 MT) being the top producers. Of the total 277,006 MT, most of the cultured tilapias were harvested from freshwater ponds (155,433 MT) and cages (85,440 MT). Except for the Cordillera Autonomous Region (CAR), tilapias are farmed in every region of the country with some (albeit very low) production even coming from marine cages (0.44 MT) and pens (0.10 MT).

Tilapia Species and Commercial Strains

As mentioned, several species of tilapia are now in the Philippines and have been propagated and reared for commercial production. Below is a brief description of each:

Nile tilapia (*Oreochromis niloticus*)

The Nile tilapia is the most popular, globally farmed tilapia species. It has vertical black bands on the body and caudal or tail fin. The dorsal fin (or the fin on the top part of the fish) has a black outline and the caudal fin has a red margin. Nile tilapia is most preferred because it grows fast, is hardy, and well adapted for farming in warm tropical countries like the Philippines. Nile tilapia comprises about 70-80% of the world's tilapia production. In the late 1990s, there were several genetically improved strains or stocks of Nile tilapia that were developed in the Philippines, for example, the Genetically Improved Farmed Tilapia (GIFT) strain, Genetically Male Tilapia (GMT), Genomar Supreme Tilapia (GST) among others.

Fig. 1. The Nile tilapia *Oreochromis niloticus*

Genetic strains of Nile tilapia

In the late 1980s, several Nile tilapia genetic improvement programs were conducted in the Philippines, some of them with fund support from international sources. Three of these strains (GIFT, GST and GMT) were even distributed globally except in Africa where natural sources of Nile tilapia exist. This is to avoid the "genetic contamination" of Nile tilapia populations in the natural breeding grounds in Africa. Unfortunately, there are already recent reports of aquaculture-mediated transfers of the genetically improved stocks (developed in the Philippines) to Ghana, one of the natural sources of the Nile tilapia, despite the fact that they have developed their own improved strain (e.g. Akosombo tilapia strain). To date, the following (see Table 1) are the currently available genetically improved Nile tilapia strains in the Philippines:

Table 1. Genetically improved Nile tilapia strains that are available in the Philippines as of 2019

Name of Tilapia Strain	Source Agency
Freshwater Aquaculture Center Strain Tilapia (or FaST, 39th generation)	Freshwater Aquaculture Center, Central Luzon State University (FAC-CLSU), Muñoz, Nueva Ecija
Genetically Improved Farmed Tilapia-Malaysia strain (GIFT- Malaysia)	Bureau of Fisheries and Aquatic Resources (BFAR in selected regions)
Genetically Male Tilapia or YY Supermale Tilapia (GMT)	FAC-CLSU
Improved Excel strain tilapia (i-Excel)	BFAR-National Freshwater Fisheries Technology Center (BFAR-NFFTC), Muñoz, Nueva Ecija
Improved Brackishwater Enhanced Strain Tilapia (i-BEST)	BFAR-NFFTC, Muñoz, Nueva Ecija
Cold tolerant tilapia strain	BFAR-NFFTC, Muñoz, Nueva Ecija
Molobicus	BFAR National Inland Fisheries Technology Development Center (BFAR-NIFTDC), Dagupan, Pangasinan
Genomar Supreme Tilapia (GST)	Genomar Philippines (www.genomar.no)

Genetic improvement in most of the strains were focused on growth enhancement while strains such as i-BEST and Molobicus were developed for saline tolerance. The cold tolerant strain on the other hand, was developed for culture in areas in the Philippines where the ambient temperature (especially the rearing water temperature) is below the ideal or optimal rearing conditions that favor fast growth (27-31°C). Meanwhile, the GMT Tilapia was developed for monosex tilapia farming.

It is to be expected that fingerlings of these improved strains are sold at premium prices in view of the added value of better traits. The potential of higher yields within a shorter period of rearing may thus be achieved, provided efficient husbandry techniques are applied. On the other hand, farmers can very well improve their own stocks through simple, conventional, on-farm selective breeding (e.g. mass selection) methods if the genetically improved stocks could not be procured. Farmers may also improve tilapia growth through environmental interventions such as administration of better feeds and/or maintaining good water quality in their culture facilities.

Mozambique or 'Java' tilapia (*Oreochromis mossambicus*)

The Mozambique or 'Java' tilapia is generally black in color. The underside of the head is white, and dorsal and caudal fins have red margins. The *O. mossambicus* can thrive in freshwater, brackishwater and/or seawater and it is the most common tilapia found in coastal waters upstream of the surf zone. This tilapia breeds in short and successive cycles. It is a commercial food fish, and the small-sized Mozambique tilapias are also used as forage fish for carnivorous marine fishes like groupers, snappers, and sea bass. This fish accounts for about 10% of world tilapia production.

Oreochromis mossambicus is commonly mated with other tilapia species to produce all-male fingerlings. When stocked in a common enclosure, monosex tilapias such as all-male tilapias are observed to grow faster than when rearing female and male tilapias communally. When the grow-out enclosures contain only male fish, early breeding and stunting are prevented and yields are higher.


Source: iucnredlist.org

Fig. 2. The Mozambique or 'Java' tilapia *Oreochromis mossambicus*

Red tilapias (*Oreochromis spp.* hybrids)

The red tilapias are hybrids produced from crosses between *Oreochromis mossambicus* and *O. niloticus* (Taiwanese red tilapia) or *O. mossambicus-hornorum* and *O. niloticus* (Philippine red tilapia). Red tilapias have no stripes on the caudal fin. Red tilapia fingerlings are produced and sold to fishfarmers by BFAR, SEAFDEC/AQD and a few private hatcheries.

Red tilapias grow as fast as the Nile tilapia and can grow even better in brackish water ponds and sea cages. They have become a popular choice for farming especially in some Latin American countries. In most parts of Southeast Asia, red tilapia enjoys a good market in fresh, chilled, or live form. Red tilapia is marketed as a premium fish in supermarkets and upscale Chinese restaurants (for freshly cooked seafood-based meals), where the red tilapias are given other fancy names as 'King fish' or 'Pearl fish'. Red tilapias have good prospects in the export market. In Japan and the USA, the red tilapia is sold as fillets or in some other processed forms.

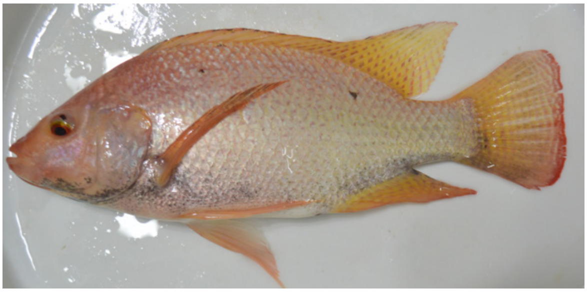

Fig. 3. A red tilapia *Oreochromis* sp.

Apart from the commercially reared tilapias, some tilapia species have been used in experimental aquaculture. The following is an example:

Blue tilapia (*Oreochromis aureus*)

The blue tilapia looks similar to the Nile tilapia with black blotches on the body and the caudal fin. An obvious distinguishing characteristic of the blue tilapia is its yellow underside and yellow margins on the caudal and pectoral fins.

The blue tilapia grows fast and thrives in colder waters, such as those found in mountain lakes and reservoirs. At present, the blue tilapia is maintained for experiments undertaken at research and academic institutions such as the Freshwater Aquaculture Center of the Central

Luzon State University, Bureau of Fisheries and Aquatic Resources, and some private companies. One such study is on the improvement of cold tolerance in the Nile tilapia through hybridization with the blue tilapia.

Meanwhile, in the past three or so years, we have seen another tilapia species being sold in local markets. This tilapia species has been assumed to have been unintentionally 'introduced' into marine waters as they were brought in through ballast waters of ships that traverse Philippine seas. This species can withstand saltier environments. Although commercially valuable in the countries where it is endemic, its commercial culture in the Philippines is not being promoted. This is because based on reports, when the black chinned tilapias are found in abundance, they could potentially disturb the ecological balance and biodiversity in natural waters. However, since it is already being caught from the wild fishery (and sometimes as invasive stocks in aquaculture ponds), this tilapia has somehow found a niche in the local market. The black chinned tilapia or *Sarotherodon melanotheron* is sold at very low prices (about PHP 20.00/kg; see Figure 4) since it is smaller than the Nile tilapia and the taste, compared to the Nile tilapia, is less appealing to consumers. Below is a description of the black chinned tilapia which has been named by local market sellers as 'Tilapyang arroyo', 'Gloria' or 'molmol.'

Black chinned or Blackchin tilapia (*Sarotherodon melanotheron*)

The main difference between this and the other tilapia species mentioned earlier is that the black-chin tilapia is a paternal mouthbrooder. Tilapias classified under the genus *Oreochromis* (e.g. Nile tilapia, Mozambique tilapia, red tilapia etc.) are known as maternal mouthbrooders, meaning the female parent incubates the fertilized tilapia eggs in their mouth for these to hatch into swim-up fry. The *S. melanotheron* found in the Philippines have black blotches on the lower part of the head and this character has become the basis for farmers to call this species as "tilapyang Gloria" or in some areas, the fish is called "molmol". In a study confirming the identity of these tilapia species found in Manila Bay and in an aquaculture pond in Bulacan, some were noted to have melanic areas or black blotches around the lower part of the mouth. Those collected from Manila Bay had a distinct golden hue on the operculum (gill cover). The top part (dorsal part) of the fish has a dark metallic gray color which becomes lighter towards the bottom part (ventral part) of the fish. Metallic yellow to orange streaks can also be found on the body of the fish. This fish is highly carnivorous and when found in aquaculture ponds where milkfish, tilapia or shrimp are farmed, they tend to feed on smaller fish larvae, eggs and insects.

Fig. 4. "Tilapyang Gloria" or "arroyo"or "molmol", sold in a local public market

Basic Tilapia Farming Concepts

Environmental and Nutritional Requirements

To best understand the conditions necessary in optimizing growth in farmed tilapias, one needs some basic knowledge of its environmental and feed requirements as well as its feeding behavior. Since most of the traded species belong to the genus or scientific group *Oreochromis* or the maternal mouthbrooders, for purposes of discussion, this section shall focus on the Nile tilapia as a reference species since the culture requirements for nearly all the maternal mouthbrooding tilapias farmed in the Philippines are similar.

The Nile tilapia is generally euryhaline which means that it can thrive in a wide range of salinity from fresh to sea water; only, it grows best in freshwater under optimal temperatures of 27-31°C. The other species (Mozambique, red hybrid etc.) are more tolerant to saline waters. When the temperature is low, tilapias like most tropical species, do not feed as much and not as frequent. The water quality parameters that are necessary and can be tolerated by tilapias for them to thrive and grow are summarized in Table 2.

Table 2. Water quality requirements for tilapia farming (from Mjoun et al, 2010)

Parameter	Range	Optimum for growth	Reference
Salinity (ppt or parts per thousand)	0-36 ppt (depending on species)	Up to 19 ppt	El-Sayed (2006)
Dissolved oxygen (mg/L)	Down to 0.1	>3	Magid and Babiker (1975); Ross (2000)
Temperature (°C)	8-42	22-29	Sarig (1969); Morgan (1972); Mires (1995)
pH	3.7-11	7-9	Ross (2000)
Ammonia (mg/L)	Up to 7.1	<0.05	El-Shafey (1998); Redner and Stickney (1979)

Tilapias are known to be herbivorous or consume feed materials of plant origin. This is especially true at the early stages where they feed on phytoplankton or plant plankton. However the tilapias also actually feed on periphyton, zooplanktons (animal plankton), other larval fish and detritus. Hence if these are to be reared in lake-based cages, one has to know if the lake is eutrophic or have natural food (phytoplankton, zooplankton) in abundance and if so, perhaps full feeding using artificial diets may not be necessary. The same is true for fertilized ponds.

As tilapias grow, they can also be trained to eat artificial diets such as the commercially available tilapia feeds that contain plant and animal protein among other ingredients that are sources of nutrients such as lipids, carbohydrates, vitamins and minerals. Several commercial diets, even phase diets or feeds for different tilapia growth stages (e.g. feeds for tilapia fry, fingerlings and juveniles) are available locally. The farmers need to be guided by the crude protein (CP, usually ranging from 28-56%) requirements of tilapia at every growing phase. Fish feed companies usually provide a feeding guide and sometimes, offer technical support as they sell their artificial diets to fish farmer clients. Both the feed ration (based on fish biomass) and the CP requirement is adjusted (usually reduced) with the age and size of the tilapias as the culture period progresses. More details on feeds and feeding management are discussed in another section in this manual.

Farming in Net Cages

Tilapias can be grown in net cages in natural water bodies where the fish have long been introduced. Stocking them in local water resources, where tilapias are not found or do not thrive, is discouraged to prevent displacement of endemic aquatic species. The cages are net enclosures much like oversized net boxes suspended from posts or stakes. Cage sizes range from 1 m^3 (1 m x 1 m x 1 m) to 2,700 m^3 (30 m x 30 m x 3 m) depending on the site, production target, financial, and technical capability of the farmer. Cages for tilapia farming can be suspended from floating or fixed-frame modules set up in lakes, dam reservoirs, and sometimes in sea water.

In 2018, about 31% of the total tilapia production in the Philippines came from cages. Tilapia in net cages set in eutrophic lakes like Laguna de Bay can subsist on natural food and reach marketable size relatively quickly, depending on the lake's primary productivity. However, tilapia stocked in cages in oligotrophic lakes like Taal in Batangas, and in water reservoirs like Pantabangan, Magat, and Ambuklao, must be fed commercial diets to enable them to reach marketable size quickly. Net cages in these lakes and dams are stocked with as much as 50-100 fingerlings/m^3.

Choosing the right cage farming site

Physical, biological, and social factors should be considered in choosing a farm site that is suitable for tilapia cage farming. These are --

Peace and order. The farm should be located in a community that is relatively peaceful. The presence of the farm itself in the community must be acceptable to the residents so that security and poaching do not become problems.

Proximity to markets and roads. Since a fish farm would need supplies such as fuel, fish nets, rope, floats, feeds, etc., the chosen site must be near an urban center and a major market where farm supplies can be procured and the farm produce can be profitably sold. Convenient road and telecommunication access would be advantageous.

Shelter from winds and waves. Ideal farm sites are coves and inlets as these are somehow protected from strong winds and waves. In such places, the terrain of the surrounding shore areas weakens or deflects strong winds and waves.

Availability of fingerlings. The site should be near reputable hatcheries that could provide quality tilapia fingerlings for stocking anytime.

Natural food. Tilapia feed on phytoplankton and zooplankton, therefore the water where the tilapia cage farming site is to be set up must be sufficiently rich in these organisms. Water abundant in plankton is brownish, bluish green, or grass green in color. Natural water bodies where frequent algal blooms are reported must be avoided as the rearing water in these areas can become oxygen-depleted, and cause fish kills.

Water quality and circulation. Apart from the water quality parameters indicated in Table 2, the farm site must be free of harmful pollutants, for example, fertilizer and pesticide runoff from rice fields, heavy metals from industries, or sludge and decomposing organic matter from livestock farms. The area where the net cages are to be installed must have good water circulation so that the fish can have adequate dissolved oxygen which it needs to grow and survive well.

Type of soil/substrate. The kind of bottom soil in the farm site determines whether the fish cage modules can be the floating type or fixed type. Farm sites in shallow water with sandy to clay loam bottom are better off with fixed type cage modules. This is because the soil will allow easy and firm penetration of bamboo poles and support for the cages. Meanwhile, deep (>5m) lakes or water reservoirs with rocky or loose bottom substrates call for modules of the floating type.

Cage module types

Cage modules are the fabricated floating and/or staked structures where the tilapia net cages are hung. The two types are described as follows:

Fixed cage module. A fixed module is usually made of bamboo poles or palm tree trunks staked 1-2 m deep into the bottom of shallow lakes, reservoirs, lagoons, or bays. The net cages are secured onto the bamboo poles, and are properly arranged to allow good water circulation.

Fig. 5. A fixed cage module

Floating cage module. If the selected culture site is in relatively deep lakes, reservoirs, lagoons or bays, a module that stays afloat on the water would be most ideal. A floating cage module consists of (a) net cages that will contain the tilapia stocks and exclude predators, (b) flotation system, (c) mooring system, and (d) module frame with working platform. Net cages are tied securely to the frame but move freely with the water level.

Fig. 6. Examples of floating cage modules

Floats could be bamboo poles, empty drums, and/or hard styrofoam blocks. The anchors may be concrete blocks or specially designed weights/structures submerged at the bottom substrate. The frame holds the components together and may double as floats and as working platform.

In large-scale tilapia farming, fish cage modules can be arranged in rows either diagonally or parallel to each other. This way, order is maintained, water flow is not impeded too much, and operations can be done with ease — boat movements, harvesting fish, inspecting and repairing the net cages, etc.

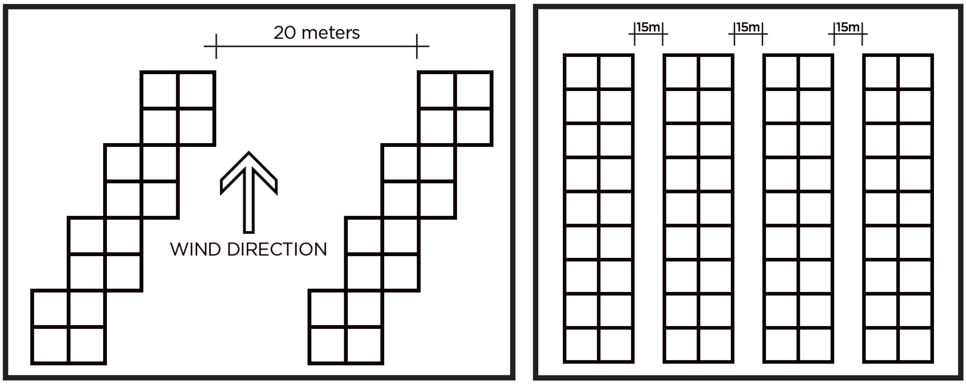

Fig. 7. Arrangement of fish cage modules in rows that are diagonal (top) and parallel (above) to each other

Fabricating net cages

Most tilapia net cages are rectangular. Apart from the fact that it is more economical to fabricate a rectangular net cage, it is easier for a small boat to lift and manage a rectangular net cage especially during harvest.

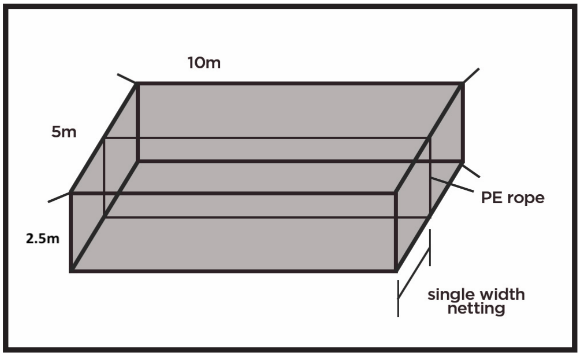

Fig. 8. A small net cage measuring 5 m x 10 m x 2.5 m

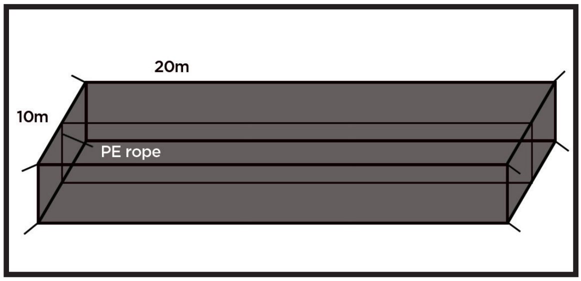

Fig. 9. A big net cage measuring 10 m x 20 m x 2.5 m

The size of the cage one can use depends on the financial and technical capability of the farmer as well as the required production targets. For easy management, the cage size recommended for tilapia grow-out operations may range from 50 m^2 (5 m x 10 m) to 200 m^2 (10 m x 20 m). The depth of the net cage depends on the depth of the water layer where the fish can still obtain sufficient natural food. Since planktons thrive near the water surface, it is recommended that the depth of net cages do not exceed 5 meters. This is unless the cage is installed in a deep lake and artificial feeding is part of the rearing scheme similar to what is done in Taal Lake in Batangas.

A small cage measuring 5 m x 10 m x 2.5 m is easy to manage. One or two persons can readily lift the cage during harvest or routine inspection. Another advantage is that when a small cage gets damaged, fish loss is minimal. However, one can go for a cage as big as 10 m x 20 m x 2.5 m and save on materials and cost for the netting material and frame, compared to when one fabricates several units of small cages.

A fish cage is made from netting material sewn together to form an oversized net "box" suspended from the module frame. The cage can have a removable net cover to prevent the stocks from escaping in the event that the netcage is exposed to strong winds/waves during a typhoon. The netting material to be used depends on the intended use of the cage. For spawning net enclosures, fine-meshed netting hapa is used. For grow-out cages, the netting material is selected according to the size of the fingerlings to be stocked in the cages.

Netting materials are classified by the number of knots it has or by its mesh size. Four types of netting materials are used for tilapia grow-out cages.

Table 3. Netting materials used for tilapia grow-out cages

Type of netting	Knots in 6 inches	Mesh size (inches)
SG net (size 12)	12	1.09
GG net (size 14)	14	0.92
CC net (zize 17)	17	0.75
B net		

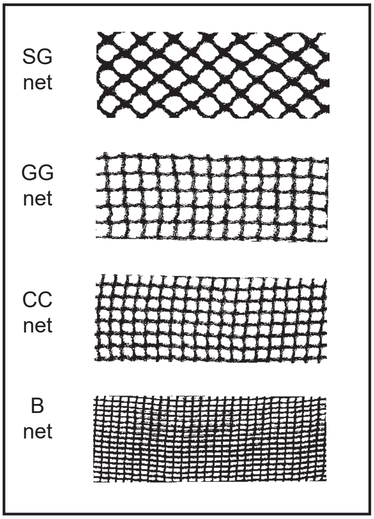

Fig. 10. Types of net used in tilapia grow-out cages

One roll of a size 17 netting material is 2.5 meters wide and about 90 meters long. For one unit of net cage measuring 5 m x 10 m x 2.5 m, 70 meters of CC net (or about one roll) is needed; that is, 30 m for the side components, 20 m for the cage bottom, and 20 m for the cage cover.

Materials for a 5 m x 10 m x 2.5 m net cage:

- 1 roll netting, CC size 17
- 1 roll polyethylene rope, #8 or 4 mm
- 3-5 rolls nylon twine, #210/18

Materials for a 10 m x 20 m x 2.5 m net cage:

- 2 1⁄2 rolls netting, CC size 17
- 2 1⁄2 rolls polyethylene rope, #8 or 4 mm
- 8 - 10 rolls nylon twine, #210/18

Fig. 11. Materials for a net cage

Sewing the net cage

1. Measure the desired length of netting material. An allowance or additional 2 cm length of the netting material should be extended at both ends. Cut the material with a pair of scissors.
2. Sew the edges of the netting material using a sewing machine.
3. Thread a polyethylene (PE) rope through the mesh at the edges of the netting material.
4. Sew together the side, bottom, and cover nets, piece by piece, until a net 'box' or cage is formed. Sew the edges of the net cage by using clover stitches with overhand knot (see Figure 12).

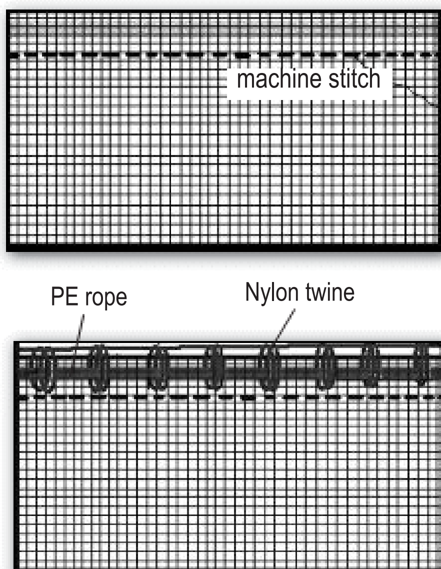

Fig. 12. Edges of the netting sewn using a sewing machine (top) and edges of a net cage sewn using clover stitches with overhand knot (above).

Constructing the module

Fig. 13. Sewing of the net cage

Bamboo poles are the most commonly used materials for fixed cage modules, at least in the Philippines, where bamboos are abundant. Bamboo poles are easy to procure and can be staked onto the substrate bottom manually. However, these have become more expensive, can last for only 3-4 years, and do not make for a very sturdy and stable working platform.

A bamboo fixed module is usually 30 meters long and 12 meters wide, and holds five net cages, each 5 m x 10 m (see diagrams on the next page). The vertical posts are staked 3 meters apart and 1-2 meters deep into the sediment. The horizontal frame is kept two meters above the water. Each net cage is secured to six posts.

Materials needed:

- 40 bamboo poles (for vertical posts)
- 10 bamboo poles (for horizontal frames)
- rope for securing bamboo poles in place

Fig. 14. Anahaw trunks used as vertical posts in a fixed cage module

On the other hand, anahaw trunks can also be used in making a fixed module. Anahaw trunks (from the palm tree *Livistonia rotundifolia*) are cheaper, sturdier (especially during typhoons), lasts longer (10 years), and provide a more stable working platform than bamboo poles. However, the source of anahaw trunks are limited apart from the fact that the anahaw requires special equipment for staking into the bottom.

An anahaw fixed module is 30 meters long and 12 meters wide, and holds five net cages, each 5 m x 10 m (see diagrams on the next page). The anahaw vertical posts are staked 5 meters apart and 1-2 meters deep into the sediment. The bamboo horizontal frame is kept 2 meters above the water. Each net cage is secured to six posts.

Materials needed:

- 18 anahaw trunks (for vertical posts)
- 10 bamboo poles (for horizontal frames)
- rope for securing bamboo poles and anahaw trunks in place

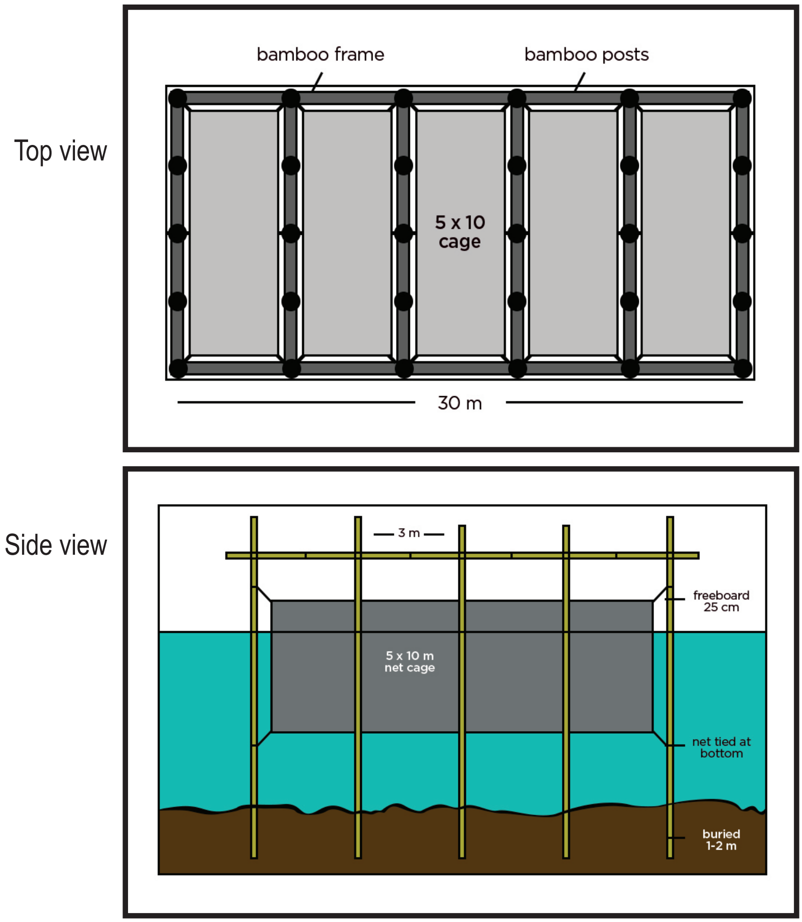

Fig. 15. Construction of a bamboo fixed module

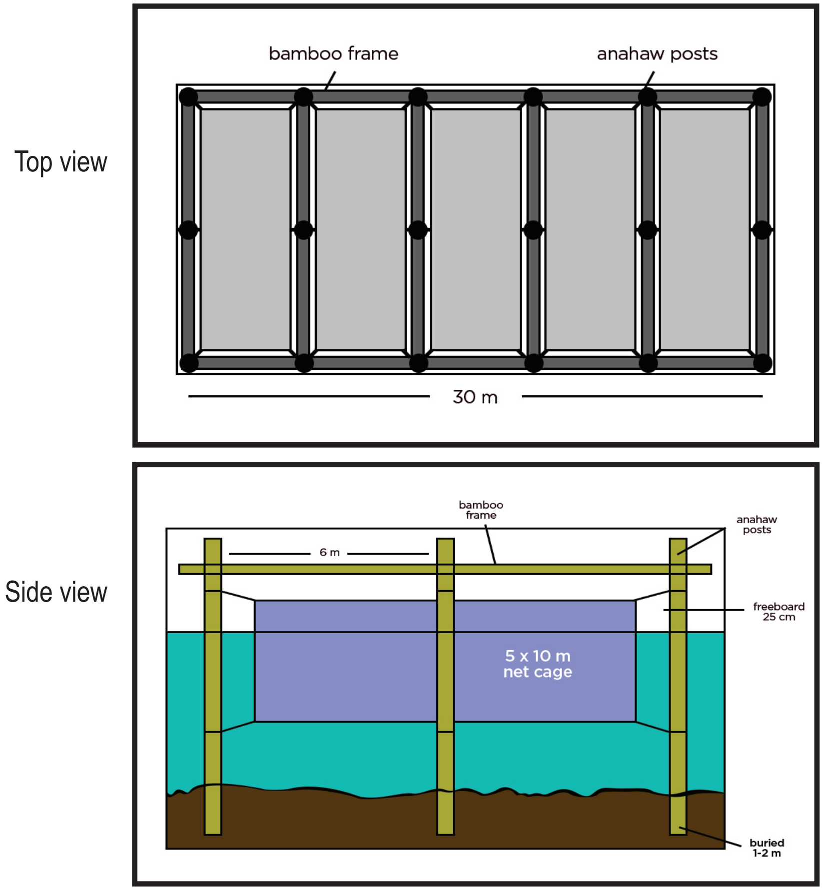

Fig. 16. Construction of a fixed module using anahaw for vertical posts

Seedstock procurement, transport and stocking

The success of any tilapia farming operation depends mainly on the quality of seedstock used. The main concern of farmers is to be able to buy quality seedstock that can grow to marketable sizes within the shortest possible time. Farmers can procure seedstock from reliable reputable hatcheries, or from their own hatchery if they operate one for themselves to be assured of good quality seed. Another option is to use all-male stocks or genetically improved stocks from licensed farms, agencies, or research institutions.

Tilapia fingerlings (sizes ranging from 37 mm or size 17, to 46 mm or size 14) are normally stocked in grow-out enclosures. Hatchery operators thus have to nurse 'fry' to marketable-sized fingerlings.

Operating a tilapia hatchery requires technical expertise. Knowledge in proper broodstock management is necessary. Genetically inferior or poorly managed breeders may produce poor quality fingerlings that grow slowly, have deformities, are susceptible to diseases, or mature too early.

Fig. 17. Fingerlings of Nile tilapia (top) and red tilapia (above)

On the other hand, good quality fingerlings have the following traits:

- Fast growth (in terms of length and weight)
- Robust body
- Normal color
- No deformities
- Efficient feed conversion

Information regarding other criteria such as sexual maturity, resistance to diseases, and social behavior may be obtained from the hatchery operator. It is also important to obtain pertinent information on the seed stock number, age, strain, ancestry or parental cross from which they were derived, and survival rate from hatching to nursery stage.

Tilapia fingerlings must be conditioned by not feeding them for at least 24 hours prior to transport. Immediately after harvest from the hatchery, fingerlings should be stocked in a conditioning tank or cage with flowing aerated water to allow them to rest and defecate. Feces should be removed before transport. It is better to transport fingerlings in the early morning or after sunset.

When packing tilapia fingerlings, enough oxygen must be available to fish at all times in preparation for the whole duration of transport. Water temperature must be lowered to about 20°C to reduce the oxygen consumption of fish. Ice packed in plastic bags may be placed in the transport containers — this is especially important for long-distance land or air transport. Loading density (number of fingerlings per transport container) must be adjusted according to fish size, water temperature or time of day, duration of transport, distance, and road condition.

- **Oxygenated plastic bags** are commonly used for long-distance transport of fingerlings. Double plastic bags (each 75 cm x 40 cm) with water and oxygen in 1:1 to 1:3 volume ratio (depending on the travel distance) can hold about 500 pieces of size-17 fingerlings. To protect against puncture, the plastic bags are placed in thicker bags for short-distances, or packed with bagged ice in styrofoam boxes or corrugated cardboard boxes for long-distance transport. For air freight, both styrofoam boxes and cardboard boxes are required.

Fig. 18. Packing tilapia fingerlings in plastic bags for transport

- **Transport boxes** made of plywood are fitted inside a truck or van. The loading density can be as much as 20,000 of size 17 fingerlings per ton of water in the box. Battery-operated aerators and medical oxygen should be provided.

- **Transport boats** are used in tilapia farming areas where lake farms get their fingerlings from lake-based hatcheries. The tilapia fingerlings are loaded into the hull of a boat in a compartment with small holes that allow free water entry as the boat moves along. To keep the boat from sinking, water is constantly bailed out by hand or by pump.

In transporting fingerlings, one should be familiar and comply with the requirements set by the Bureau of Fisheries and Aquatic Resources such as the procurement of a health certificate etc. prior to transport of domestically traded live fish. A fish health certificate is given when the fingerlings do not manifest symptoms of diseases, or harbor parasites and other pathogens.

The fingerlings are transported from the hatchery to the farm once the cages are ready to be stocked. The sealed transport bags are made to float in the cage until the water temperature in the bags becomes equal to that in the cage. Water from the cage is also slowly introduced into transport bags to help fingerlings adjust to the water temperature and salinity of the water in the cage. These are done to prevent stress which could later make them weak and prone to diseases. If transport boxes or boats are used, the water in the boxes/boats must be gradually diluted with water from the cage.

A 10 m x 20 m x 2.5 m cage may be stocked with fingerlings (3-4 cm or 10 grams) at a stocking rate of 10-15 pieces/m^3 of net cage. After stocking, the fingerlings need very little care, at least in plankton-rich farming areas where feeding is not necessary. Higher stocking densities may be used, as high as 50-200/m^3 (if permitted), but feeding then becomes necessary.

Feeding and feed management

Fig. 19. Feeding of tilapia in concrete tanks.

Although primarily herbivorous, tilapias can eat almost any available food/ feed, from microscopic phytoplankton to zooplankton, bottom invertebrates, and detritus. They also readily eat rice bran, copra meal, stale bread or pastries, and commercial feed pellets. They eat frequently and digest their food thoroughly. Because of their feeding behavior, tilapias grow fast and survive well in different farming systems (given water quality conditions that are conducive to good growth).

Studies conducted at SEAFDEC recommend a Nile tilapia formulated diet consisting of fish meal (18.25% of the dry diet), soybean meal (25%), copra meal (10%), rice bran (6%), cassava flour (36.42%), and vitamin-mineral mix (4.33%). This diet contains 28% crude protein, 4% crude fat, 4% crude fiber, 54% carbohydrate, and 10% ash. Soybean meal is noted to be an expensive import commodity hence local researches particularly funded by the Philippine Department of Science and Technology (DOST) on the use of an alternative feed ingredient such as protein enriched copra meal (PECM) were done and have shown promising results. The PECM was developed by the University of the Philippines Los Baños - BIOTECH.

Fig. 20. A farmer feeding tilapia in a floating cage in Taal Lake.

As mentioned previously, a variety of formulated diets for tilapia are commercially available, mostly containing 25-30% crude protein. The recommended feeding rate for Nile tilapia is 3-7% of the fish biomass per day, given in 2-3 rations. Tilapias prefer dry pelleted diets than moist or ground diets. The water temperature, fish size, feed quality, and presence of natural food affects feed intake in tilapias. It is best to observe the fish eating, and if hand fed, give only as much feed as they eat. Although the use of feeding devices is not popular in the Philippines, in intensive farming such as in Taal Lake, automated and/or mechanical demand feeders can be employed to improve feed management and avoid feed wastage. It would be wise as well to have a good storage facility for fish feeds should these be purchased in bulk. Diets, if improperly stored, can become rancid. Rancid diets, if still fed to fish, may cause poor growth and worse, 'nutritional' diseases. In Taal Lake, other lakes, and reservoirs where tilapia cage aquaculture is practiced, use of extruded or floating feeds, although more costly, are recommended. This is to minimize pollution caused by uneaten fish feeds that otherwise sink to the bottom if sinking pellets are administered.

Maintaining the net cages

Net cages should be regularly inspected for torn and worn out portions that must be repaired immediately to prevent escape of the fish stocks. Net cages should be cleaned at least once every two weeks depending on the extent of clogging. During bad weather, the net cages must be covered with netting and submerged 30-60 cm below the water surface so they will not be destroyed by floating debris and water hyacinths. Some farms have strategically located guard houses to secure the fish stocks from poaching or theft.

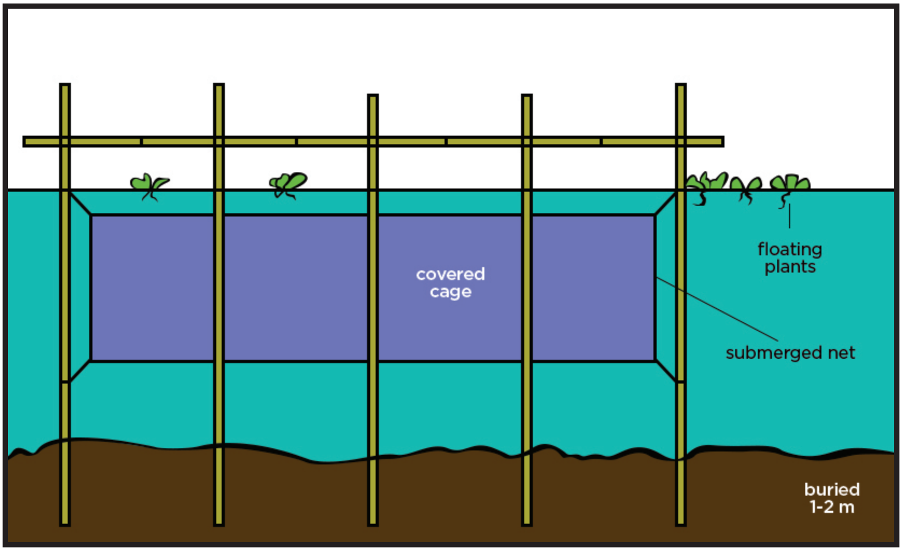

Fig. 21. A net cage covered with a netting and submerged 30-60 cm below the water surface.

Fig. 22. A farm with guard houses to secure the fish stocks from poaching or theft.

Harvesting

In most countries, the preferred market size for tilapia is 350-500 grams, but in the Philippines, 150-200 grams is already considered marketable. Under favorable conditions, in eutrophic lakes such as Laguna de Bay in the Philippines, it takes about six months for caged tilapia to grow from 10 grams to 150-200 grams (or about 5-7 pieces/kg), feeding only on natural food. However, in oligotrophic lakes such as Lake Taal in the

Philippines, it takes full feeding with commercial pellets for four months to reach the same size. When the market price allows good profit, larger tilapia may be partially harvested (this also usually improves the growth of the remaining fish).

At least two persons are needed to lift a 5 m x 10 m net cage during harvest. For bigger cages, at least 3-4 persons are needed to lift the cage from a small boat.

To lift large net cages from a small canoe (banca) or boat,

1. Untie the net cages from the frames, posts, or anchor.
2. Get the boat inside the cage and position it at one end of the cage that is of the same length as the canoe.
3. Slowly pull the net cage towards the hull of the boat.
4. Lift the net onto the boat, making sure no fish gets stuck in the net.
5. When fish are gathered in the remaining submerged part of the net cage, carefully scoop out the marketable-size fish.
6. After all the large fish have been harvested, return the net cage into the water.
7. Tie the net cage back in place.
8. Sew back the cage cover to allow the remaining fish to grow further.

Fig. 23. Harvesting of tilapia in a net cage.

Cost and return analysis

Based on the aforementioned technical concepts and requirements, an economic viability analysis of a medium scale, tilapia cage farming operation is presented in Tables 4 to 7. Table 4 defines the technical assumptions.

Table 4. Technical Assumptions

Project duration (years)	5
Volume per 10 x 10 x 3 m cage (m^3)	300
Number of cages	10
Stocking density (pcs/m^3)	65
Number of crops per year	2
Average weight at harvest (kg/pc)	0.25
Feed conversion ratio	1
Recovery at harvest (%)	80
Number of stocks per cage (pcs)	19,500
Total number of stocks/crop (pcs)	195,000
Total amount of feeds per cropping (bags)	1,560
Total cost of feeds per crop (PhP)	1,248,000
Total recovery at harvest/crop (pcs)	156,000
Total weight of fish at harvest/crop (kg)	39,000
Farm gate selling price (PhP/kg)	65

From the tabulated information, the assumptions are for a five-year farm operation. There will be two cycles of production at six months each. Since the system of culture is semi-intensive, 65 pieces of advanced fingerlings (each costing 1.75) is stocked per cubic meter of culture volume. With semi-intensive farming, apart from the natural food in the lake, the fish shall thrive on artificial commercially available diets. The expected survival would be at least 80 percent and as such, with a farm gate selling price of PhP 65/kg, the gross sales per harvest would be PhP 2,535,000.

After having identified the technical assumptions, the investment cost for starting the farm operations have to be considered as well. Table 5 shows the investment items, the corresponding cost and depreciation value for each.

Meanwhile, Table 6 summarizes the revenue, variable and fixed costs for a semi-intensive tilapia cage farming operations given the assumptions described in Table 4.

Table 5. Investment items and depreciation costs

Item	Price (PhP/unit)	Quantity	Total Cost	Life span (year)	Depreciation cost/year
Technician's quarters/warehouse, working area	100,000/unit	1	100,000	10	10,000
SG netcages (10 x 10 x 4 m)	20,000/unit	15	300,000	10	30,000
Anahaw poles	1,500/unit	50	75,000	10	7,500
Breaker nets size 10	10,000/bundle	10	100,000	10	10,000
Service boat	50,000/unit	1	50,000	10	5,000
Battery (12 volts)	3,000/pc	2	6,000	2.5	2,400
Dugout canoe	15,000/pc	1	15,000	10	1,500
Oxygen tanks	3,000/tank	2	6,000	10	600
TOTAL			**652,000**		**67,000**

Table 6. Revenue, variable and fixed costs

	Pesos/ cropping	Pesos/ year
Revenue Gross sales assuming sold-out product 39,000 kg/crop at PhP 65/kg selling price	2,535,000	5,070,000
Costs		
A. Variable costs		
Wages, 3 workers, PhP 4,000/worker/month	72,000	144,000
Tilapia fingerlings (size 8) PhP 1.75/pc	341,250	682,500
Fuel	30,000	60,000
Incentives for staff at 3-6.5% of the net income	13,208	52,832
Feeds (bags) PhP 800/bag	1,248,000	2,496,000
Transport cost	15,000	30,000
Total variable costs	**1,719,458**	**3,465,332**
B. Fixed costs		
Maintenance, repairs (2% of investment costs per year)	65,200	130,400
Rent or permit for cages	7,500	15,000
Interest on investment and variable costs (12% per year)	247,040	494,080
Depreciation costs	33,500	67,000
Operator's management fees, part-time	42,000	84,000
Total fixed costs	**395,240**	**790,480**
TOTAL COSTS	**2,114,698**	**4,255,812**

Finally, Table 7 describes the economic indicators of a five-year semi-intensive tilapia cage farming operations.

Table 7. Economic Indicators

	Per cropping	Per year
Net income (PhP) = (gross revenue-total costs)	420,302	814,189
Return on Investment (%) = (net income/investment cost) x 100		125
Payback period (years) = investment cost/(annual net income + annual depreciation)		0.74
Break-even price (PhP/kg) = annual total cost/annual production		54.56
Break-even production (pcs) = total cost/selling price		65,474
Total capital investment required (PhP) = investment cost + twice the variable cost		4,090,916

On the whole, there is a potential economic benefit in semi-intensive tilapia cage farming based on the economic indicators. Net income per cropping is estimated at PhP 420,302 or about PhP 814,189 on a yearly basis. Return on investment is computed at 125%.

Tilapia Pond Farming

Ponds are earthen impoundments, either excavated or diked in, depending on the terrain, such that flooding and draining of water can be done with ease at any given time. Earthen ponds are the most widely used system for growing tilapia to marketable size. Pond compartments may be as small as 100 m^2 or as large as one hectare (10,000 m^2). Ponds may be from 0.5 to 3 meters deep, depending on the operator's capability, preference, and production target.

About 63% of the total tilapia production in the Philippines comes from ponds, freshwater and brackish water. The species farmed in brackish water ponds are euryhaline tilapias such as the *mossambicus*, the hybrid red tilapias, and some of the locally available genetically improved stocks such as i-BEST and Molobicus, both developed by the Bureau of Fisheries and Aquatic Resources. One is able to stock Nile tilapia as well but these need to be gradually acclimated from freshwater to brackish water. However, the Nile tilapias would best be grown in freshwater for they have been noted to grow poorly despite surviving in both brackish water and full-strength seawater.

The aforementioned salt-tolerant species are either grown by themselves or in polyculture with tiger shrimp, milkfish, and other marine fishes. The tilapia harvests from ponds, especially those located in Pampanga and Bulacan, are transported live in aerated tanks by pick-up trucks and brought to the wet markets in Metro Manila and some are sold live along the major provincial roads. Because of the availability of saline-tolerant tilapias, we can now find tilapias being farmed widely in Visayas and Mindanao.

Choosing the pond farming site

Similar to the criteria in choosing a tilapia cage farming site, the following physical, biological, and social factors should be considered in selecting a tilapia pond farm site:

Peace and order. The neighborhood and the communities surrounding the farm must be peaceful. An ideal community would be one that is safe and where any activity related to fish farming is acceptable so that security and poaching do not become problems.

Proximity to markets and roads. The farm site must be near an urban center and major market where farm supplies (i.e. fuel, fish nets, rope, floats, food supplies, etc.) can be obtained, and where the farm produce can be profitably sold. Convenient access to roads and telecommunications is an advantage.

Topography. The farm site must be relatively safe from flooding, soil erosion, waves, and storms. The lay of the land must be such that water can easily flow in and out of the pond without need for a water pump. If possible, choose an area with a gentle slope to take advantage of the existing contours.

Water supply. The farm site must have an abundant supply of clean water. Water may come from rivers, streams, irrigation canals, etc. One can also invest in a deep well with pump. The water source must be free of harmful pollutants — fertilizer and pesticide runoff from rice fields, heavy metals from industries, or sludge and decomposing organic matter from livestock farms.

Soil type. The clay loam type of soil is best for ponds. This type of soil is ideal for natural food production and has properties that prevent leakage of water out of the pond. To determine the pond site's soil type, soil samples may be taken for analysis at a soil laboratory normally associated with agriculture agencies or universities. The pH of the soil must be checked to determine its acidity. Acidic pond soils are not conducive to fish farming since this type limits the production of natural food and may, at extreme levels, kill the fish. The laboratory personnel can also give advice on the kinds of fertilizers that would be appropriate for use based on the soil types.

Availability of tilapia fingerlings. If possible, the farm site must be near reputable hatcheries that could provide quality fingerlings for stocking anytime. The criteria for selection of good-quality fingerlings are given in an earlier section of this manual.

Farming intensity

There are three types of fish rearing management systems based on the level of inputs. These are -

The **extensive pond farming system** entails proper pond preparation to get rid of unwanted species and promote the growth of natural food on which the tilapia feed. Periodic application of fertilizers is necessary to sustain the growth of natural food. Fertile ponds can support stocking rates of 1-2 tilapia fingerlings/m^2 for six months until harvest. Water exchange is minimal. While yields per unit area depend on pond productivity and are relatively low, but so are the costs.

The **semi-intensive pond farming system** uses moderately high stocking rates of 3-4 tilapia fingerlings/m^2. Adequate pond preparation and periodic application of fertilizers are necessary to produce sufficient natural food. Supplemental food or a complete tilapia diet is provided on the third week of culture at 2-3% of the total fish biomass daily. Regular water exchange is necessary to maintain optimum water quality. Additional costs are incurred for feeds, but the yields are higher at 1-3 tons per hectare of 150-200 gram fish.

The **intensive pond farming system** is ideal where land is limited or expensive. Stocking rates are 5-10 fingerlings/m^2 and commercial feeds are given at 3-5% of fish biomass daily throughout the growing cycle. It is important to have life support systems for water quality management such as (a) paddlewheels to maintain high dissolved oxygen and (b) pumps to allow daily water change (5-10% of the volume). Some farms use probiotics to maintain good pond conditions. Production costs are high, but the yields are also high, about 5-15 tons per hectare, usually of 300-gram fish. Without proper management, intensive ponds become polluted, diseases may set in, and mass fish kills may occur.

Fig. 24. An intensive pond

Constructing and preparing the ponds

For large-scale farms, it is important to consult a civil engineer for the right pond design. Fish ponds greater than one hectare require digging equipment (backhoe, etc.). For smaller farms, ponds may be dug or diked manually, given enough workers. A depth of at least 1-1.5 meters is ideal for small fish ponds. The elevation of the main water canal must be lower than the elevation of the fish pond bottom, so that water outflow is easier.

Fish ponds must have a structure to control the flow of water in and out. For ponds smaller than 500 m^2, a stand pipe connected to a drain pipe by an elbow may be installed at the deepest end of the pond or a culvert may be used. Ponds larger than 500 m^2 must have a sluice gate to control the inflow and outflow of water.

If the pond water comes from irrigation, river, or stream, it is advisable to construct a water reservoir. The pond reservoir should have an area of at least 1⁄4 the total area of the grow-out ponds to ensure sufficient water supply in the farm. The reservoir may be stocked with a few pieces of tilapia to serve as indicators that the water is safe.

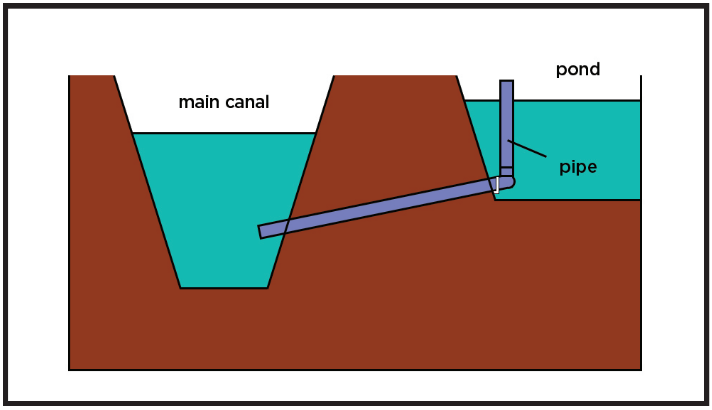

Fig. 25. Pond must be at least 1 m deep and elevated higher than the main canal

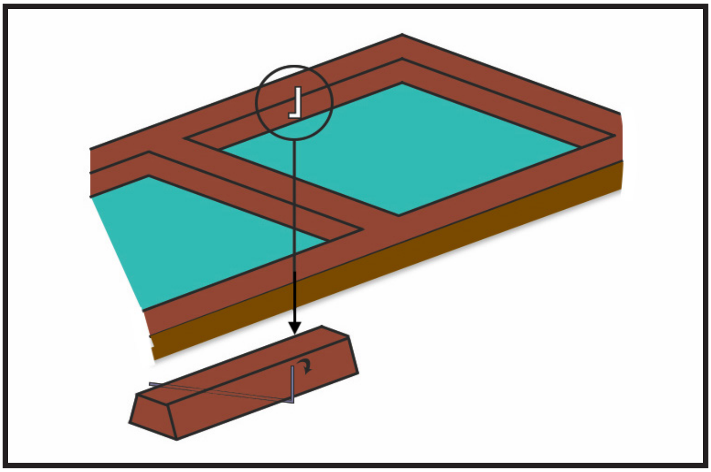

Fig. 26. A stand pipe connected to a drain pipe by an elbow can control water inflow and outflow in a small pond

Fig. 27. Small pond with water inlet; drained for pond preparation

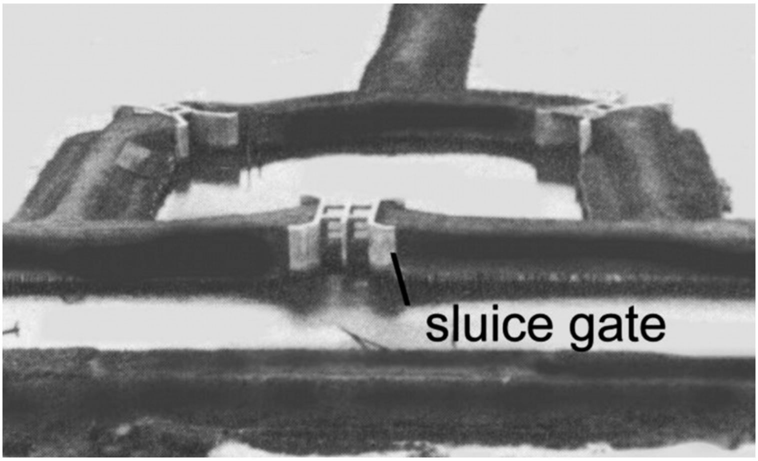

Fig. 28. Large ponds have a sluice gate to control water inflow and outflow

Fish ponds for stocking tilapia are prepared as follows:

Fig. 29. Application of lime to pond bottom.

- Sun-dry the pond bottom to rid it of unwanted organisms.
- Apply lime to stabilize the soil and water pH. Lime application is not necessary when the pH of the bottom soil is above 7.5 and the alkalinity of the pond water is above 50 mg/liter of $CaCO_3$.
- To protect the farmed stock and ensure a good harvest, farmers eradicate unwanted organisms such as potential competitors, predators, pests, and parasites. Natural toxins such as derris root, tea seed cake, rotenone, saponin, tobacco dust, as well as lime and ammonia fertilizers, work against pests.
- Collect all dead organisms twelve hours after application of the toxins. A two-week period is allowed for the pond to be rid of toxins. To test for residual toxicity, test fish are stocked in a cage set in the pond. If the test fish survive and show no adverse reaction, then the pond will be ready for stocking after fertilization.

Table 8. Natural toxins, doses, and application

Toxin, Dose (g/m^3)	Ways to prepare and apply
Derris root, 20-40	Cut fresh derris roots into small pieces. Soak in water overnight, extract rotenone by squeezing, dilute, and mix with pond water.
Tea seed cake, 50-70	Soak dried and finely ground tea seeds in lukewarm water for 24 hours. Dilute and mix with water in ponds.
Rotenone, 20	Dissolve amount required in pond water.
Saponin, 2-5	Dissolve amount required in pond water.
Tobacco dust, 30	Dissolve amount required in pond water.
Quick lime, 200-300	Mix 1 part of quick lime to 4 parts water and spread mixture over the pond bottom.
Hydrated lime, 300-460	Broadcast lime over the dry pond bottom. In partially irrigated ponds, apply as uniformly distanced heaps.

From Coche et al. (1996)

- In extensive and semi-intensive ponds, production of natural food is very important. Apply fertilizers to the pond to promote growth of plankton, which is a natural food item of tilapia. Commercial inorganic fertilizers provide ammonia, nitrate, phosphate, potassium, and other limiting nutrients for algal growth. Natural fertilizers are usually agricultural and livestock wastes that contain a mixture of organic matter and mineral nutrients. Farmers usually apply both kinds.

Basal fertilizer application is done after draining, plowing, and liming and before introducing water into the pond. Organic fertilizer (poultry droppings or cow and pig manure) is broadcast over the pond bottom at a basal rate of 2-3 tons/ha.

- Gradually allow water to flow into the pond (over three days) to a depth of 20 cm.
- Wait for 2-3 days until algae are seen growing. The water level is then increased to 75-100 cm. The pond is ready for stocking when the color of the water becomes green.

Periodic fertilizer application is done every two weeks, at a lower than basal rate, to sustain the plankton production. There are four methods of periodic application:

- Broadcast method: commercial fertilizers are applied at 10% of the basal rate
- Heap method: fertilizer is distributed in heaps along the dikes

- Hanging method: sacks half-filled with organic fertilizer are hung at the corners of the pond to be distributed by wind-induced waves or currents
- Platform method: fertilizer is submerged 10-20 cm below the water surface from a platform

Fig. 30. Pond being prepared to grow natural food

Stocking tilapia fingerlings

When the ponds are ready for stocking, the tilapia fingerlings are transported from the hatchery to the farm. Once in the farm, these must be gradually acclimated to the pond water's salinity and temperature levels. The sealed transport bags are allowed to float in the ponds until the water temperature inside the bags is equal to that of the pond water. The bags may also be opened and pond water gradually added to the bags.

Fig. 31. Tilapia fingerlings ready for stocking in ponds

Water quality management

Table 9. Water quality requirements of farmed tilapia (Balarin and Haller, 1982)

Water variable	Tolerance range
Temperature (ºC)	8-42
Salinity (ppt)	<20-35
Critical oxygen level (mg/l)	0.1-3.0
pH	4-11
Lethal ammonia levels:	
Total (mg/l)	>20
NH_3 -N (mg/l)	2.3 (0.5*)
Lethal CO_3 concentration (mg/l)	>73
Nitrite tolerance limits: LC_{50} (mg/l)	2.1

*level at which growth is affected

Pond conditions must be maintained within the optimum range for tilapia to ensure good health and fast growth. Tilapias tolerate wide ranges of salinities and water temperatures. Nile tilapia tolerates temperatures from 8°C to 42°C but the normal tolerance range is from 17°C to 35°C. Although mainly a freshwater species, many tilapias can grow in saline environments. Mozambique tilapias can thrive best in seawater while red tilapias grow faster in sea water.

Tilapias are generally hardy and tolerate poor water quality. In fact, some tilapias are able to survive in habitats with dissolved oxygen as low as 1 mg/l or 1 ppm. Some tilapias live and reproduce in swamps and shallow lakes where oxygen depletion occurs regularly.

Maintaining the ponds

Aside from the capital investments, fingerlings and feed inputs, farming practices that promote optimal environmental conditions help ensure successful tilapia production. Some of the DO's:

- Maintain water depth at 100 cm — shallow water is conducive to the growth of natural food, which supports tilapia growth.
- Prevent entry of predators into the ponds by installing screens at the water inlet and outlet. Predators reduce the tilapia yield.
- Remove aquatic weeds — they compete with phytoplankton in ponds, and reduce fish growth.
- Prevent contamination of pond water with agricultural pesticides, especially in water from an irrigation system.
- Maintain the growth of natural food by applying fertilizers periodically.
- Monitor water quality and ensure adequate dissolved oxygen and low ammonia.

Fig. 32. Predatory birds perched on floating cages at SEAFDEC/AQD's Binangonan Freshwater Station in Binangonan, Rizal

CLIMATE SMART TIP:

To counter overly warm temperatures (especially during El Niño) that would adversely affect tilapia survival in ponds, one can install net shading over the grow-out ponds. This has been proven effective in a study conducted at the Central Luzon State University (Emmanuel Vera-Cruz, pers comm).

Harvesting

Tilapia may be harvested from the ponds when the fish reach marketable size (150-300 grams; 3-7 fish/kg). There are two methods of harvesting marketable size tilapia from fishponds:

Total harvest. This is done on the sixth month after initial stocking. All the fish are harvested regardless of size. Harvesting is done after the pond has been totally drained of its water.

Selective harvesting. Selective harvesting is done when the market demand for tilapia is not high. The larger fish are harvested on the fourth month from stocking. More fish may be harvested every 2-4 weeks. The smaller fish are able to grow until the next scheduled harvest.

Fig. 33. Selective harvesting of tilapia

It is the responsibility of fish farmers to ensure that they produce and market wholesome products. Harvested tilapias must be handled properly to maintain the freshness of the product until they reach the market and the consumers' kitchen. One way to keep fish fresh is to pack or stack the fish alternately with ice in buckets, or in insulated plastic fish boxes. Another way is to place newly harvested live tilapia in aerated transport tanks.

Fig. 34. Tilapia stacked alternately with ice in a bucket (A) and in an insulated plastic fish box (B).

Fig. 35. Transport boxes for harvested tilapia

Cost and return analysis

From the aforementioned farming concepts and technical requirements, Tables 10-13 show details of an economic viability analysis of a medium scale, intensive tilapia pond operation. Table 10 defines the technical assumptions.

Table 10. Technical Assumptions

Project duration (years)	5
Area (hectares)	1
Stocking density (pcs/m^2)	10
Total initial number of fish stocked (pcs)	100,000
Cost of fingerlings (PhP)	0.80
Number of crops per year	3
Average weight at harvest (kg/pc)	0.25
Recovery at harvest (%)	85
Total number of harvested fish stock/cropping (pcs)	85,000
Feed conversion ratio	1.3
Total number of harvested fish stock per year (pcs)	300,000
Total amount of feeds used (kg/cropping)	27,625
Total amount of feeds per cropping (bags)	1,105
Total cost of feeds (PhP/year)	884,000
Price of feed (PhP/kg)	32
Total weight of fish at harvest/crop (kg)	21,250
Farm gate selling price (PhP/kg)	80
Gross sales after harvest/crop (PhP)	1,700,000

From the tabulated information, the assumptions are for a five-year farm operation. There will be three cycles of production at four months each. Since the system of culture is intensive, 10 pieces of fingerlings (each costing 0.80) is stocked per square meter of the culture area. With intensive farming, apart from the natural food in the fertilized pond, the fish shall thrive on artificial (commercially available) diets. The expected survival would be at least 85% and as such, with a farm gate selling price of PhP 80/kg, the gross sales per harvest would be PhP 1,700,000.

After having identified the technical assumptions, the investment cost for starting the farm operations have to be considered as well. Table 11 shows the investment items, the corresponding cost and depreciation value for each.

Table 11. Investment items and depreciation costs

Item	Price (PhP)/unit	Quantity	Total Cost	Life span (year)	Depreciation cost/year
SG net #14 (harvest net)	5,000/roll	2	10,000	2.5	4,000
Net fabrication	10,000/unit	1	10,000	2.5	4,000
Pond development	300,000/ha	1	300,000	10	30,000
Caretaker's quarters	50,000/unit	1	50,000	5	10,000
TOTAL			**370,000**		**48,000**

Meanwhile, Table 12 summarizes the revenue, variable and fixed costs for the tilapia pond farming operations given the assumptions described in Table 10.

Table 12. Revenue, variable and fixed costs

	Pesos/ cropping	Pesos/ year
Revenue Gross sales assuming sold-out product 21,250 kg/year at PhP 80/kg selling price	1,700,000	5,100,000
Costs		
A. Variable costs		
Wages, 3 workers, PhP 5000/worker/month	60,000	180,000
Tilapia fingerlings (size 14) PhP 0.80/pc	80,000	240,000
Fuel	25,000	75,000
Feeds (bags) 1,105 @ PhP 800	884,000	2,652,000
Maintenance, Repairs	15,000	45,000
Incentives for workers, 2% of gross revenue	34,000	102,000
Total variable costs	**1,098,000**	**3,294,000**
B. Fixed costs		
Maintenance, repairs (2% of investment costs per year)	2,467	7,400
Interest on investment & variable costs (12% per annum)	58,720	176,160
Rent on land, PhP 20,000/ha/yr, total area = 1.5 ha including farm house and work area	10,000	30,000
Depreciation costs	16,000	48,000
Total fixed costs	**87,187**	**261,560**
TOTAL COSTS	**1,185,187**	**3,555,560**

Finally, Table 13 describes the economic indicators of a five-year intensive tilapia pond farming operations.

Table 13. Economic Indicators

	Per cropping	Per year
Net income (PhP) = (gross revenue-total costs)	514,813	1,544,440
Return on Investment (%) = (net income/investment cost) x 100		417
Payback period (years) = investment cost/ (annual net income + annual depreciation)		0.23
Break-even price (PhP/kg) = annual total cost/ annual production		55.71
Break-even production (pcs) = total cost/ selling price		44,445
Total capital investment required (PhP) = investment cost + twice the variable cost		2,566,000

On the whole, there is a potential economic benefit in intensive tilapia pond farming based on the economic indicators. Net income per cropping is estimated at PhP 514,813 or about PhP 1,544,440 on a yearly basis. Return on investment is computed at 417 percent.

Other Methods

Monosex male tilapia culture

One way of increasing fish yield in the farm is to use single sex or specifically, all-male tilapia fingerlings for grow- out. Male tilapias grow faster and larger than females when grown separately. The following techniques have been developed to produce all-male tilapia offsprings through stock manipulation:

Manual sexing. This involves visual identification and manual separation of male and female tilapia fingerlings prior to stocking in the grow-out ponds. The success of this method depends on the ability of the technicians and farm workers to accurately distinguish male tilapias from female tilapias. This method is extremely laborious and is subject to human error.

Sex reversal by hormone treatment. This method involves feeding newly hatched tilapia with diets containing the synthetic hormone 17-α methyltestosterone for 4-5 weeks to induce sex reversal in the female tilapia fry. The hormone is mixed with the diet at rates of 10-60 milligrams hormone per kilogram of feed. Once the tilapia fry stock becomes all-male and on-grown, breeding of stocks in the grow-out culture ponds will not take place. The success of having all male tilapias using this method varies from 90-100%.

Sex reversal using non-synthetic agents. A phyto-androgen derived from an organic source (Benguet pine pollen) has been used effectively in inducing sex reversal in tilapia fry. The mode of application is that the extract (raw pine pollen powder) is dissolved by mixing the same in 95% ethanol. The solution is then allowed to sit for a week then sprayed onto the tilapia fry feed. The pine pollen powder-feed mixture will be administered to the fry for 28 days to induce sex inversion. The treatment may produce male seedstock ranging from 87-95% based on studies done at the Central Luzon State University (Velasco, pers comm.) and verified on farm by collaborators from Bicol University.

Hybridization. This method entails the mating of different species of tilapias that are known to produce all-male hybrids. This method has a limited commercial application for it is difficult to obtain pure genetic lines of the different species. The purity of the stock is necessary in obtaining consistent results. Some of the hybrid crosses that produce all-male tilapias are listed in Table 14 below.

Genetically male tilapia (GMT) or YY supermale technology. This technology was developed in the late 1980s by the University of Wales (now known as Swansea University), Swansea, Wales, UK in collaboration with the Freshwater Aquaculture Center of the Central Luzon State University in Muñoz, Nueva Ecija, Philippines. The collaborative work was implemented to produce all-male Nile tilapia fry/fingerlings on a large scale. All-male populations are obtained through a series of genetic manipulation, feminization, and progeny testing to produce novel YY males. The genetically male YY genotypes, when mated with normal XX females can produce all-male XY progenies. This method has a mean success rate of 96.5% males.

Table 14. Crosses of tilapia *Oreochromis* spp. that produce all-male hybrids

Female parent	Male parent	Reference
O. mossambicus	*O. urolepis hornorum*	Hickling (1960)
O. niloticus	*O. urolepis hornorum*	Pruginin (1967)
O. spilurus niger	*O. urolepis hornorum*	Pruginin (1967)
O. niloticus	*O. aureus*	Fishelson (1962)

Rice-fish (tilapia) culture

This is an integrated system that consists of a rice field cum fishpond. Fish are reared either simultaneously or alternately with rice. This system enables the production of fish, in this case tilapia, in the same area where rice is grown without adversely affecting rice yield. The fish is either intentionally stocked or may enter rice fields from surrounding water ways when flooding occurs. If rice-fish culture is practiced, pesticides should not be applied in the rice field.

Saltwater culture of tilapias

Since most tilapias are known to be euryhaline, meaning, they can tolerate a wide range of salinity levels, they can be reared in either brackish water or seawater environments. As mentioned in an earlier section of this manual, the Mozambique tilapia, red tilapia hybrids and the genetically enhanced brackishwater tolerant tilapias such as the i-BEST and the Molobicus (both are hybrids) can be grown in brackishwater ponds.

Aquaponics

Fig. 36. An aquaponics system

Aquaponics is the culture of fish and plants in a recirculating system. It is a way of optimizing the use of water for both fish and plant rearing. The system uses fish effluents (composed of waste solids and dissolved nutrients) from a recirculating aquaculture subsystem, as a medium that will provide nutrients for plants to grow since this is connected to a hydroponic subsystem. The system is mutually beneficial to the plant being grown and the fish being reared since metabolites that are toxic to the fish are taken up as nutrients by the plants. Such a system is usually ideal as a form of urban aquafarming. The plants that can be grown are usually leafy salad greens (lettuce, etc.), herbs and other vegetables (e.g. tomatoes, etc.). Fish grown in an aquaponics system could vary from tilapias, catfish to koi carps (and other ornamental fishes) while freshwater prawns (crustaceans) can also be stocked.

Tilapia Health Management

Although known to be a relatively hardy fish, tilapias are still susceptible to pathogens or disease-causing agents, such as parasites, bacteria and the recently reported tilapia lake virus (TILV), should conditions in the rearing water environment (e.g. poor water quality, etc.) become stressful to the fish.

Apart from poor water quality conditions, increasing intensification and lack of proper health management measures could lead to many disease problems of bacterial, viral, parasitic, and fungal origin. Fish cultured in floating net-cages and pens are susceptible to diseases particularly when environmental parameters including temperature, dissolved oxygen, and suspended particles suddenly or erratically fluctuate. Thus, once conditions suitable for pathological changes develop, disease progression in warm water environments rapidly advances. Diseases of tilapias are generally classified into infectious and noninfectious diseases. Infectious diseases can be caused by bacteria, parasites, fungi, or viruses. On the other hand, noninfectious diseases or abnormalities can be caused by environmental stress, contaminants, or nutritional deficiencies.

Infectious Diseases

A great number of aquatic bacteria are opportunistic, meaning they may be present but rarely affect the fish unless their immune system is compromised. Hence, under normal conditions, these aquatic bacteria do not cause disease. They become pathogenic only when the balance between the host and environment is altered by increased stocking density, inadequate nutrition, or other stress factors. Generally, the early signs of bacterial infections include lack of appetite or reduced feed intake, lethargy, abnormal swimming behavior such as swimming near the water surface, and discoloration due to abnormal pigmentation of the skin. However, as the disease progresses, fish develops exophthalmia, abdominal distention, pale gills, scale loss, frayed fins, skin lesions, and necrosis.

Important bacterial diseases of tilapias include aeromonad septicemia, edwarsiellosis, columnaris, pseudomonad septicemia, and streptococcosis respectively caused by the following bacterial species -- *Aeromonas* spp., *Edwardsiella tarda*, *Flavobacterium columnare*, *Pseudomonas* spp., and *Streptococcus iniae* or *S. agalactiae*.

Fig. 37. Tilapia *Oreochromis niloticus* infected with *Aeromonas hydrophila* manifesting bilateral exophthalmia.

Parasites are invertebrate organisms that attach to the skin, digestive tract and various organs of the fish. In most cases, affected fish appear weak with excessive mucus production and with frayed fins and gills. Fish heavily infected with parasites rub their body against objects which may lead to extensive damage and hemorrhage or bleeding under the skin's surface. Some of the common parasites that attack tilapias are protozoans (*Ichthyophthirius multifilis*, *Trichodina* spp., *Chidonella*), trematodes (*Dactylogyrus*, *Gyrodactylus*), crustacean copepods (*Lernea*, *Argulus*), and leeches (*Hirudina*).

Some species of fungi may induce heavy infections in tilapias that may result in abnormal swimming behavior and mortality. However, far less is known about fungal diseases of tilapias compared to bacterial or parasitic diseases. Fungal infection is easily recognized by the cotton-like growth that occurs on skin injuries either caused by handling or external parasites or ectoparasites.

Research on viruses has recently received new impetus following high mortalities in hatchery-bred juvenile tilapias soon after transfer to culture ponds or pens and floating net-cages in lakes or streams. Nervous necrosis virus (NNV) and TILV are by far the emerging viruses responsible for significant mortalities of tilapias reared in hatcheries and grow-out culture facilities. The definite signs of viral nervous necrosis induced by NNV in tilapia fingerlings and juveniles include abnormal swimming behavior and the presence of vacuoles in the eyes, brains, and nervous tissues. On the other hand, TILV causes skin lesions and ulcers, loss of appetite, slow movement, eye abnormalities, opacity of fish eye lens, gathering of fish at the pond bottom, and reduced schooling behavior. Outbreaks seemingly appear frequently during summer months with different strains of tilapia being affected. Notably, in polyculture systems, other species like mullets and carps do not die.

Noninfectious Diseases

Environmental stress, contaminants coming from industrial and agricultural pollution or run-off, and nutritional deficiencies can cause serious disease in farmed tilapias, while inadequate diets and uncontrolled water quality can induce secondary infection. Physical injuries often encountered in pen- or net-caged tilapias include skin damage caused by net abrasion in over-stocked fish, and susceptibility to opportunistic pathogens especially in fish that are handled without due care.

Disease Prevention and Control

As pointed out earlier, under stressful conditions, the prevalence and spread of infectious diseases will inevitably rise as a result of higher infection pressure, environmental deterioration, and crowded conditions, particularly in semi-intensive and intensive culture systems. Accordingly, effective methods of controlling infectious diseases have become more and more important in the cultivation of tilapias. Good health management is therefore the best way to control if not eradicate disease occurrence. Pertinent strategies include:

- adherence to proper pond preparation (e.g. appropriate drying and liming) prior to stocking as such can eliminate or destroy pest and parasites;

- use of healthy and good quality fingerlings, i.e. ascertained to be from a reliable source and not infested with external parasites prior to stocking;

- minimization of stress when transporting and handling the fish for stocking;

- adherence to appropriate stocking density as overcrowding can induce stress that affects fish growth and survival;

- adherence to good husbandry techniques such as maintenance of good water quality, thus, whenever possible, conduct water exchange regularly to avoid the build-up of parasites, fungal, and bacterial pathogens;

- feeding optimization by providing and following the appropriate feeds and recommended feeding rates, respectively, to optimize fish growth;
- avoidance of overfeeding fish as nutrients in uneaten feeds that leach into the water can be utilized by bacteria during decomposition resulting in oxygen depletion and pollution of the culture environment. Thus, floating feeds are recommended as sinking feeds are difficult to monitor whether they have been consumed or not by the fish;

- regular disease monitoring (surveillance and reporting) of the fish stocks should be conducted to enable early detection of any behavioral (e.g. lack of appetite, gasping for air, abnormal swimming, etc.) or physical (e.g. fin rot, bulging eyes, hemorrhages, etc.) abnormalities;

- immediate removal and disposal of dead fish by burying;

- responsible administration of chemicals and veterinary drugs to control if not eradicate pathogens in cultured fish. This is done by first determining the correct diagnosis of the disease thereby effective treatment and control measures can be achieved. It should be borne in mind that misuse of veterinary drugs, particularly antibiotics, can result in residue build-up and antimicrobial resistance in fish which is detrimental to human health; and

- use of commercially available vaccines coupled with biosecurity measures in areas where a specific disease problem, such as streptococcal infection persists, is logically practical as emphasis must be on prevention rather than therapy.

Tilapia Processing

Product Forms

Tilapia can be sold as live, frozen whole and gutted, frozen fillet, dried (*tilanggit*) and as value-added products (tilapia *tocino*, tilapia *longganisa*, nuggets, rolls etc.). In the interest of food safety, tilapia producers/processors are advised to comply with the Philippine National Standards (PNS) for the commonly farmed and traded fish species, to include the tilapias, as set by the Bureau of Agriculture and Fisheries Standards (BAFS) of the Department of Agriculture. For details of the approved PNS for live and frozen forms of the tilapia, you may visit their website (www.bafs.da.gov.ph).

Apart from the traditional products from tilapia, novel forms have been produced through projects funded by the Department of Science and Technology. These include tilapia cookies and the tilapia ice cream, the latter having been developed and promoted by the Central Luzon State University (www.pcaarrd.dost.gov.ph).

Fig. 38. Dried tilapia or *tilanggit* (left) and smoked tilapia or *tinapa* (right)

Marketing

Trading tilapias locally differ depending on the location of the supply sources. The farmers can choose to sell their tilapia harvests to wholesalers or retailers, consumers, and sometimes, brokers. As the product is now in various forms, one can find tilapias not only in wet public markets but also in supermarkets where the fish are sometimes also sold in the live form, kept in aerated glass aquaria or tubs.

Local trade has always been steady and since the tilapias have become a popular food fish even in temperate countries, they can be easily exported to the US and Europe, mostly as frozen fillets or frozen value-added products.

Fig. 39. Pickup trucks transporting live tilapia in aerated tanks

Suggested Readings

Argana, R.R. 2017. Protein enriched copra meal (PECM) as feed protein for tilapia, milkfish and shrimp aquaculture. DOST-PCAARRD. www.pcaarrd.dost.gov.ph.

Arriesgado, D.M. (n.d.). Tilapia farming for tilanggit production. MSU:Naawan, Misamis Oriental.

Balarin JD, RD Haller. 1982. The intensive culture of tilapia in tanks, raceways and cages, p 267-355. In: JF Muir, RJ Roberts (eds) Recent Advances in Aquaculture. Croom Helm Ltd., London.

Calanoga, E. and Encarnacion, A. (2002). Development of Value-added Products from Tilapia (*Oreochromis* sp.). National Aquatic Resources Research and Development System.

Cnaani A and Hulata G. 2011. Improving salinity tolerance in Tilapias: past experience and Future Prospects. The Israeli Journal of Aquaculture-Bamidgeh IIC:63.2011.533. 21p.

De Verdal H, Rosario, W., Vandeputte, M., Muyalde, N., Morissens, P., Baroiller, J.F., and Chevassus, B. (2014). Response to selection for growth in an interspecific hybrid between *Oreochromis mossambicus* and *O. niloticus* in two distinct environments. Aquaculture. 430: 159-165

Dos Santos VB, Sliva VV, de Almeida MV, Mareco EA and Salomao RAS. 2019. Performance of Nile tilapia *Oreochromis niloticus* strains in Brazil: a comparison with Philippine strain. Journal of Applied Animal Research. 47(1):72-78.

DOST-PCAARRD. 2018. Philippines Recommends for Tilapia. Department of Science and Technology Philippine Council for Agriculture and Aquatic Resource Research and Development, Los Baños, Laguna, Philippines.

Eguia RV, Romana-Eguia MRR 2016. Salt tolerant Nile tilapia production: prospects in aquaculture. *In:* Remany MC, Kumar J. Proceedings of the India Tilapia Summit 2014 and 2nd edition of the Dr. EG Silas Endowment Lecture; 18 December 2014; Vijayawada, India. Tamil Nadu, India: Rajiv Gandhi Centre for Aquaculture, pp. 72-74.

Eguia RV, Eguia MRR and Salayo ND. 2011. Modyular na pag-aalaga ng tilapya sa kulungang lambat. Aquaculture Extension Manual. SEAFDEC/AQD.

Eguia RV and Eguia MRR. 2007. Pag-aalaga ng Tilapia. (Tilapia culture). Aquaculture Extension Manual No. 22, 3rd edition SEAFDEC Aquaculture Department, Philippines. 46pp.

Eguia RV and Eguia MRR. 2007. Pagpapaanak ng Tilapia. (Tilapia Seed Production). Aquaculture Extension Manual No. 23. 3rd edition SEAFDEC Aquaculture Department, Philippines. 43pp.

Eguia RV and Eguia MRR. 2007. Tilapia Broodstock and Hatchery Management. Aquaculture Extension Manual No. 38. SEAFDEC Aquaculture Department. Philippines, 40pp.

Eguia RV and Eguia MRR. 2004. Tilapia farming in ponds and cages. SEAFDEC/ AQD Extension Manual No. 36. SEAFDEC Aquaculture Department, Philippines, 40pp.

El-Sayed, AM. 2006. Tilapia culture in salt water: Environmental requirements, nutritional implications and economic potentials. Eighth Symposium on Advances in Nutritional Aquaculture. November 15–17, Nuevo Leon, Mexico.

El-Shafey AAM. 1998. Effect of ammonia on respiratory functions of blood of *Tilapia zilli*. Comparative Biochemistry and Physiology Part A 121:305-313.

Escover E.M., Salon O.T. and Smith I.R., 1987. The Economics of Tilapia Fingerling Production and Marketing in the Philippines, Aquaculture and Fisheries Management, Vol. 18, pp 1-13.

Espejo-Hermes, J. (1998). Fish processing technology in the tropics. Tawid Publications.

Hickling CF. 1960. The Malacca tilapia hybrids. J. Genet. 57: 1-10.

Magid A and Babiker MM. 1975. Oxygen consumption and respiratory behaviour of three Nile fishes. Hydrobiologia 46: 359–367.

Mair GC, JS Abucay, JA Beardmore, DOF Skibinski. 1995. Growth performance trials of genetically male tilapia (GMT) derived from YY-males in *Oreochromis niloticus* L.: On station comparisons with mixed-sex and sex-reversed male populations. Aquaculture 137: 313-322.

Mires, D. 1995. The tilapias. In: Production of Aquatic Animals: Fishes (eds Nash, C. E., and A. J. Novotony. Elsevier, New York, pp. 133–152.

Mjoun K, Rosentrater KA and Brown ML. 2010. Tilapia: environmental biology and nutrient requirements. Fact Sheets. Paper 164. http://openprairie.sdstate.edu/extension_fact/164.

Ordoñez JFF, Asis AMJM, Catacutan BJ, De la Peña J and Santos MD. 2015. First report on the occurrence of invasive black-chin tilapia *Sarotherodon melanotheron* (Ruppell, 1852) in Manila Bay and of Mayan cichlid *Cichlasoma urophthalmus* (Gunther, 1892) in the Philippines. BioInvasions Records 4(2):115-124.

Pakingking R Jr., Cruz-Lacierda E, and Alapide-Tendencia E. 2009. Major Diseases of Fish and Crustaceans. Rural Aquaculture: A Handbook for Human Resource Development (2nd ed.). Southeast Asian Fisheries Development Center-Aquaculture Department, Tigbauan, Iloilo, Philippines. 308 p.

Pakingking Jr. R, Palma P, Usero R. 2015 Quantitative and qualitative analyses of the bacterial microbiota of tilapia (*Oreochromis niloticus*) cultured in earthen ponds in the Philippines. World Journal of Microbiology and Biotechnology 31: 265-275.

Pakingking Jr. R., de Jesus-Ayson EG. 2016. Supporting ASEAN Good Aquaculture Practices: Preventing the Spread of Transboundary Aquatic Animal Diseases. Fish for the People 2: 76-82.

Pakingking Jr., R. 2017. Control and Prevention of Present and Emerging Transboundary Aquatic Animal Diseases (pp. 113-118). *In* SEAFDEC. 2017. Southeast Asian State of Fisheries and Aquaculture 2017. Southeast Asian Fisheries Development Center, Bangkok, Thailand. 167 pp.

Panfili J, Mbow A, Durand J-D and Diop K. 2004. Influence of salinity on the life-history traits of the West African black chinned tilapia (*Sarotherodon melanotheron*): Comparison between Gambia and Saloum estuaries. Aquatic Living Resources 17(1):65-74.

PNS/BAFPS 67:2008. Philippine national standard: frozen tilapia. Bureau of Product Standards, Department of Trade and Industry, Makati City, Philippines.

Pruginin Y, S Rothbard, G Wohlfarth, A Halevy, R Moav, G Hulata. 1975. All-male broods of *Tilapia nilotica* x *T. aurea* hybrids. Aquaculture 6: 11-21.

Pullin RSV, RH Lowe-McConnell (eds). 1982. The Biology and Culture of Tilapias. ICLARM Conference Proceedings 7, 432 p. International Center for Living Aquatic Resources Management, Manila, Philippines.

Rana, K.J. 1990. Reproductive biology and hatchling rearing of tilapia eggs and fry. *In:* J.F. Muir and R.J. Roberts (Editors). Recent Advances in Aquaculture, Vol. 3 pp. 343-406. Croom Helm Ltd., London and Canberra.

Redner, B. D., and R. R. Stickney. 1979. Acclimation to ammonia by *Tilapia aurea*. Trans. Am. Fish. Soc. 108: 383–388.

Richter H, U Focken, K Becker, CB Santiago, WB Afuang. 1999. Analysing the diel feeding patterns and daily ration of Nile tilapia, *Oreochromis niloticus* (L.) in Laguna de Bay, Philippines. J. Appl. Ichthyol. 15: 165-170.

Romana-Eguia MRR, Ikeda M, Basiao ZU, Taniguchi N. 2010. Growth comparison of Asian Nile and red tilapia strains in tank and lake-based rearing enclosures. Aquaculture International.18 (6):1205-1221.

Romana-Eguia MRR, Ikeda M, Basiao ZU, Taniguchi N. 2005. Genetic changes during mass selection for growth of Nile tilapia assessed by microsatellites. Aquaculture Research 36: 69-78.

Romana-Eguia MRR, Ikeda M, Basiao ZU, Taniguchi N. 2004. Genetic diversity in farmed Asian Nile and red tilapia stocks evaluated from microsatellite and mitochondrial DNA analysis. Aquaculture236,131-150.

Romana-Eguia MRR and Eguia RV. 1999. Growth of five Asian red tilapia strains in saline environments. Aquaculture 173:161-170.

Romana-Eguia MRR and Doyle RW. 1992. Genotype-environment interaction in the response of three Nile tilapia strains to poor nutrition. Aquaculture 108: 1-12.

Rosario, W. R., Chevassus-Au-Louis, C. G. B., Morissens, P., Muyalde, N. C., Cruz, A. E., Vera, F., and Poivey, J. P. 2004. Selection from an Interspecific Hybrid Population of Two Strains of Fast Growing and Salinity Tolerant Tilapia. *In:* Remedios B. Bolivar, Graham C. Mair, and Kevin Fitzsimmons (eds) New Dimensions on Farmed Tilapia Proceedings of the 6th International Symposium on Tilapia in Aquaculture Philippine International Convention Center, Roxas Boulevard, Manila, Philippines September 12-16, 2004.

Ross, L. G. 2000. Environmental physiology and energetics. pp. 89–128. *In:* M. C. M. Beveridge and B. J. McAndrew (eds.) Tilapias: Biology and Exploitation, Fish and Fisheries Series 25, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Santiago CB, RM Coloso, OM Millamena, IG Borlongan. 1994. Feeds for Small-Scale Aquaculture. SEAFDEC Aquaculture Department, Iloilo, Philippines, 144 p.

Santiago CB, OS Reyes, MB Aldaba, MA Laron. 1986. An evaluation of formulated diets for Nile tilapia fingerlings. Fish. Res. J. Philipp. 11:5-12.

Sarig, S. 1969. Winter storage of tilapia. FAO Fish Culture Bulletin. 2: 8–9

Sotelo Y. 2019. Tilapia Gets Gene Boost. Philippine Daily Inquirer. Jan 14, 2019 issue.

Toledo JD Acosta BO, Eguia MRR, Eguia RV and Israel D. 2008. Sustainable Tilapia Farming: A Challenge to Rural Development. Fish for the People magazine. SEAFDEC Bangkok, Thailand. published June 2008.

Tayamen, M. M., Abella, T. A., Reyes, R. A., Danting, M. J. C., Mendoza, A. M., Marquez, E. B., Salguet, A. C., Apaga, M. M., and Gonzales, R.C. Development of Tilapia for Saline Waters in the Philippines. *In* R. Bolivar, G. Mair & K. Fitzsimmons, eds. Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, pp. 463–478. Manila, American Tilapia Association, Aquaculture, CRSP, and Ministry of Agriculture, 854 pp.

Velasco RR, Abella TA, Noscal LD, Mendoza JB, Dolente DJM, Abella MZ and Suarez EAG. 2016. Phytoandrogen on sex inversion of Nile tilapia (*Oreochromis niloticus* L.) Paper presented during the 28th National Research Symposium of the Department of Agriculture Bureau of Agricultural Research, October 26-27.

Vera Cruz, E.M., E.B.T. Jimenez, B.M. Apongol, D.R.G. Sanchez, J.S. Abucay and Z.P. Bartolome. 2014. Refinements in grow-out and hatchery management of Nile tilapia (*Oreochromis niloticus* L.). Unpublished Project Terminal Report, Central Luzon State University.

WorldFish Center. 2004. GIFT Technology manual: An aid to tilapia selective breeding. WorldFish Center, Penang, Malaysia, 56 p.

www.pinoybisnes.com/food-business-ideas/value-added-products-from-tilapia

Acknowledgments

The authors wish to thank the members of the SEAFDEC/AQD Publications Review Committee for their comments and suggestions which helped improve the technical manual. We especially thank Dr. Nerissa Salayo for her invaluable comments on the cost-and-returns analyses.

About the Authors

Dr. Maria Rowena R. Romana-Eguia obtained her BSc Zoology degree from the University of the Philippines in Diliman in 1982 after which she joined SEAFDEC/AQD. She gradually rose from the ranks from a Research Assistant to a Scientist after completing an MSc in Genetics from the Swansea University, Wales, U.K. in 1985 and a PhD in Agricultural Science (major in Fish Population Genetics) from the Tohoku University, Sendai, Japan in 2004. These aside from having several scientific publications in between. Some of her scientific journal publications, particularly on Nile tilapia and red tilapia have won two Elvira O. Tan Memorial Awards as Best Published Paper in Aquaculture in 1995 and 2004 from the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development or PCAARRD of the Department of Science and Technology. She has also edited conference proceedings and co-authored books and technical manuals on tilapia, milkfish and mangrove crabs. Apart from being a technical evaluator for government projects in aquaculture, she sits as Scientific adviser of the Philippine government in UN meetings on issues related to marine genetic resources and aquatic biodiversity. Population genetics of tropical aquaculture species such as tilapia, freshwater prawn, milkfish, abalone, mangrove crab and Anguillid eels are her major research interests. Weng also serves as lecturer on topics like aquaculture genetics, good aquaculture practices as well as tilapia/freshwater prawn breeding, hatchery and nursery operations.

Ruel V. Eguia completed his MSc Aquaculture at the Universiti Putra Malaysia, in Serdang, Selangor, Malaysia in 1999 and his BSc Inland Fisheries at the Central Luzon State University, Nueva Ecija, Philippines in 1982. He trained in fish genetics in Canada in 1990 and in freshwater aquaculture in Malaysia in 1995. Ruel also learned on-farm skills from working in various local private fish farms and hatcheries, including a stint as Fish Hatchery Supervisor at the Saudi Fisheries Company in Dammam, Kingdom of Saudi Arabia. He worked with the SEAFDEC Aquaculture Department from 1982 to 2008 starting from being a Technical Assistant to becoming a Research Specialist until he left SEAFDEC/AQD to manage the CDO Foodsphere Inc. Aquaculture Farm in 2009 to date. From his various assignments including some local and international FAO short term project engagements, Ruel acquired extensive knowledge in the breeding and farming of fishes such as carp, tilapia, sea bass, milkfish and mangrove crab. Even while working as an Aquaculture Farm manager, he is still invited to serve as lecturer and practical instructor in Freshwater Aquaculture and other training courses at SEAFDEC/AQD.

Dr. Rolando V. Pakingking, Jr. is a scientist of the Fish Health Section, SEAFDEC/AQD, where he actively engages in researches that delve on interactions of viruses and bacteria in fish. He has conducted research with funding from the Government of Japan Trust Fund (GOJ-TF), Philippine Council for Agriculture, Aquatic and Natural Resources Research-Development (PCAARRD)-Department of Science and Technology (DOST) and National Research Council of the Philippines (NRCP)-DOST among others. He obtained his master's (M.S. Biology) and doctoral (Ph.D. Aquatic Pathobiology) degrees respectively from the University of the Philippines Visayas and Hiroshima University, Japan. He has served as consultant/fish disease expert of the Food and Agriculture Organization of the United Nations assigned at the Fish Farming Center, Jeddah, Kingdom of Saudi Arabia and visiting professor of Universiti Teknologi Malaysia. He has authored and co-authored book chapters and scientific articles published in peer-reviewed journals and serves as referee to several scientific journals. He has been a recipient of various awards including the 2019 Elvira O. Tan Memorial Awards for Outstanding Published Paper in Aquatic Science Category and has been conferred as Diplomate in Microbiology by the Philippine Academy of Microbiology.

ABOUT SEAFDEC

The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 to promote fisheries development in the region. The member countries are Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

The policy-making body of SEAFDEC is the Council of Directors, made up of representatives of the member countries.

SEAFDEC has five departments that focus on different aspects of fisheries development:

- The Training Department (TD) in Samut Prakan, Thailand (1967) for training in marine capture fisheries
- The Marine Fisheries Research Department (MFRD) in Singapore (1967) for post-harvest technologies
- The Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines (1973) for aquaculture research and development
- The Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia (1992) for the development and management of fishery resources in the exclusive economic zones of SEAFDEC member countries, and
- Inland Fishery Resources Development and Management Department (IFRDMD) in Palembang, Indonesia (2014) for sustainable development and management of inland capture fisheries in the Southeast Asian region.

AQD is mandated to:

- Conduct scientific research to generate aquaculture technologies appropriate for Southeast Asia
- Develop managerial, technical and skilled manpower for the aquaculture sector
- Produce, disseminate and exchange aquaculture information

AQD maintains four stations: the Tigbauan Main Station and Dumangas Brackishwater Station in Iloilo province; the Igang Marine Station in Guimaras province; and the Binangonan Freshwater Station in Rizal province. AQD also has an office in Quezon City.

www.seafdec.org.ph

ISSN 0115-5369

9 770115 536008