Food and Agriculture
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TRAINING CURRICULUM AND PRACTICAL MANUAL ON SUSTAINABLE AQUACULTURE

With the technical and financial support of

TRAINING CURRICULUM AND PRACTICAL MANUAL ON SUSTAINABLE AQUACULTURE

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Preparation of this document

The first version of this training curriculum and manual was primarily prepared for all sub-Saharan African countries interested in developing sustainable aquaculture. Upon request by the Government of the Republic of Zambia and numerous African aquaculture stakeholders for FAO to turn complex science and policy subjects into practical knowledge and make it useful for common people to develop the sector, the FAO Fisheries and Aquaculture Division (NFI) prepared this comprehensive training curriculum and practical manual on sustainable aquaculture. The training curriculum and the manual are mostly dedicated to technical schools, aquaculture farmers and extension officers as well as those working with financial aquaculture businesses. This document benefited from the Unilateral Trust Fund "Technical Assistance to the Zambia Aquaculture Enterprise Development Project" (UTF/ZAM/077/ZAM), funded by the African Development Bank and the Government of the Republic of Zambia through the Zambia Aquaculture Enterprise Development Project (ZAEDP).

The preparation of this publication was coordinated by Ms Ana Menezes, in collaboration with FAO's Fisheries and Aquaculture Division (NFI) staff Mr Pierre Murekezi and Ms Elisabetta Martone, and external experts Mr Abdoul Aziz Badiane (FAO consultant in hatchery management), Mr Boniface Mulonda (FAO consultant on pond construction) and Mr Timothy Tonga (government expert on planning and development).

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Foreword

In the context of sustainable aquaculture development, the combination of technical with enviro-socio-economic and governance principles has a very crucial role to play. One of the major concerns for the Africa region is that fish availability per capita is foreseen to decrease in the coming decades if growth in aquaculture production lags behind demographic growth. Apart from its demonstrated capability to reduce poverty and improve food nutrition security and livelihoods, aquaculture can be a significant driver for growth and some countries have well-established aquaculture programmes. The sector has also been identified by many African countries as a priority area. Some of the factors identified as necessary for the development of the sector are the creation of knowledge and the strengthening of institutional and technical capacities. Formal and non-formal education should be prioritized in order to increase the level of expertise, competency and skills of the different actors in the aquaculture sector. In that regard, forming innovative education and training programmes to create or enhance knowledge and skills and improve food security, nutrition, economic growth and employment are necessary to advance the sector.

This document was designed as a resource guide, and addresses the needs of fish farmers, extension officers, government officers and financial institutions with or without specific knowledge of the aquaculture sector. The curriculum and training manual were also built to enhance the technical schools' (teachers and students) knowledge and competencies on sustainable aquaculture practices.

This training curriculum and practical manual are the outcome of many years of work and dedicated tailor training programmes in Africa to support the development of technically, environmentally sustainable and socioeconomic responsible aquaculture on the continent. Furthermore, the Zambian Government (Ministry of Fisheries and Livestock) and the African Development Bank within the framework of the Zambia Aquaculture Enterprise Development Project (UTF/ZAM/077/ZAM) contributed greatly to the preparation of this document.

It is our hope that this curriculum and manual will function as a living document to ensure complementarity of opportunities and clear progression of education and capacity development for each actor involved in the sector.

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The authors would further like to thank the colleagues from the Aquaculture Branch of the FAO Fisheries and Aquaculture Division and the FAO Zambia colleagues for their support in various ways and for their dedication and commitment. The authors would like to particularly recognize some FAO contributors, namely Rodrigo Roubach, Nathanael Hishamunda, Nada Bougouss, Junning Cai, Xiaowei Zhou, Austin Stankus, Vasco Schmidt, Francis Chimpangu and Chorouk Benkabbour.

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Acronyms and abbreviations

CF	contract farming
CO_2	carbon dioxide
CP	crude protein
DO	dissolved oxygen
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
GPS	Global Positioning System
HDPE	high-density polyethylene
NFI	FAO Fisheries and Aquaculture Division
NH_3	un-ionized ammonia
PPP	public-private partnership
PVC	polyvinyl chloride
RAS	recirculation aquaculture system
UTF	Unilateral Trust Fund
UTF/ZAM/077/ZAM	Unilateral Trust Fund called "Technical Assistance to the Zambia Aquaculture Enterprise Development Project"
UTIDA	User-Friendly Tool for Investment Decision Making in Aquaculture
WG	Working Group
ZAEDP	Zambia Aquaculture Enterprise Development Project

PART I
Curriculum development

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National Aquaculture Research and Development Centre
Credit: NARDC
The National Aquaculture Research and Development Centre in Mwekera, Copperbelt Province, Zambia, is seen in the satellite image.
In the inset photo, three spawning tanks with egg collection chambers are in the foreground. The spawning tank layout and design, developed and fashionable in the early 1960s for carp hatchery operations in Asia, is a vestige of government efforts in the early days of introducing aquaculture in Zambia through international experience sharing.
Today, the introduced Nile tilapia, blue tilapia and a few native tilapia species dominate in aquaculture in Zambia. While common carp is still farmed in small quantity, the filter-feeding carps and the herbivorous grass carp once farmed commercially in the country have been phased out.
Background image: Esri
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INTRODUCTION

In 2020, global aquaculture production reached a new record high of 122.6 million tonnes (valued at USD 281 billion), namely 57.5 million tonnes of finfish, 11.2 million tonnes of crustaceans, 17.7 million tonnes of molluscs, 1.1 million tonnes of miscellaneous aquatic animals or animal products for non-food purposes, and 35.1 million tonnes of aquatic plants. The Asian region is the predominant aquaculture producer, accounting for 91.6 percent of world aquaculture production in 2020. Excluding aquatic plants, aquaculture production in 2020 contributed 49.2 percent of the world's total fishery production; the majority of the production (62.2 percent) came from inland aquaculture (FAO, 2022).

It is essential that this continuing growth of aquaculture be mirrored in the African continent where fish, fish products and aquatic plants play an important role by contributing to food security and nutrition, poverty eradication and economic development. In 2020, 98 percent of aquaculture production (excluding aquatic plants) in sub-Saharan Africa came from inland aquaculture, which primarily comprised tilapias (50 percent) and catfishes (37 percent). Countries in the region with relatively large inland aquaculture production (over 10 000 tonnes) include Nigeria (43.3 percent of the sub-Saharan African total), Uganda (20.5 percent), Ghana (10.6 percent), Zambia (7.6 percent), Kenya (3.3 percent), the United Republic of Tanzania (2.9 percent) and Zimbabwe (2.6 percent).

Aquaculture production in Zambia increased from 4 240 tonnes in 2000 to 45 670 tonnes in 2020 (the fifth highest in sub-Saharan Africa); the average 12.6 percent annual growth was higher than the world, Africa and sub-Saharan Africa averages. Tilapias were the primary contributor to the overall aquaculture production. The share of aquaculture in Zambia's total fishery production increased from 6 percent in 2000 to 30 percent in 2020.

Of particular concern for the region is that fish availability per capita is foreseen to decrease in the coming decades if growth in aquaculture production lags behind demographic growth. Apart from its demonstrated capability to reduce poverty and improve food nutrition security and livelihoods, aquaculture can be a significant driver for growth and some countries now have well-established aquaculture programmes. The sector also has been identified by many African countries as a priority area. Some of the factors identified as necessary for the development of the sector are the creation of knowledge and the strengthening of institutional and technical capacities. Formal and non-formal education should be prioritized in order to increase the level of expertise, competency and skills of the different actors in the aquaculture sector.

Against this background, the Zambian Government, in collaboration with FAO, undertook the elaboration of this curriculum (Part I) within the framework of the Zambia Aquaculture Enterprise Development Project (UTF/ZAM/077/ZAM). Furthermore, FAO complemented the practicality of this curriculum by drafting and refining the Training Manual (Part II), which has been tested in many African countries and with different stakeholders. To ensure complementarity of opportunities and clear progression of education and capacity development, each actor involved in the sector should strive to network with teaching institutions, researchers and producers to guarantee that the curriculum remains relevant and stays abreast of developments for aquaculture practitioners; this will include developing national, regional and international linkages with institutions involved in aspects of training for aquaculture. Therefore, this curriculum will function as a living document.


Pond fish farm ventures into cage culture
Seen from the satellite image is a fish farm on the bank of Mulungushi River in Central Province, where the river makes a U-turn. Occupying a plot of land of about 4 hectares, the farm carries out hatchery operations, nursing and grow-out culture of tilapia and catfish in plastic sheet-lined earthen ponds and cement tanks. The farm also sells fingerlings to other farmers.
Since 2019, the farm has expanded its tilapia farming operation by installing floating net cages mounted to tailor-made steel frames with plastic drums as floaters in the river, though this additional new operation is not visible in this satellite image because it is not up to date.
The next move planned by the farm is to install solar panels to generate electricity for its own use.
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CURRICULUM DEVELOPMENT AND RATIONALE

Sustainable aquaculture cannot be regarded only from a solely biological, technical, environmental or economic point of view. The sustainability of any aquaculture venture requires the combination of technical principles with enviro-socio-economic and governance principles. In that regard, forming innovative education and training programmes to create or enhance knowledge and skills and improve food security, nutrition, economic growth and employment are necessary to advance the sector in Africa.

This curriculum was developed as part of the Zambia Aquaculture Enterprise Development Project (UTF/ZAM/077/ZAM). It is foreseen that other African countries can adopt and adapt this curriculum and training materials dependent upon their specific context. Partnerships should be created with the ministries of agriculture, livestock and fisheries, and research and extension institutions as well as farmers.

The present document includes a training curriculum (Part I), which is further elaborated upon in the form of a comprehensive training manual on "sustainable aquaculture" (Part II – Modules 1 to 5). This document was designed as a resource guide, and addresses the needs of fish farmers, extension officers, government officers and financial institutions with or without specific knowledge of the aquaculture sector. Furthermore, the curriculum and training manual were also built to enhance the technical schools' (teachers and students) knowledge and competencies on sustainable aquaculture practices.

The training manual touches upon different aquaculture aspects, from technical, economic and financial matters to governance and social acceptability matters, with specific training lectures and exercises offered to practitioners (trainers and trainees), for the sound planning and implementation of sustainable aquaculture.

Curriculum main objectives

The curriculum covers the subjects and topics that need to be taught during short-, medium- and long-term courses in order for stakeholders to be able to make a real contribution to sector development in Africa.

Main objectives

1. Develop educational/training programmes on sustainable aquaculture to enable users of the curriculum and training manual to apply – interchangeably and through action learning – a holistic approach to aquaculture development, governance and economic principles along the entire value chain.
2. Develop knowledge competencies to allow users to be innovative and apply the information and gained skills appropriately, whether from the planning of the activity to the end goal of aquaculture that is the consumer's table, by using the technical foundations acquired during training to help decision-making, management and production systems.
3. Fostered within the framework of the existing aquaculture projects is the ongoing consideration and planning for the creation of a sustainable aquaculture development programme framework. In a holistic manner, it will integrate all disciplines required for a professional hands-on training course (farmers and extension workers), and for a medium- and long-term education curriculum that can serve technical and higher education schools and institutes.

Sub-objectives

1. Enhance the capacity of aquaculture stakeholders (farmers, traders and financial institutions) on the key technical, financial, economic and governance principles of conducting aquaculture.
2. Improve the capacity of trainees and trainers, students and lectures of technical schools and universities to develop a good understanding of the key principles and major factors affecting or boosting aquaculture development with real-life examples through practical learning and exchanges.
3. Acquire a sound knowledge of aquaculture governance through theoretical sessions and the ability to conceive their application in real-life situations.
4. Develop a good understanding of the major factors affecting the economics of aquaculture and of the key parts of a business plan for a commercial aquaculture venture.
5. Create teaching courses on technical, economic, governance and social aspects of sustainable aquaculture.
6. Develop practical training at the class and farm level to allow trainees to apply and master competencies (skills) from knowledge acquired from the theoretical sessions.

Scope of curriculum

The scope of a curriculum indicates the width and depth, the parameters, of what participants need to learn. It is a way to cover the whole subject while remaining focused on important subjects. Defining a scope avoids overwhelming the learners and enables the teachers to stay focused and evaluate progress.

The next sections provide an overview of the subjects covered by the curriculum, which will be further developed under modules that are designed to meet a specific number of learning objectives.

The curriculum is organized in five modules:

MODULE 1	The Technical Dimension of Sustainable Aquaculture
MODULE 2	The Governance and Social Dimension of Sustainable Aquaculture
MODULE 3	The Economic Dimension of Sustainable Aquaculture
MODULE 4	Extra Reading and Practices: Post-Harvest, Processing and Value Addition
MODULE 5	Practical Hands-On Training

Module 1 – THE TECHNICAL DIMENSION OF SUSTAINABLE AQUACULTURE

The Technical Module is the most comprehensive of all modules since it covers an extensive amount of the basic knowledge needed to set up and develop an aquaculture farm on a commercial basis (FAO, 2017a). It covers topics from selecting an appropriate location, to measuring and making the pond, to introducing the seed and the whole process until the harvest of fish appropriate for selling to the consumer.

The Technical Module is split into two parts. The first part consists of the key principles and definitions of terms needed to enable participants to grasp the basics of sustainable aquaculture aspects and progresses to the more technical aspects. The second part lays out the different types of aquaculture, seed production, farm management, feeds and nutrition as well as the required basic knowledge of on-site selection and pond construction (FAO, 2010).

Module 2 – THE GOVERNANCE AND SOCIAL DIMENSION OF SUSTAINABLE AQUACULTURE

The Governance Module comprises two parts. As in the other modules, each part is developed as a separate section designed to meet a specific number of learning objectives. The first section focuses on the role and types of aquaculture governance and drivers of sustainability and sets out the conceptual framework of aquaculture governance in the broad context of governance (FAO, 1999). It introduces the concept of sustainable aquaculture development as reflected in the FAO Code of Conduct for Responsible Fisheries (the Code), guidelines commonly referred to as "governance tools" (FAO, 1995). The second part reflects on the key guiding principles and trends in aquaculture governance, examines the principles of good governance, and highlights the growing importance of incorporating sound governance principles in the design and implementation of aquaculture policies, strategies and plans (FAO, 2017b). It looks at the challenges of governance in the framework of creating an enabling policy environment.

The social dimension part sets out the concept of how the sector may be perceived by the public and why this is an important issue in aquaculture. It references known misconceptions, truths and myths. Specifically, it shows how social acceptability can be addressed and why the perception of the public and involvement of mass media are important.

Module 3 – THE ECONOMIC DIMENSION OF SUSTAINABLE AQUACULTURE

The Economic Module consists of two parts. The first part is a general introduction to commercial aquaculture, planning and accounting, touching not only on the development of a business plan but also on the preparation of a budget and the introduction of other accounting tools (Hishamunda, Martone and Menezes, 2017). The second part presents the FAO user-friendly toolkit specially designed to guide important decisions regarding the development and expansion of commercial aquaculture.

Module 4 – EXTRA READING AND PRACTICES: POST-HARVEST, PROCESSING AND VALUE ADDITION

For aquaculture planning to succeed, care should be taken to look at the overall picture, from the production to the consumer. Additionally, post-harvest technologies are important to improvement of the fish quality, shelf-life and add value to the products besides facilitating access to markets.

While there are many factors hampering the full development of aquaculture value chains, this curriculum and training manual offer a good understanding of the basic techniques, methods and procedures to be followed during production, post-harvest handling and processing, allowing the producer to acquire basic skills and competencies to market higher-quality aquatic products and maintain a sustainable enterprise (INFOSA, 2009a, b, c, d, e; Menezes *et al*., 2016a, b).

Module 5 – PRACTICAL HANDS-ON TRAINING

Field visits to aquaculture farms will be organized, and whenever possible, trainees will acquire hands-on experience and apply the theoretical principles during the visits. Such visits expose trainees to a real scenario where simulations of aquaculture situations are provided. Trainees will be called upon to provide advice to visited farmers based on the technical, governance and economic principles they have learned during theoretical sessions. The programme for the field visits will be developed together with national entities and farmer associations. For participants desiring a training certification (8–12 weeks' training), in-farm practical training and daily performance at the farm will be part of the curriculum.

TRAINING

Training methodologies and materials

In developing the training based on the established curriculum, the principles of adult learning have been taken into account. Despite the vast amount of theoretical knowledge offered, a concerted effort was made to include as many examples as possible to raise the theory to the level of real situations and to include as many practical exercises as possible.

The training will provide both a sturdy theoretical background on the different topics as well as the opportunity of hands-on experience and exchange with and between the participants. Training will be developed in the form of lectures, seminars, working group sessions and field visits to aquaculture farms. Because an interactive approach is essential, during and around the lectures participants will be able to apply their knowledge on the subjects and connect the basic biological, economic and governance principles in farming systems to overall aquaculture planning.

During the working group sessions and other practical exercises, the participants may use internet tools, presentations and handouts to recall the theoretical principles, as the objective is not to test the literal knowledge of the subjects but rather the understanding and knowledge of the use of tools.

Training and manual structure

The training has been developed following the capacity-building needs emerging from the Zambia Aquaculture Enterprise Development Project (ZAEDP) assessments, as well as other needs manifested in various policy and technical capacity-building forums in sub-Saharan Africa.

The training manual is organized in five modules. The elaboration of the curriculum in terms of topics and training methods is then presented as an initial short overview that will be proposed over the course of the training.

Module 1 – THE TECHNICAL DIMENSION OF SUSTAINABLE AQUACULTURE[1]

The specific topics to be covered in the training are:

- Key terminologies for the principles of sustainable aquaculture
- Aquaculture overview: definitions of aquaculture
- Factors influencing carrying capacity in water
- Types of aquaculture
- Feeding and nutrition
- Ecological principles
- Technical principles
- Economic principles

[1] For in-depth reference, see FAO, 2017a.

Module 2 – THE GOVERNANCE AND SOCIAL DIMENSION OF SUSTAINABLE AQUACULTURE[2]

The specific topics to be covered in the training are:

- Introduction of the concept of governance in general and aquaculture governance in particular
- FAO guidelines on accountability, effectiveness, and efficiency and equity
- Good legal and regulatory frameworks, licensing policy and administration
- Public-private partnerships and contract farming in aquaculture
- Meaning and concept of social acceptability
- Perceptions, misconceptions, truths and myths
- Role of mass media and public perception

Module 3 – THE ECONOMIC DIMENSION OF SUSTAINABLE AQUACULTURE[3]

The specific topics to be covered in the training are:

- Sustainable commercial aquaculture: definition, objectives and basic principles
- Concept of commercial aquaculture
- Technical, social and economic reasons for performing commercial aquaculture
- Proper farm management: budget, income statement and financial analysis
- Business plan
- Prerequisites for conducting commercial aquaculture
- Introduction and use of the FAO "User Friendly Tool for Investment Decision Making in Aquaculture" (UTIDA)

Module 4 – EXTRA READING AND PRACTICES: POST-HARVEST, PROCESSING AND VALUE ADDITION

The specific topics to be covered in the training are:

- The importance of proper fish handling, post-harvest and value addition
- Salting and drying fish
- Smoking fish
- Chilling fish
- Freezing fish
- Sanitary conditions in fish markets

Module 5 – PRACTICAL HANDS-ON TRAINING

The practical sessions will cover specific topics derived from the other modules, and will provide instructions for the exercises, elaboration of some of the exercises and the forms to fill in. In each module, the exercises are mentioned or announced. However, the trainer should be creative and further elaborate and propose practical exercises to the trainees based on the circumstances where the training takes place and the evolution and development of the sector.

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[2] For in-depth reference, see FAO, 2017b, and Murekezi, Menezes and Ridler, 2018.
[3] For in-depth reference, see Hishamunda, Martone and Menezes, 2017.

Examples and exercises can be found as follows:

- Exercises related to the Technical Module (Module 1)
- Exercises related to the Governance Module (Module 2)
- Exercises related to the Economic Module (Module 3)
- Exercises related to the use of UTIDA: User-Friendly Tool for Investment Decision Making (Module 3)

Logistics and tips for trainers

In the short term, the training can be condensed over seven to ten days with further practical sessions at the farm level. It can also be offered and conducted for certification of farmers, in which case the training should last a minimum of 26 weeks with practical hands-on exercises in aquaculture farms. However, this curriculum can also be used by aquaculture and agricultural technical schools, as the included materials can be taught for one extended period of 12–14 months.

Tips for trainers and participants

Before each session, the trainers should send some materials in the form of questionnaires, readings, etc., to the participants. This will allow the participants to come better prepared to the session and to think about the topics to be addressed.

Trainees and trainers should collect data and information from farms to be able to elaborate on practical exercises.

Trainees and trainers should resort to other country-specific training materials and guidance, such as, for example, the "Zambia Aquaculture Entrepreneurs' Incubation Programme Training Manual".[4]

[4] Ministry of Fisheries and Livestock. 2018. Zambia Aquaculture Entrepreneurs' Incubation Programme Manual. Zambia Aquaculture Enterprise Development Project, Lusaka, Zambia.

Training curriculum summary

Objectives	The objective of the course will be to: Touch upon different aquaculture aspects, from technical, economic and financial to governance and social acceptability matters, with specific training lectures and exercises offered to practitioners (trainers and trainees).
Target	Aquaculture government officials, extension services, farmers, financial institutions, media, technical students and aquaculture/rural trainers in general.
Participant profile	The training curriculum is designed for participants from private and public organizations that play a production and advisory role in the sector, as well as agricultural/aquaculture technical students and trainers and any agent of social media. The course will assume a basic theoretical or practical knowledge on aquaculture; it will raise public awareness and promote sustainable aquaculture value chains at different levels (small-medium-large) and at different levels of enterprise/business.

By the end of the training on sustainable aquaculture, trainees will be able to interchangeably apply a holistic approach to aquaculture development, governance and economic principles along the whole value chain, from planning the activity to the consumer's table, using the technical foundations acquired during training to inform decision-making and management and implement production systems (Table 1).

Table 1: Topics, purpose and timing

Topic	Purpose	Time	
		Short-term courses (7–12 days including practical)	*Medium to long term (from 26 to 30 weeks)*
INTRODUCTION **Importance of fisheries and aquaculture**	This session will provide an overview of the global fisheries and aquaculture situation, and more specifically in Africa Participants will engage in a Q&A session	45-minute presentation 20-minute plenary session Q&A	½ day
MODULE 1 **Overall key principles of aquaculture**	This session will address the scientific and technical basis for sustainable aquaculture development. It will discuss the most important key aquaculture terminologies, such as the following: Aquaculture overview: definitions of aquaculture Types of aquaculture Ecological principles Factors influencing carrying capacity in water Factors influencing water quality Feeds and nutrition Participants will also obtain knowledge on the key aquaculture economic and governance terminology (which will be further developed in Modules 2 and 3) Participants will be working in groups and plenary sessions for Q&A	10 hours 20-minute Q&A session and working groups after every two hours	2 weeks Daily practical sessions on the various topics
MODULE 1 **Site selection and infrastructure**	This session will provide an introduction to the basic concepts of site selection and address the design structure of fish ponds and reservoirs Participants will be working in groups followed by a conclusion and a Q&A session	5 hours 20-minute Q&A session after every hour Practical sessions at the farm level are detailed in Module 5	1 week
MODULE 1 **Seed production**	This session will introduce relevant aspects of seed production and hygiene in hatcheries Participants will be working in groups and engaging in a Q&A session throughout the lectures	8 hours 20-minute Q&A session after every hour Practical sessions at the farm level are detailed in Module 5	2 weeks

Topic	Purpose	Time	
		Short-term courses (7–12 days including practical)	*Medium to long term (from 26 to 30 weeks)*
MODULE 2 **Fish value addition**	This session will address different handling and processing techniques to preserve fish and add value to fish through the development of fish products Participants will be working in groups followed by a conclusion and Q&A session	12 hours 30-minute Q&A session after every hour	2 weeks with practical hands-on training
MODULE 2 **Aquaculture planning**	This session will address the major legal and institutional policy tools and the role of aquaculture governance	7 hours 20-minute Q&A session after every hour	2 days
MODULE 2 **Governance models**	This session will address the trends in aquaculture and the types of aquaculture governance as well as its pillars and principles	6 hours 20-minute Q&A session after every hour	1 and ½ days
MODULE 2 **public-private partnerships (PPPs) and contract farming (CF) in aquaculture**	This session introduces the concept of PPP and CF in aquaculture	4 hours 20-minute Q&A session after every hour	1 day
MODULE 2 **Perceptions, misconceptions, truths and myths**	Participants will be introduced to the role of mass media in the perceptions, misconceptions and acceptance of aquaculture	4 hours interactive	1 and ½ days
MODULE 3 **Economic key terminologies in aquaculture farm management**	Participants will be introduced to the reasons for developing commercial aquaculture	2 hours 20-minute Q&A session	1 and ½ days
MODULE 3 **Basic principles in commercial aquaculture**	Participants will be introduced to the factors affecting economics and production, as well as record-keeping and proper farm management	3 hours 20-minute Q&A session after every hour	2 days
MODULE 3 **Budgeting, accounting and a business plan in aquaculture**	Participants will be taught to create an income statement and balance sheet, and learn about cash flow and financial analysis	8 hours 20-minute Q&A session after every hour	1 week

Topic	Purpose	Time	
		Short-term courses (7–12 days including practical)	*Medium to long term (from 26 to 30 weeks)*
MODULE 3 **The FAO "User-Friendly Tool for Investment Decision Making in Aquaculture" (UTIDA)**	Participants will be introduced to the UTIDA tool	8 hours 2-hour presentation in theory and 6 hours of interactive computer practice	1 week
MODULE 3 **Financial risks and hazards in developing aquaculture as a business**	Participants will learn how to identify and analyse risks and different challenges regarding risk analysis in an aquaculture business	4 hours 20-minute Q&A session after every hour	2 days
MODULE 4 **Fish value addition**	This session will address different handling and processing techniques to preserve fish and add value to fish through the development of fish products Participants will be working in groups followed by a conclusion and Q&A session	12 hours 30-minute Q&A session after every hour	2 weeks with practical hands-on training
MODULE 5 **Practical hands-on training**	Practical sessions	3 days at the farm level Practical sessions at the classroom level are determined *in loco* by the trainer	From 4 to 6 weeks at the farm level


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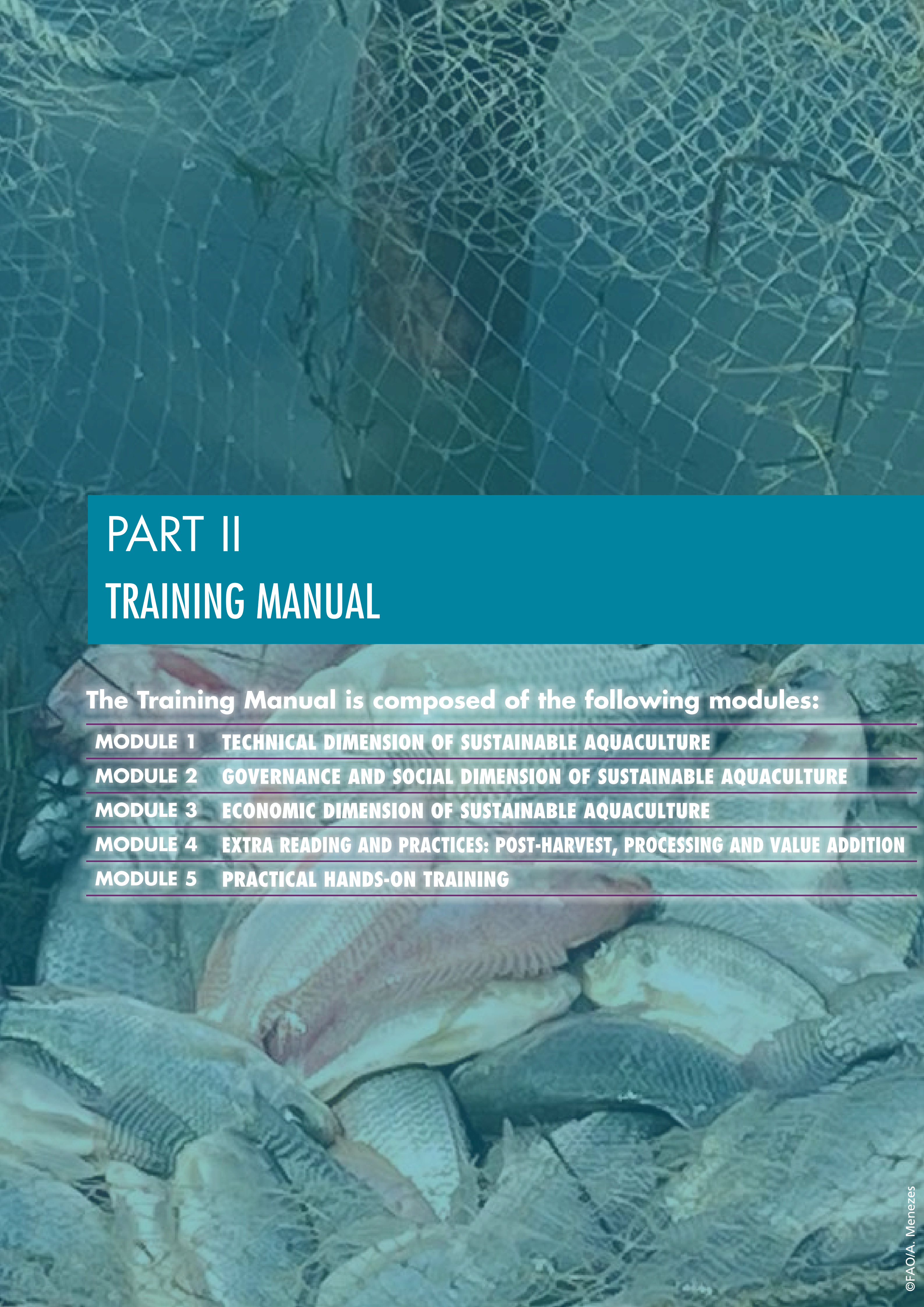

PART II
TRAINING MANUAL

The Training Manual is composed of the following modules:

MODULE 1	TECHNICAL DIMENSION OF SUSTAINABLE AQUACULTURE
MODULE 2	GOVERNANCE AND SOCIAL DIMENSION OF SUSTAINABLE AQUACULTURE
MODULE 3	ECONOMIC DIMENSION OF SUSTAINABLE AQUACULTURE
MODULE 4	EXTRA READING AND PRACTICES: POST-HARVEST, PROCESSING AND VALUE ADDITION
MODULE 5	PRACTICAL HANDS-ON TRAINING

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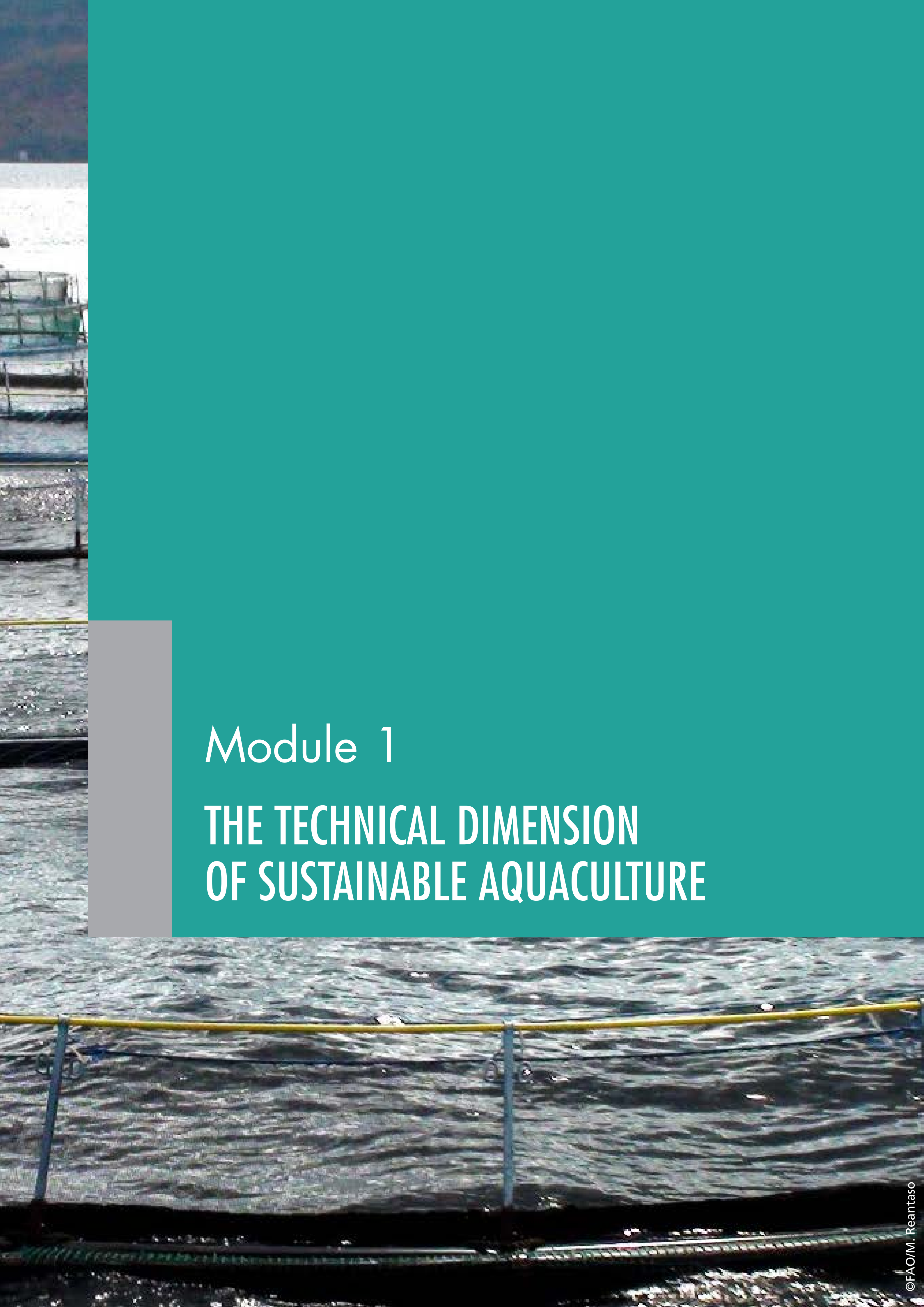

Module 1

THE TECHNICAL DIMENSION OF SUSTAINABLE AQUACULTURE

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INTRODUCTION TO BASIC TERMINOLOGY

The first part of this module consists of the key principles and definitions of terms needed to enable participants to grasp the basics of sustainable aquaculture aspects and progress to the more technical aspects.

KEY PRINCIPLES OF AQUACULTURE

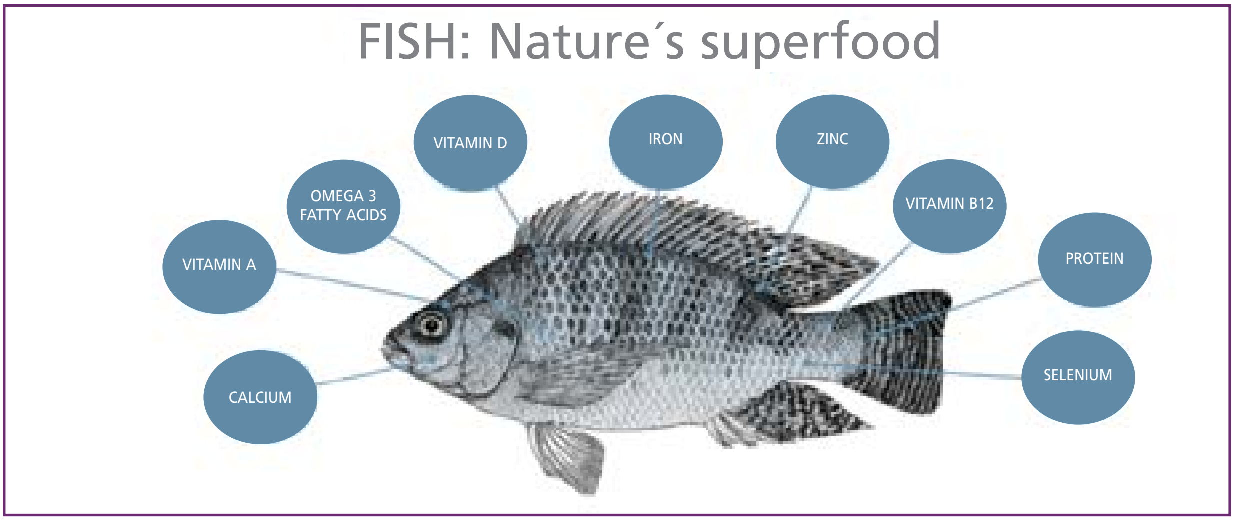
The Technical Module comprises five segments and specific interaction sessions where participants will exchange and discuss their own experiences. The purpose of this module is to enhance the knowledge and capacities of individuals seeking to understand and apply the overall technical concepts necessary to set up, develop and manage a commercial aquaculture farm.

The module summarizes the essence of aquaculture with scientific, technical and management principles and practices, and lists the main building blocks for the economic dimension of aquaculture farming and development. These principles hold true regardless of the aquaculture product (e.g. fish, shrimp and molluscs) and the farming system (e.g. pond, cage and tanks). However, respective biological and socioeconomic principles must be combined to ensure that the aquaculture farm is profitable and sustainable.

Literature for the development of the Technical Module is listed in the references section.

At the end of this module/session, participants will:
Realize and be able to apply the main key principles and good aquaculture practices.
Understand the ecological principles that determine the weight and growth of an organism that can be harvested from a unit of water in a given period and at a specific level of farming culture.
Develop an understanding of the relationship between the farmed organism, its stocking density, the nutrient inputs into the culture unit, and the effect of all these elements on water quality.
Be aware of the differences in management intensity, which consequently impact the production rate and economic value.
Comprehend that sustainable aquaculture cannot be regarded from a solely biological and technical point of view. The sustainability of any aquaculture venture must be combined with socioeconomic and governance principles to ensure that aquaculture is profitable and sustainable and responds to the goals of food security, nutrition and people's well-being, as fish and fish products are considered to be nature's superfood (Figure 1).

Figure 1: Nutritional elements in fish products



The intention of this training manual is to promote the implementation and development of responsible aquaculture.

The foundation for successful aquaculture is the understanding of ecological principles, which determine the weight of an organism that can be harvested from a unit of water in a given period and at a level of culture. In order to be successful, the farmer needs to develop an understanding of the relationship between the farmed organism, its stocking density, the nutrient inputs into the culture unit, and the effect of all these elements on water quality.

Segment 1: Some essential definitions

This first segment of this chapter starts with a few basic terms and concepts, some of which will be developed further in this and subsequent chapters (FAO, 2017a; Lovshin, 1999).

What is aquaculture?

- Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants (FAO, 2017a).
- Aquaculture implies some form of human intervention in the rearing process to enhance production.
- A farm for aquatic products contains stock owned collectively or by one individual.
- Aquatic organisms that are exploitable by the public from a common property resource are capture fisheries and NOT aquaculture.

The farming of aquatic organisms and plants can be done for several purposes, such as (human) consumption but also for jewellery or for the cultivation of ornamental fish. Figure 2 shows the different uses of aquaculture products.

Figure 2: Use of aquatic products

Animals and plants are farmed for:

- **Food**
- **Ornamental fish**
- **Bait**
- **Jewellery**
- **Pharmaceuticals**
- **Recreation**
- **Stock enhancement**

Photos clockwise from top left: ©FAO Zambia, ©L. Lovshin, ©FAO/A. Stankus.

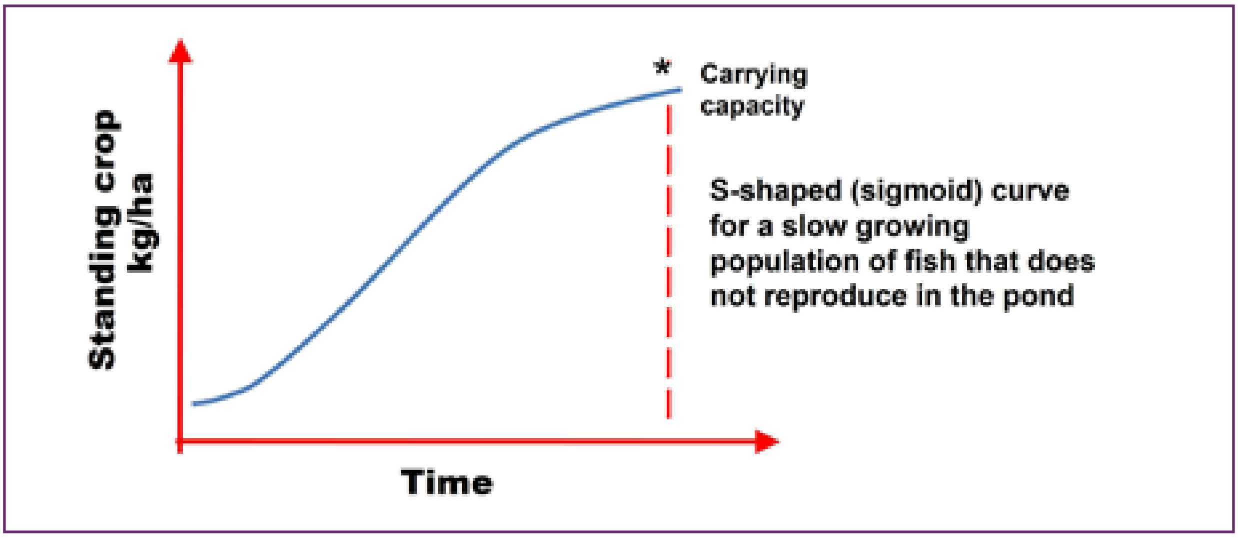
What is the carrying capacity?

Aquaculture farming comprises various steps, from pond construction, seed production and nursery, to grow-out, harvest and markets. For every single step in the process of aquaculture farming, we need to know the carrying capacity and the production factors, including the factors influencing water productivity, the production rate and the yields.

Carrying capacity is the fish weight in a given unit of water where growth stops. Carrying capacity is recorded as kg/ha, kg/m^3, and lb/acre, among others. The carrying capacity measures the maximum biomass of a farmed species that can be supported without violating the maximum acceptable impacts to the farmed stock and its environment in a given unit of area (Figure 3) (Stigebrandt, 2011). Time is not a factor in determining when carrying capacity is reached.

No matter what the farming system used is, the carrying capacity is key.

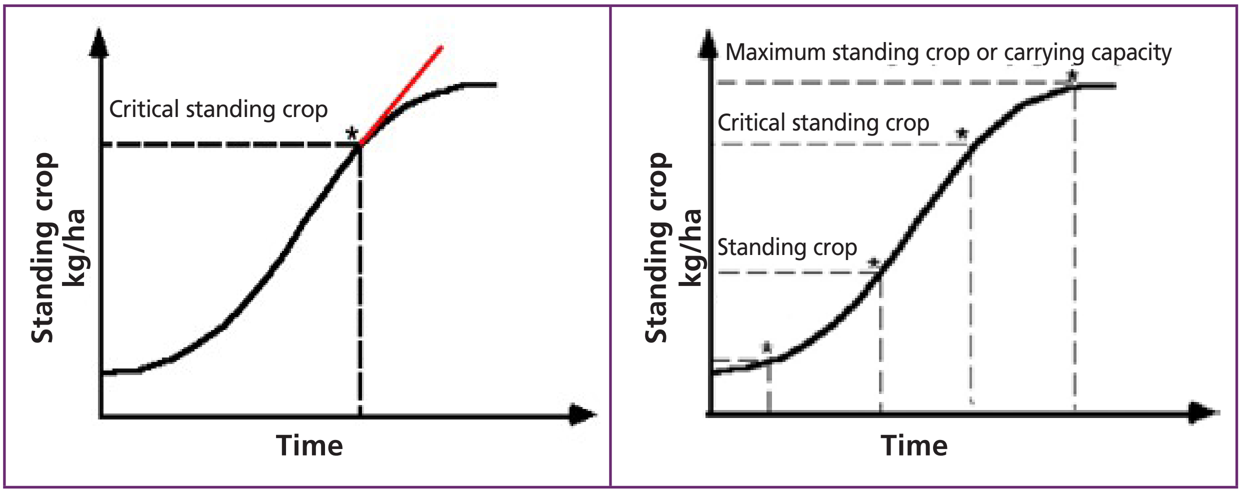
Figure 3: How carrying capacity works



What is a standing crop?

A standing crop is a biomass in a unit of area at a given moment where growth slows from the maximum growth line (Figure 4). Standing crop can be expressed as, for example, pounds per acre (lb/acre), kilograms per hectare (kg/ha), and kilograms per cubic metre (kg/m^3).

Figure 4: Standing crop and carrying capacity



What does the term yield indicate?

When using the term yield in aquaculture, we need to differentiate between different types of yield and how it links to the production rate, as demonstrated in the box below. The gross yield defines the total biomass of the organisms harvested per unit of area (volume) in a given period. It can be expressed as, for example, pounds per acre per year (lb/acre/yr), kilograms per hectare per year (kg/ha/yr), and kilograms per cubic metre per year (kg/m^3/yr). The net yield indicates the total weight of the organisms harvested minus the total weight of organisms stocked per unit of area (volume) in a given time.

Gross yield versus net yield	
Gross yield Total biomass of organisms harvested per unit of area (volume) in a given period of time. **Represented in:** kg/ha/yr lb/acre/yr kg/m³/yr **Example:** 5 000 kg/ha/yr	**Net yield** Total weight of organisms harvested minus total weight of organisms stocked per unit of area (volume) in a given period of time. **Represented in:** kg/ha/yr lb/acre/yr kg/m³/yr
Gross yield versus net yield	**Production rate**
Net yield example **Gross yield minus stocking weight = net yield** 5 000 kg/ha/yr gross yield minus 500 kg stocking weight = **4 500 kg/ha/yr net yield**	**Production rate** The increase in weight (growth) of a population of organisms per unit area in a given period of time. **Represented in:** kg/ha/day lb/acre/day kg/m³/day

Segment 2: Factors influencing carrying capacity in water

Carrying capacity is defined by all of the following factors:

- Water quality factors, specifically dissolved oxygen, temperature, ammonia, water flow and volume;
- Fish species and size;
- Feed/nutrients;
- Polyculture.

For instance, different species and sizes of fish have different requirements related to water quality. Feeds influence carrying capacity because of their impact on the quantity of fish biomass in the unit and on the water quality. Water flow and volume influence the carrying capacity because they determine the water quality and the presence or absence of natural feeds.

Water quality

The quality of water determines the success or failure of any aquaculture operation. This section explains why water quality is important for production and describes how to manage the related factors during production.

A unit of water can produce and maintain only a certain weight of fish (known as the "carrying capacity"), depending on a number of factors and their interactions. Water has a certain carrying capacity; as noted above, there are several natural factors that influence that capacity. Human interference results in additional factors influencing the carrying capacity.

Alkaline waters are normally more fertile and productive than acid waters because alkaline waters have more minerals (nutrients) available for plant growth in contrast to acid waters.

Freshwater with a pH between 5.5 and 6.5 and/or alkalinity below 20 mg/L should be limed to improve water productivity.

If the total alkalinity (mg $CaCO_3$/L) is	If the soil pH is	Apply this amount of lime
<5	<5	3 000 kg/ha
5–10	5.0–5.4	2 500 kg/ha
11–20	5.5–5.9	2 000 kg/ha
21–30	6.0–6.4	1 500 kg/ha
31–50	6.5–7.0	1 000 kg/ha

Note: $CaCO_3$ = calcium carbonate.

As previously noted, the weight of fish that can be produced in fertilized ponds is dependent upon the ability of water to produce the necessary plants. The ability of water to produce the plants is dependent upon such factors as light, temperature, minerals, carbon and dissolved oxygen. Any of these resources alone or in combination can be a limiting factor and can reduce photosynthetic production.

Limiting factors and levels of tolerance to environmental and human induced factors:

➤ Liebig's "law" of the minimum

Liebig's law states that growth only occurs at the rate permitted by the most limiting factor.

The availability of the least abundant factor will tend to be the limiting one; or, to put it more plainly, "A chain is only as strong as its weakest link." The basic requirements vary with the species and with the situation.

➤ Shelford's "law" of tolerance

An organism not only has a minimum requirement but also a maximum level of tolerance to succeed. Thus, organisms have an ecological minimum and maximum with a range in between which represents the limits of tolerance.

Organisms may have a wide range of tolerance for one factor and a narrow range for another. For example, tilapia has a narrow temperature tolerance but a wide tolerance regarding water quality.

Factors that influence tolerance

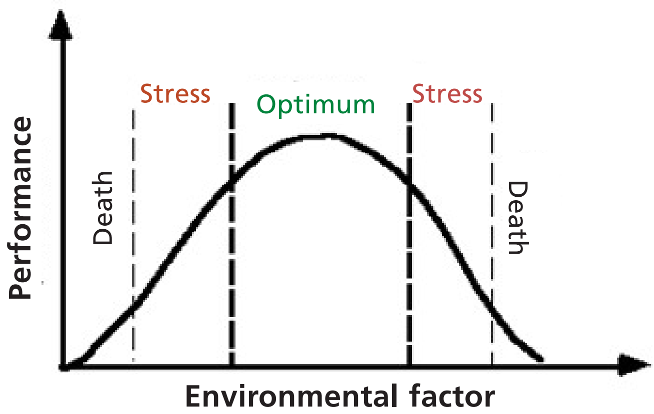
Important factors that influence tolerance of a farmed organism are species, age, genetics, environmental interactions and the rate of change, and stocking density, among others (Figure 5).

Figure 5: Environmental factors and performance

Factors that influence tolerance

Relationship of levels of an environmental factor and its influence on the growth of the aquatic organism cultured

- **Species**
- **Age**
- **Genetics**
- **Environmental interactions and the rate of change**
- **Stocking density**



Dissolved oxygen

Maintenance of suitable dissolved oxygen levels is more dependent on photosynthesis than on diffusion from the air.

In the absence of rooted vegetation, the more fertile the water, the denser the phytoplankton concentration, the shallower the light penetration, and the lower the photosynthetic levels, thus reducing dissolved oxygen in deeper waters. Heavy phytoplankton concentrations in top waters cause high dissolved oxygen in surface waters and low dissolved oxygen in deeper waters. Photosynthesis cannot proceed at rates exceeding respiration at depths where the light intensity is lower than 1 percent.

REMEMBER

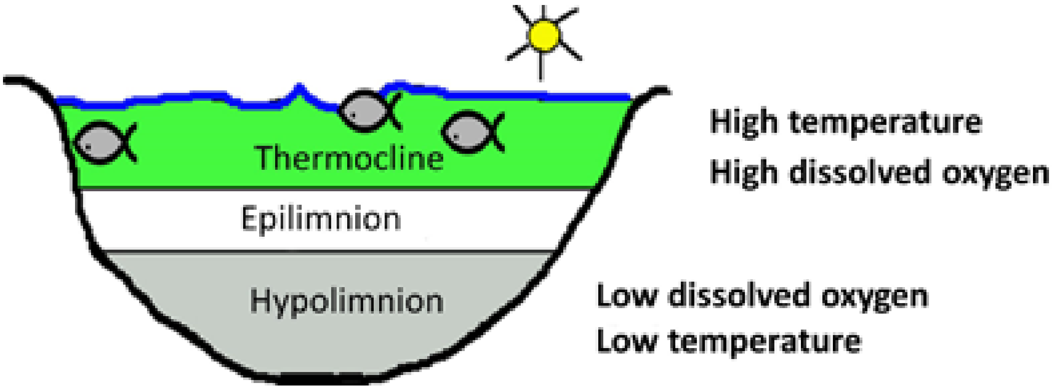
Dissolved oxygen:
- Aquatic plants and animals require oxygen, just as air breathing animals do.
- Oxygen contained in water is called "dissolved oxygen".

Biological oxygen demand: By carefully monitoring the early morning dissolved oxygen, farmers can observe the slow decline in dissolved oxygen concentrations and predict when dissolved oxygen could reach critical levels. If phytoplankton populations remain, dissolved oxygen increases rapidly with photosynthesis during the day.

The deeper the fish pond, the higher the percentage of the total volume that is deficient in dissolved oxygen and the greater the danger of fish kills.

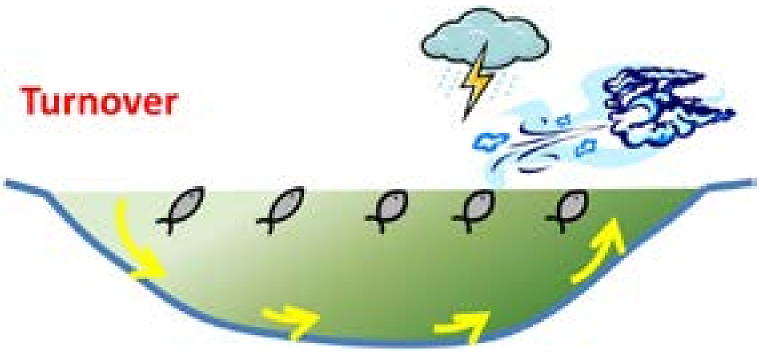
Thermal stratification is common in deep-water ponds during the hot/rainy season (see Figure 6). As the summer progresses, a greater percentage of the total pond volume becomes devoid of dissolved oxygen. In the summer months, the mixing of oxygen deficient water in the hypolimnion with the epilimnion rich in oxygen can lower the dissolved oxygen and cause fish deaths.

Figure 6: Thermal stratification



The mixing of pond water layers is called turnover. Turnover is caused by the cooling of the surface waters, usually because of heavy rainfall accompanied by strong winds during a thunderstorm (Figure 7). The best way to avoid thermal stratification is to mix the pond water with an aerator or a water blender. However, as the use of aeration can be costly due to the cost of fuel or electricity increasing production costs, such a decision to use it should be weighed against production objectives.

Figure 7: How to eliminate stratification



Turnover is difficult to forecast since the storms causing turnover are likewise hard to predict. Once turnover occurs, dissolved oxygen (DO) levels can decline rapidly and fish can die quickly, within minutes.

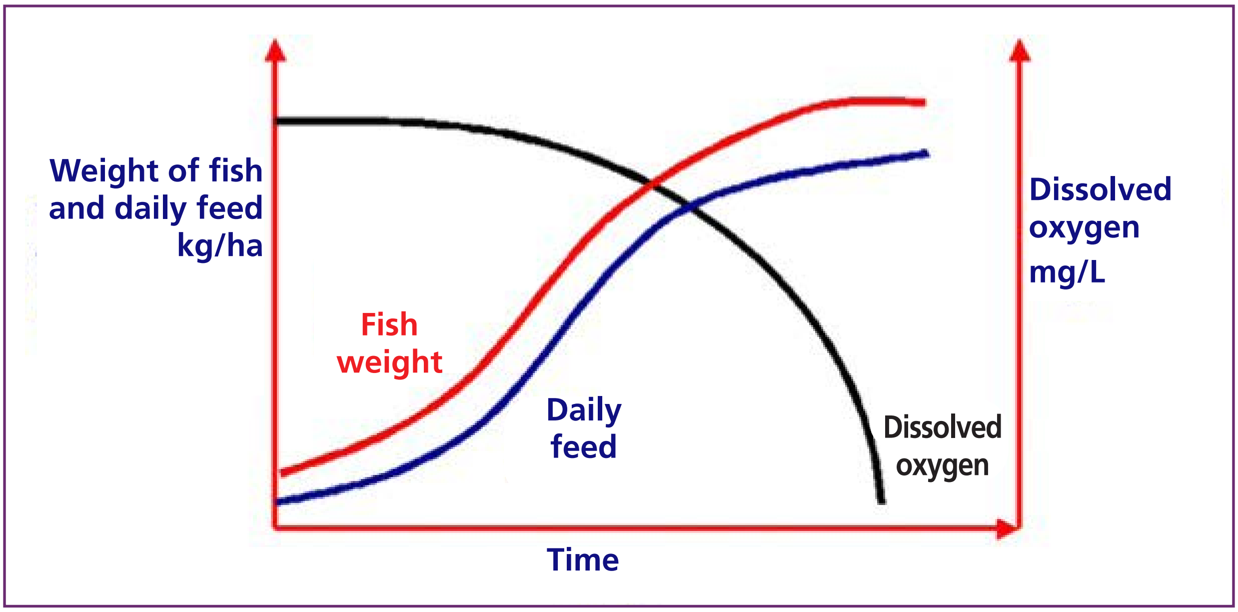
Phytoplankton die-off: Complete or partial phytoplankton deaths are difficult to predict because the causes of such die-offs are not known. An experienced farmer can tell if a phytoplankton die-off is near by the colour of the pond water reflected in the amount of phytoplankton in the water. After a complete phytoplankton die-off, the water colour will change from green to muddy or tea coloured. DO levels will drop slowly after a die-off: Critical concentrations are normally reached about 12 hours later. DO levels will remain low for several days, as the phytoplankton that replenishes the DO during photosynthesis is not present. Some farmers who manage heavy phytoplankton populations reduce the chances of die-offs by killing a portion of the population with chemicals (copper). Phytoplankton-eating fish will also control phytoplankton and reduce the chances of a die-off. Low DO is best controlled with aeration together with water exchange (if water is available to exchange large volumes of water) and lowering or stopping feeding until DO increases.

The maximum biomass of fish that can be produced in static water without aeration depends on the quality of the feeds and the quantity of feeds that can be distributed into the pond daily without causing DO concentrations in the pond to drop to levels that are stressful or fatal to the fish.

The quantity of feed that can be fed per unit area per day is limited by the waste disposal and reoxygenation efficiency of the ecological system. The amount of feed that can be fed per unit of water per day is influenced by the fish species raised. These topics will be developed in the section Feeding and nutrition.

Figure 8 shows the relationship of fish weight, feeding rate and dissolved oxygen level over time.

Figure 8: Fish weight, feeding rate and dissolved oxygen



Water exchange and ammonia

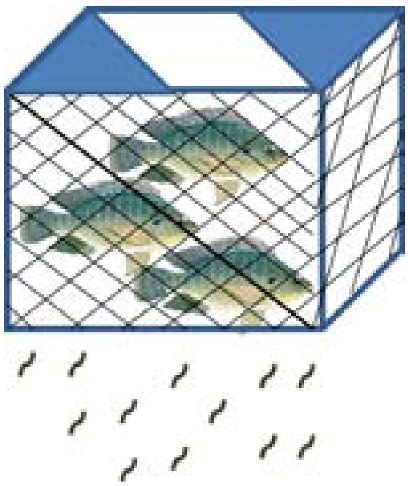
Carrying capacity per unit of area can be increased by exchanging water to reduce ammonia concentration and organic matter and increase dissolved oxygen levels, allowing for higher rates of feeding.

Systems using water exchange:

1. Partial water exchange – less than 2 total volume of water exchanges/day.
2. Continual water exchange – 1 to 10 total volume of water exchanges/hour.

Figure 9 shows special consideration to waste disposal when using cage culture. Placement of fish should observe proper waste disposal space and site.

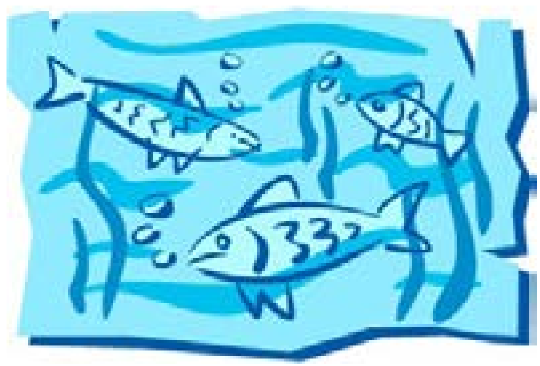
Figure 9: Cage culture



Fish species and size

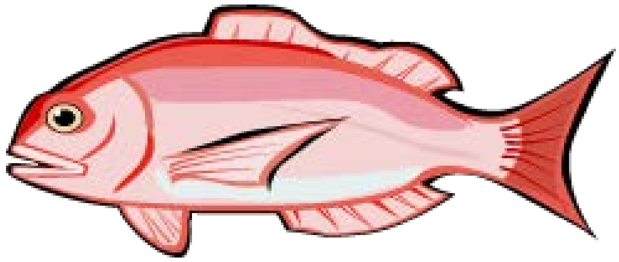
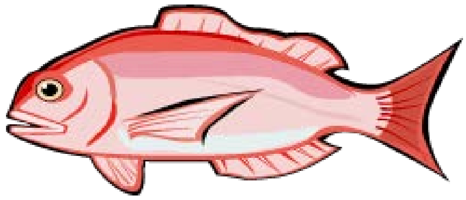
Culture species influence the carrying capacity by fish size, feeding habits and resistance to poor water quality.

- Fish size
- Feeding habits
- Resistance to poor water quality



Fish size

For a given carrying capacity, the weight of fish can be composed of a large number of small fish or a small number of large fish of the same species.

Example: Carrying capacity = 4 000 kg/ha 8 000 fish × 500 g each = 4 000 kg/ha	
Or 16 000 fish × 250 g each = 4 000 kg/ha	

Feeding habits

Because some fish are herbivorous, some omnivorous and some carnivorous, and therefore have different nutritional requirements and digestion times, their feeding times should be planned accordingly.

Resistance to poor water quality

Like all living organisms, farming aquatic species requires good and healthy environments to allow fish to achieve their potential. Water quality is the first factor to consider in fish farming management (laboratory, hatchery, tanks, ponds, cages or any other farming systems). Unfortunately, in Africa and many other parts of the globe, farmers usually neglect farm management practices and fish become less and less resistant to diseases and to other external factors because they are already striving to survive in poor water quality environments.

For farmed fish species, the maximum growth rate occurs in water with an optimum level of pH, dissolved oxygen (DO), carbon dioxide (CO_2), salinity, un-ionized ammonia (NH_3), etc. This optimum water quality needs to be determined, since it varies for each fish species. In general, a good growth rate will occur in waters with:

- DO above 5 mg/L;
- pH between 6.5 and 8.5 in the morning;
- CO_2 less than 10 mg/L; and
- NH_3 less than 0.05 mg/L.

You can control the carrying capacity by providing higher-level conditions.

When DO levels become a limiting factor in feed and standing water ponds, aeration can be used to raise DO concentrations, permitting increased feeding rates and thus increasing the carrying capacity per unit area of the pond (see Figure 10 and Figure 11).

Figure 10: Feeding rate with and without aeration

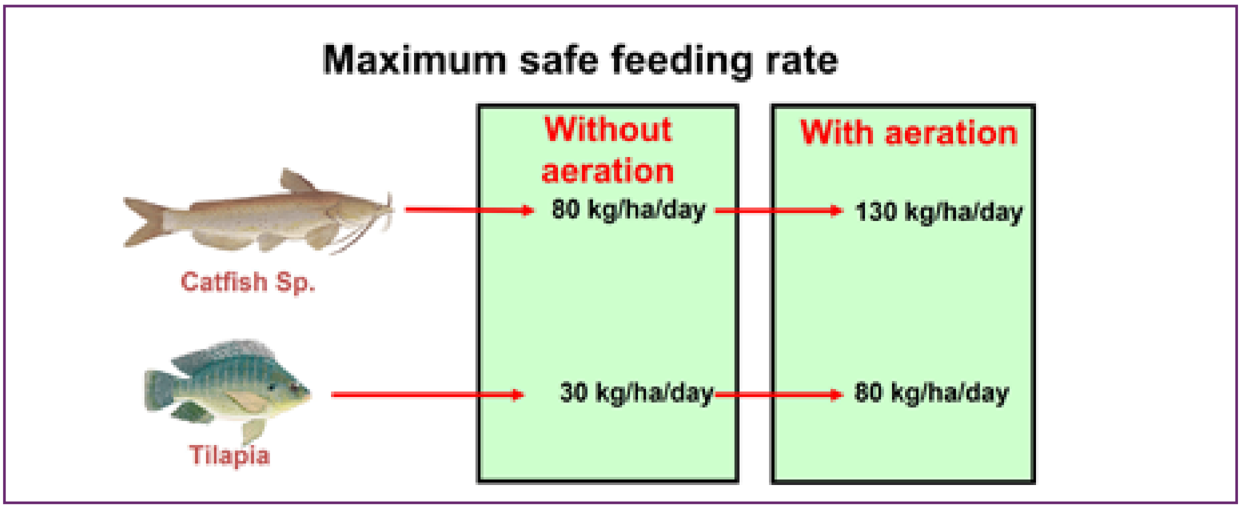
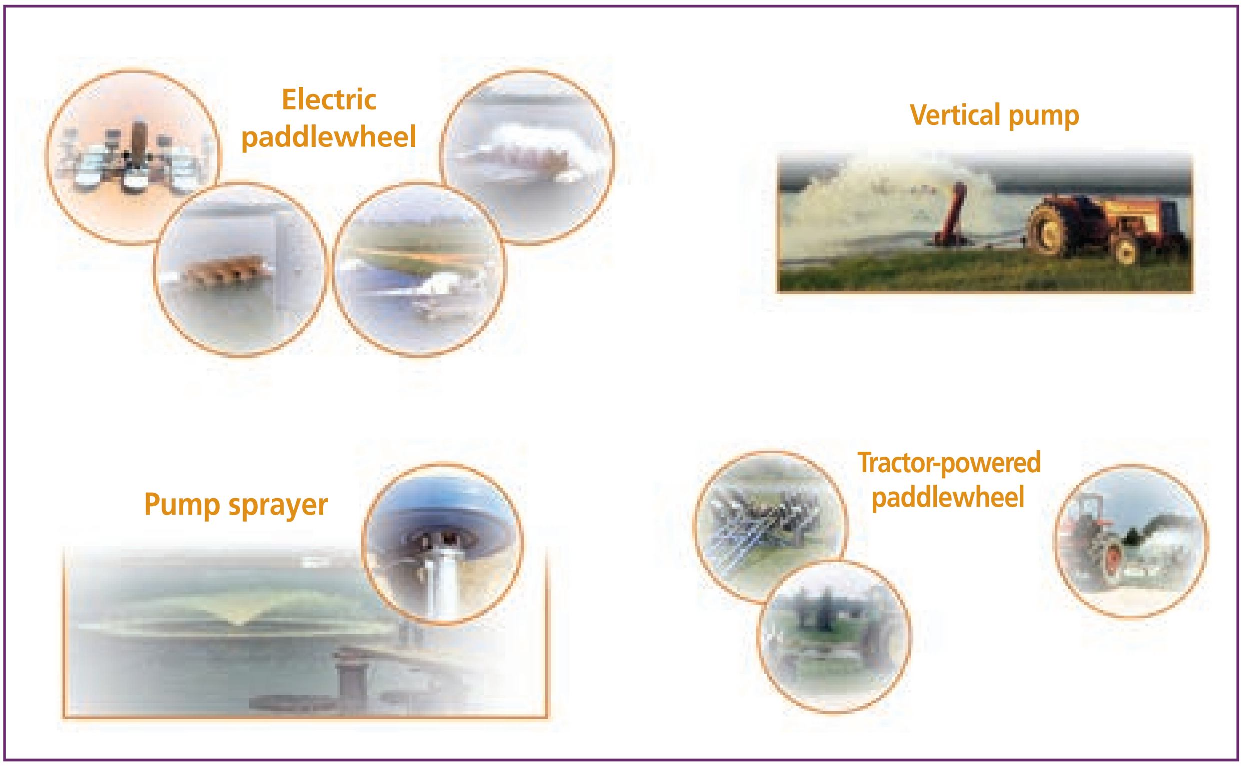


Figure 11: Mechanical tools creating aeration



Photos: ©L. Lovshin.

Feed

If fish species are consuming all the natural food organisms existing in a pond and the carrying capacity of the pond itself has been reached, an increase in carrying capacity can be obtained by providing supplemental feed.

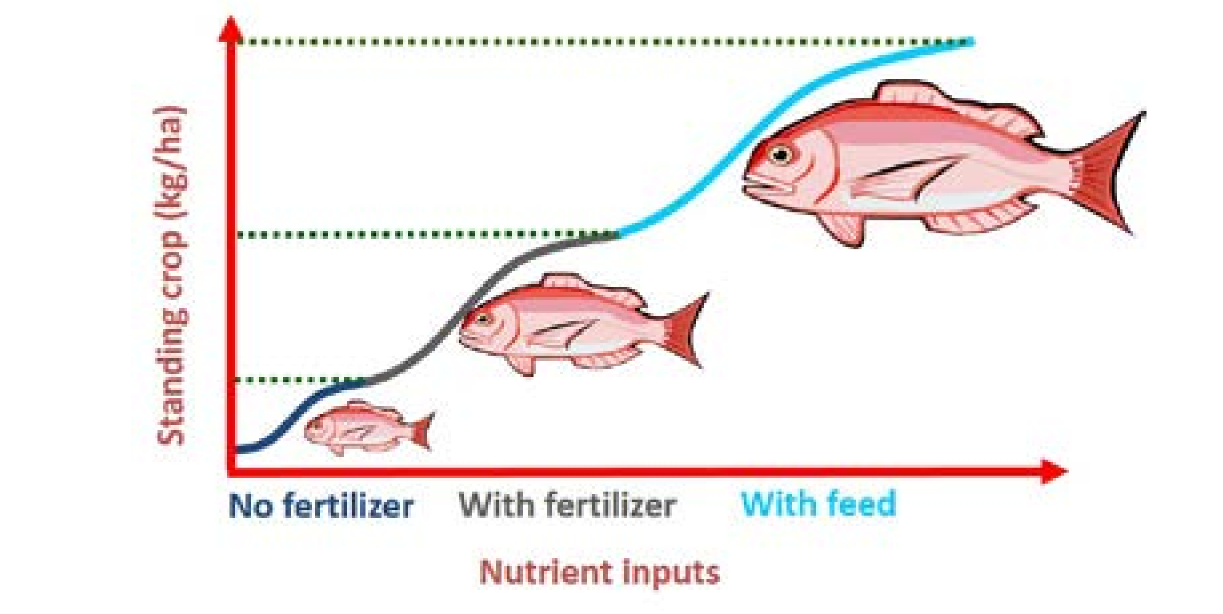
When feed is supplied as a pond supplement, its quality must be upgraded by natural fish food organisms eaten by the fish. Supplemental feed is not nutritionally complete but provides a source of energy to complement protein-rich natural feed. Examples are rice bran, wheat bran and cottonseed meal. Conversion of supplemental feeds by tilapia is usually 3–5 kg of feed per kilogram of weight gained.

Feed can also be problematic if not well managed; and, normally, it is the main source of nitrogen. When fish eat feed, they excrete ammonia, which is toxic to aquatic animals.

Quantity and quality of supplemental feed

When the fish in a pond are fully utilizing the natural food organisms present and the carrying capacity of the pond has been reached, an increase in carrying capacity can be obtained by providing supplemental feed (Figure 12).

Figure 12: Nutrients and growth



Supplemental feed is not nutritionally complete but provides a source of energy to complement protein-rich natural food such as phytoplankton and zooplankton (Figure 13).

Figure 13: Various stages of zooplankton

Photos: ©FAO photo library.

Nutrients

The natural fertility of water — i.e. its quantity of minerals — is dependent upon the fertility of watershed, pond soils, and the quality and quantity of water used to fill the ponds. In general, water in high rainfall areas is low in minerals due to excessive leaching of the soils; on the other hand, water in low rainfall areas is high in minerals due to evaporation, which leaves the minerals behind. If fertilizers and pesticides placed on watersheds gain access to the culture unit, they can influence the productivity of the cultured organisms (FAO, 2017a).

The principal limiting minerals are the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and the micronutrients (or trace minerals).

The Redfield ratio, i.e. the ratio of carbon (C), nitrogen and phosphorus of phytoplankton, is 50:10:1 (C:N:P), so ponds should have about 10:1 (N:P), i.e. ten parts of nitrogen to one part of phosphorus for the best phytoplankton growth (Goldman, 1979).

In summary: The primary productivity of a unit of water and its ability to produce natural food organisms can be increased by adding inorganic and organic fertilizers – for example, nitrogen, phosphorus and potassium – to the water to increase its carrying capacity.

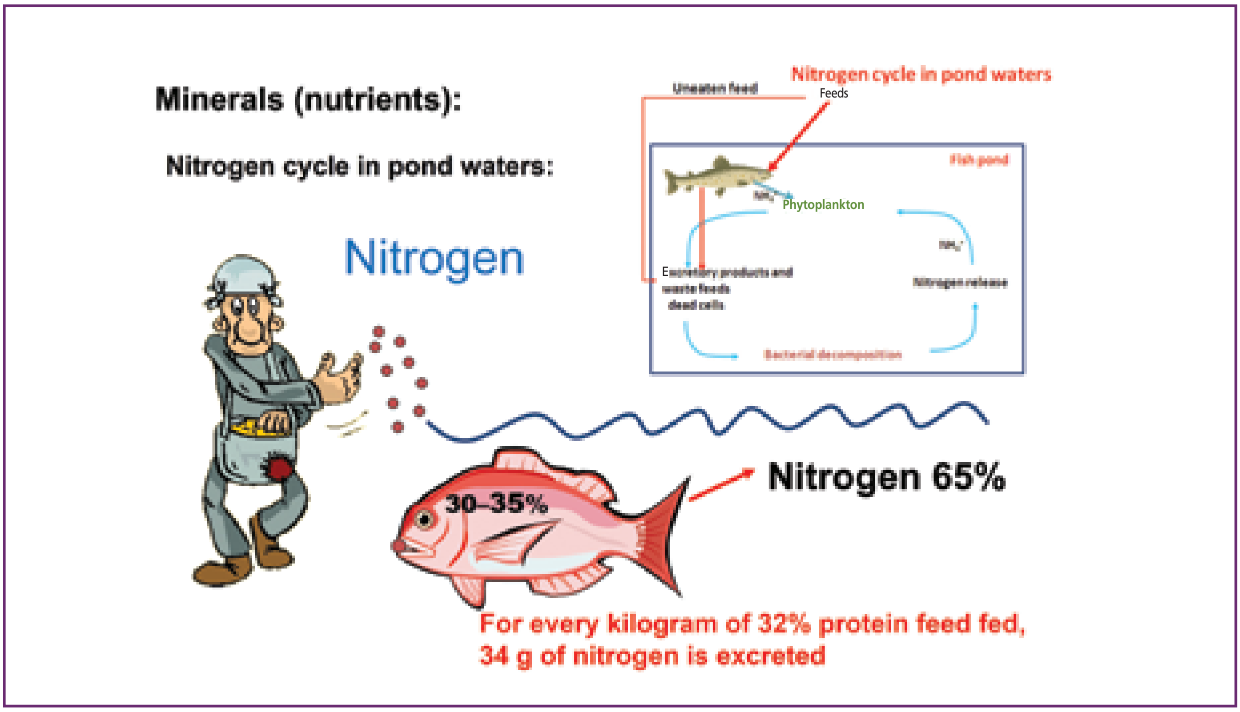
Fertilizers

Granular and liquid inorganic fertilizers (chemical) provide benefits by releasing nutrients for plant growth and increasing primary productivity (Figure 14).

Organic fertilizers (manure) provide benefits by directly releasing nutrients for plant growth through bacterial decomposition, as a feed source for animals capable to utilize them, and by acting as a substrate for bacterial growth. The organic particles are consumed by some species of fish.

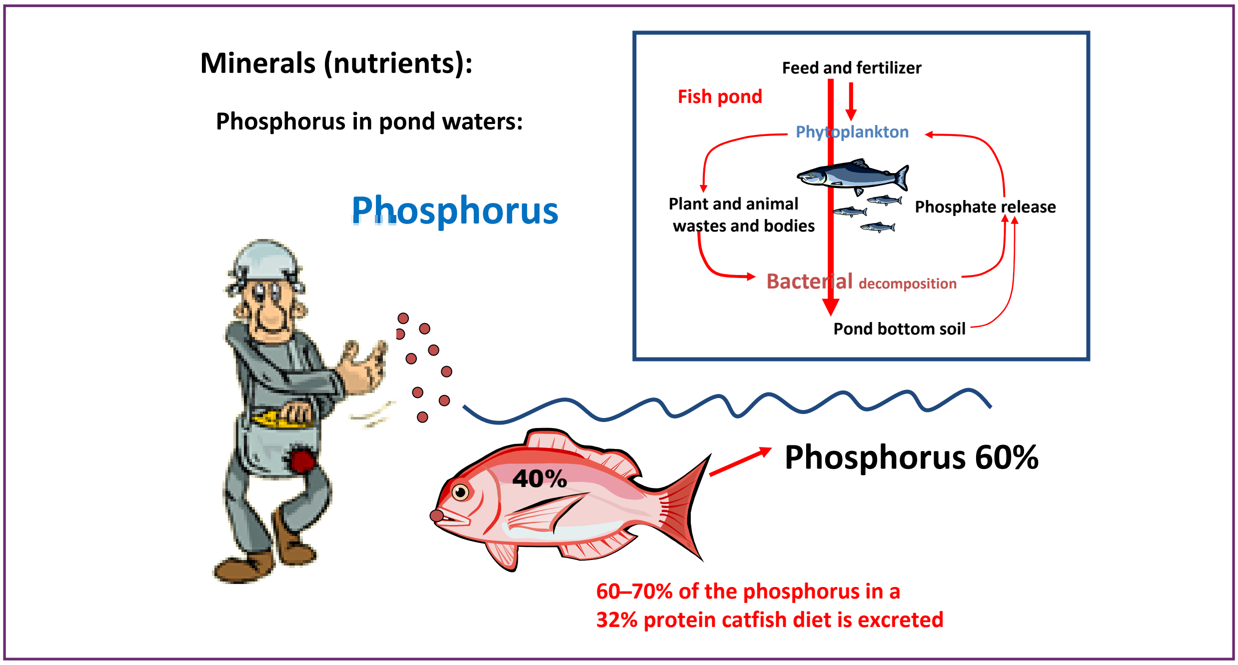
The best fertilizing results are usually obtained by combining inorganic and organic fertilizers.

Figure 14: Application of fertilizers (nutrients)



Phosphorus is not toxic to fish but can lead to heavy phytoplankton blooms and low dissolved oxygen (Figure 15).

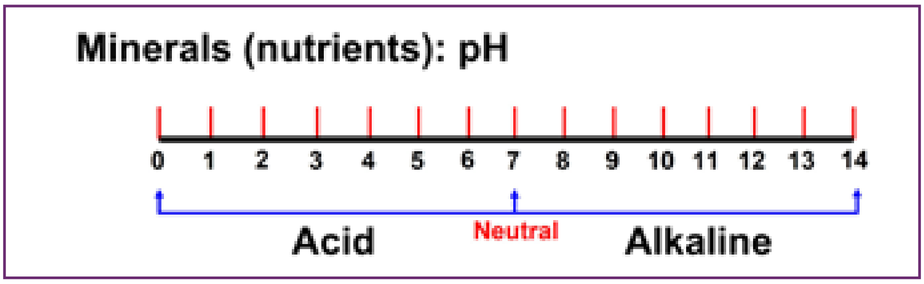
Figure 15: Use of phosphorus



Another important element is the water and soil alkalinity. Alkaline waters are normally more fertile and productive than acid waters because alkaline waters have more minerals (nutrients) available for plant growth. Freshwater between pH 5.5 and pH 6.5 should be limed to improve the productivity, whereas freshwater with a pH below 5.5 should be avoided for aquaculture purposes, as the cost of neutralizing the water with lime is often costly.

Precise liming requirements can be determined by measuring the soil capacity to resist changes in pH levels (Figure 16).

Figure 16: pH (measure of water and soil acidity and alkalinity)



Nutrient inputs: types of fertilizers and benefits	
Granular and liquid inorganic (chemical) fertilizers ➤ Release nutrients for plant growth and increase primary productivity	Benefits of organic fertilizers (manures) ➤ Release nutrients for plant growth through bacterial decomposition ➤ Are a feed source for animals that can utilize them ➤ Act as a substrate for bacterial growth

Photos: ©L. Lovshin.

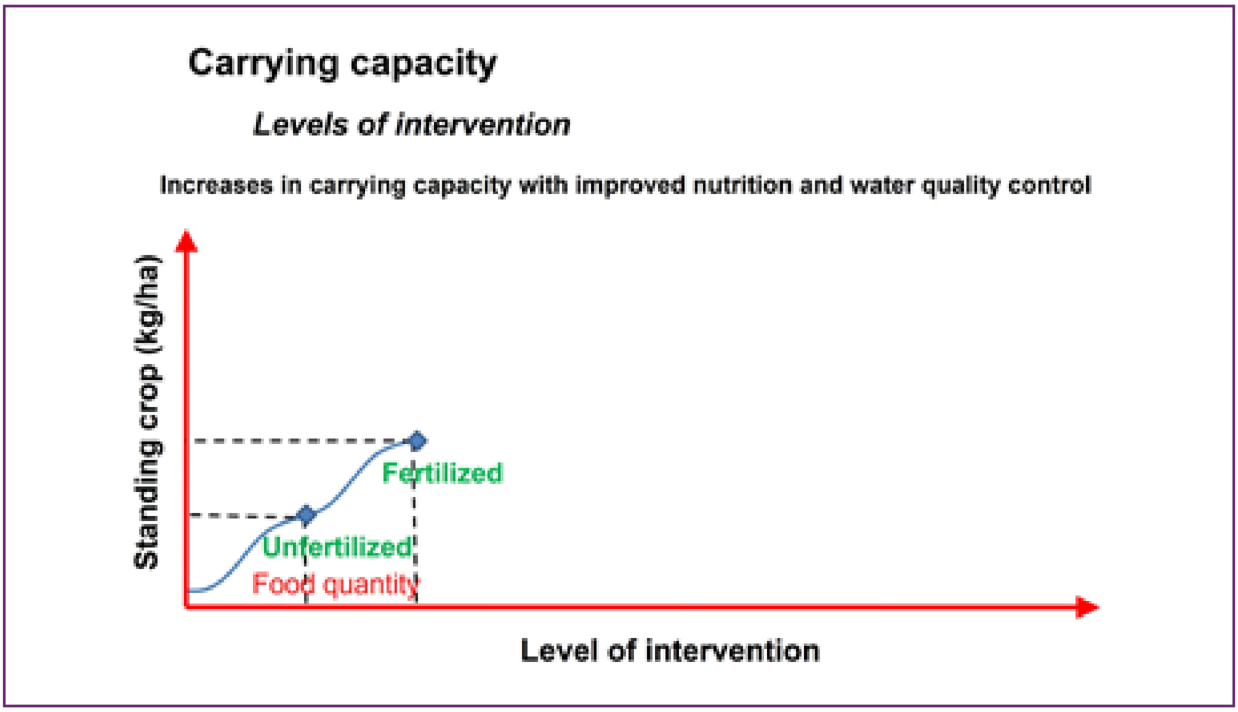
Duck manure fertilizes a fish pond, ©K. Li.

Overview intervention levels and carrying capacity

The graphs below show the different interventions and their influence on carrying capacity and subsequently on the production quantity. They show how each step increases the carrying capacity with improved nutrition and water quality control.

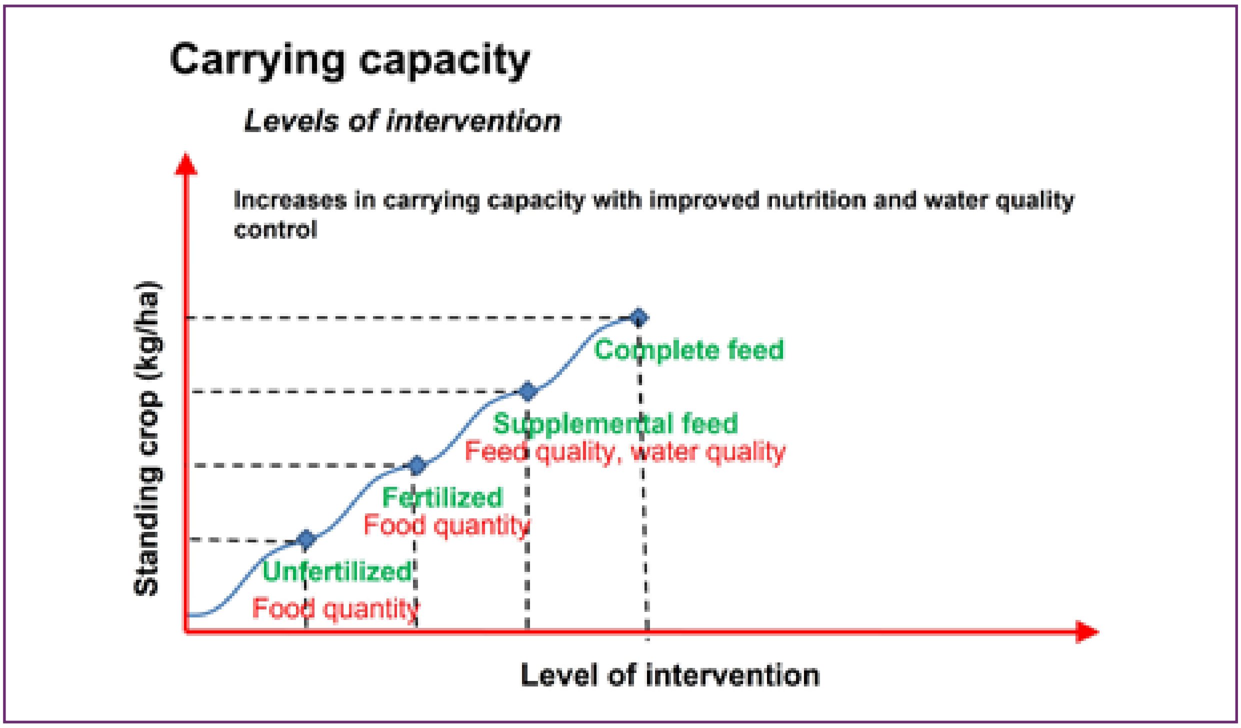
Figure 17 shows the influence of fertilization on food quantity. The fertilizer alone demonstrates an interesting increase in food quantity.

Figure 17: Step one: adding fertilizers



In Figure 18, two more intervention steps are added, first by utilizing a supplementary feed, in addition to the fertilizer, and second by adding a complete feed to the water.

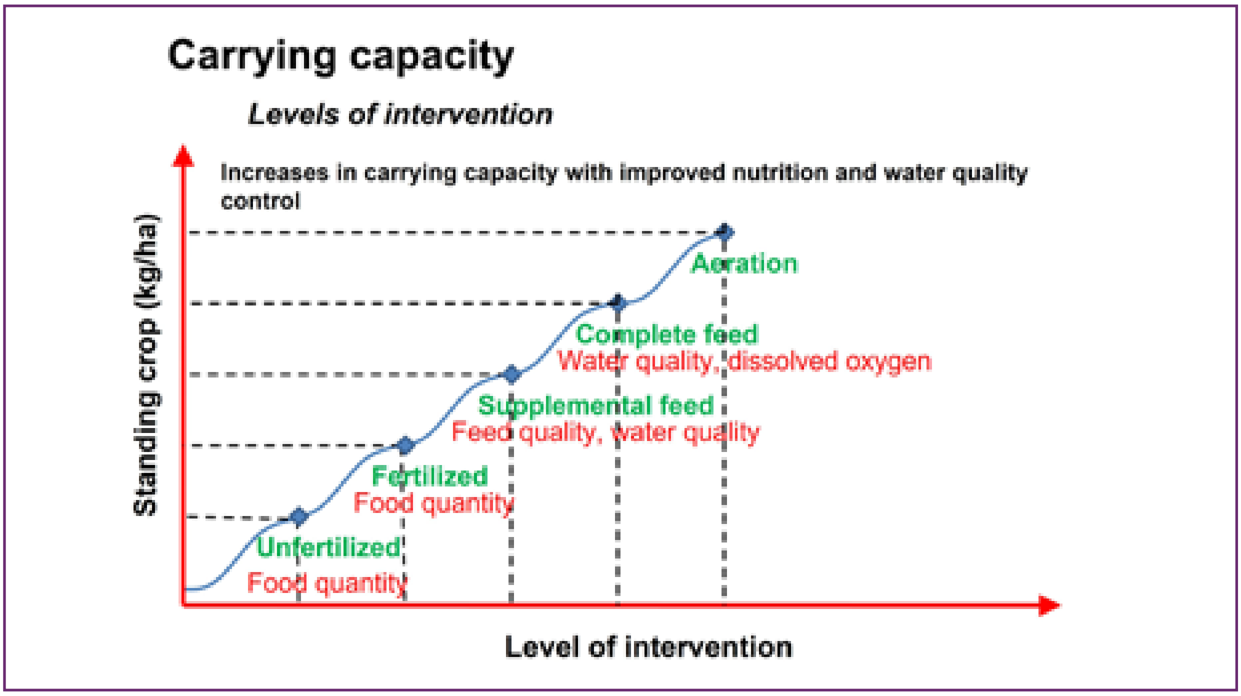
Figure 18: Interventions increasing carrying capacity



The last type of intervention to improve water quality and carrying capacity of the farming unit is that of adding aeration to the water.

The graph in Figure 19 also indicates what type of benefit each step provides: the fertilizers are mainly important for the food quantity; the supplemental feed increases the feed quality and water quality, and the complete feed also adds to the water quality and levels of dissolved oxygen.

Figure 19: Adding aeration



A few basic concepts a farmer should retain are stocking density, weight at harvest, survival rate, mortality rate and standing crop.

Standing crop indicates the biomass in a unit of area at a given moment. It can be expressed as, for example, pounds per acre (lb/acre), kilograms per hectare (kg/ha), and kilograms per cubic metre (kg/m3). As the stocking density of fish increases, the standing crop per unit of water increases; the amount of food available per fish therefore decreases and growth slows and eventually stops.

$$Stocking\ density = \frac{Carrying\ capacity\ /\ Weight\ at\ harvest}{Survival\ rate} \qquad (1)$$

$$Weight\ at\ harvest = \frac{Carrying\ capacity}{Stocking\ density - Mortality\ rate} \qquad (2)$$

Where, the Survival Rate is the percentage of stocked fish that are harvested:

$$Survival\ rate = \frac{Number\ of\ harvested\ fish}{Number\ of\ stocked\ fish} \times 100 \qquad (3)$$

The Mortality Rate is the percentage of stocked fish that die before harvest:[5]

$$Mortality\ rate = \frac{Number\ of\ stocked\ fish - Number\ of\ harvested\ fish}{Number\ of\ stocked\ fish} \times 100 \qquad (4)$$

The Standing crop (SC) at harvest can be calculated as:

$$SC\ at\ harvest = (Stocking\ density - Mortality\ rate) \times Individual\ weight\ at\ harvest \qquad (5)$$

Figure 20, Figure 21 and Figure 22 illustrate the simple application of the above equations. If water quality is not a limiting factor during the farming period, for a given carrying capacity, the weight of fish can be composed of a large number of small fishes or a small number of large fishes of the same species.

For example, if carrying capacity is 4 000 kg/ha, fish farmers might harvest 8 000 fish of 500 g each or 16 000 fish of 250 g each. If water quality is not a limiting factor, carrying capacity is not influenced by the size of farmed fish.

If an estimate of carrying capacity is available, it can be used to determine the stocking rate needed to harvest a given sized fish (Equation 1), or the harvest weight of a fish for a given stocking density (Equation 2), or standing crop at harvest (Equation 5).

[5] Where: Survival rate + Mortality rate = 100 percent;
or: Number of harvested fish + Number of dead fish = Number of fish stocked.

Figure 20: Application of Equation 1 to determine stocking density

To determine stocking density:

$$\text{Stocking density} = \frac{\text{Carrying capacity}}{\text{Harvest weight/fish}}$$

Example: $\frac{\text{4 000 kg/ha carrying capacity}}{\text{500 g (0.5 kg) harvest weight/fish}} = \text{8 000 fish stocked/ha}$

Figure 21: Application of Equation 5 to determine standing crop at harvest

To determine standing crop at harvest:

Standing crop at harvest = Stocking density × Harvest weight/fish

Example:

8 000 fish/ha stock density × 400 g (0.4kg) harvest weight/fish = 3 200 kg/ha standing crop

Figure 22: Application of Equation 2 to determine harvest weight

To determine harvest weight:

$$\text{Harvest weight/fish} = \frac{\text{Carrying capacity}}{\text{Stocking density}}$$

Example:

$\frac{\text{4 000 kg/ha carrying capacity}}{\text{10 000 fish/ha stocking density}} = \text{400 g (0.4 kg) harvest weight/fish}$

ALERT:
Determination of carrying capacity is difficult, but it can be calculated based on personal culture experience and/or information published by others who may have worked in the field.

Segment 3: Factors influencing the growth rate

In this segment, we will look at how the growth rate and production rate are linked and how the rates are closely linked (Figure 23).

The definition of growth rate is the velocity at which an organism or a population of organisms gains weight over a given time period.

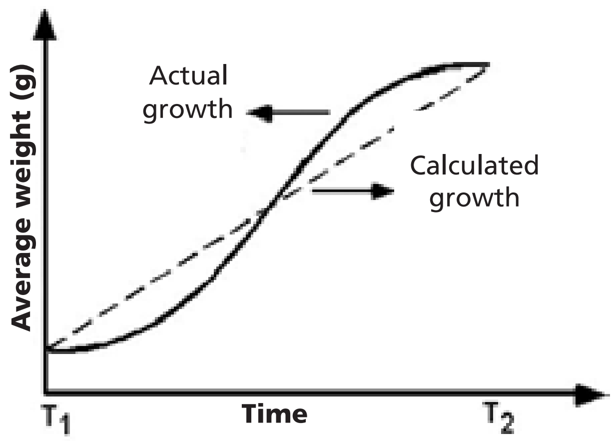
Depending on whether we talk about an individual organism (one fish) or a population (a batch of fish in a specific fish tank), we use different measures to indicate the growth rate:

1. Individual organism = g/day.
2. Population = kg/ha/day, $kg/m^3/day$, or lb/acre/day.

The growth rate and the production rate of a fish population, e.g. in a pond, are two terms for the same indicator.

Figure 23: Calculated versus actual growth

Increase in average individual fish weight between stocking (T_1) and harvest (T_2)



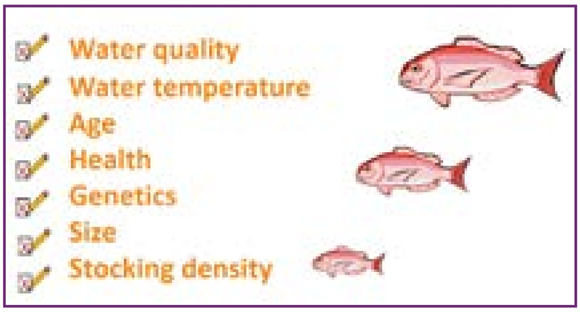
The formula used to determine the growth rate is the following:

$$\textit{Growth rate} = (\textit{final weight } T_2 \textit{ minus initial weight } T_1) \div \textit{days.}$$

Example of a situation	How to apply the formula
Stocking weight = 50 g Harvest weight = 750 g Growth period = 300 days	**750 g minus 50 g ÷ 300 days = 2.3 g/day**

Factors influencing the growth rate:

The growth rate is dependent upon a number of factors and their interactions, as shown in the illustration.



Water quality

The maximum growth rate occurs in water with optimum levels of pH, dissolved oxygen, CO_2, salinity and un-ionized ammonia, among other factors.

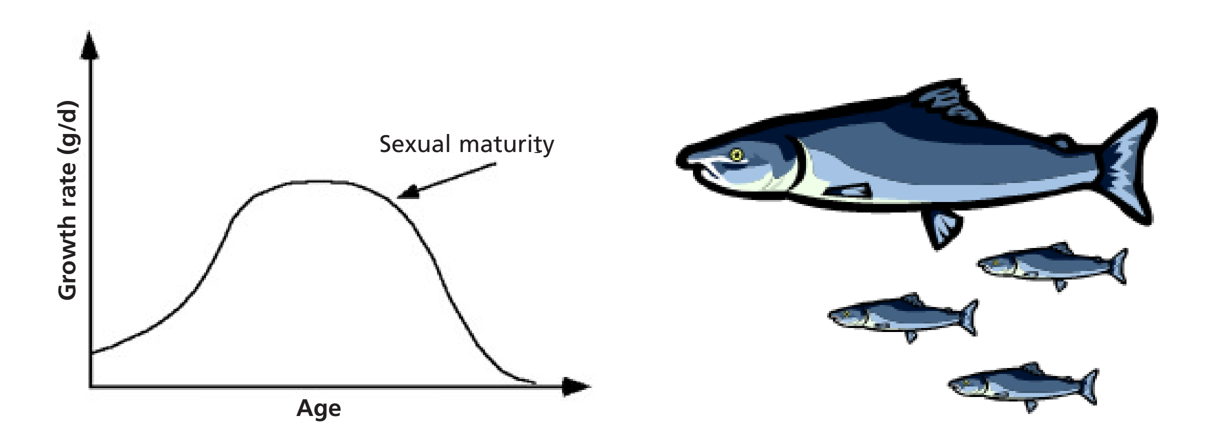
In general, good growth will occur in waters with:

	Dissolved oxygen above 5 mg/L
	pH between 6.5 and 8.5 in the morning
	CO_2 less than 10 mg/L
	Un-ionized ammonia less than 0.05 mg/L

Age and genetics

If environmental and nutritional factors are not accounted for, the growth rate is directly proportional to the maximum potential size attainable. Large fish at maturity grow more rapidly than small fish at maturity (Figure 24).

Figure 24: Influence of age on fish growth rate



Fish health

Fish that are in poor health will not grow as rapidly as fish that are in excellent health (Figure 25).

Poor health of fish can have several causes, such as:

- Handling during stocking and harvesting.
- Unfavourable water temperatures.
- Poor water quality.
- Nutritional deficiencies.

Figure 25: Examples of health problems in fish

Dissolved oxygen kill

Bacterial disease

Photos: ©L. Lovshin.

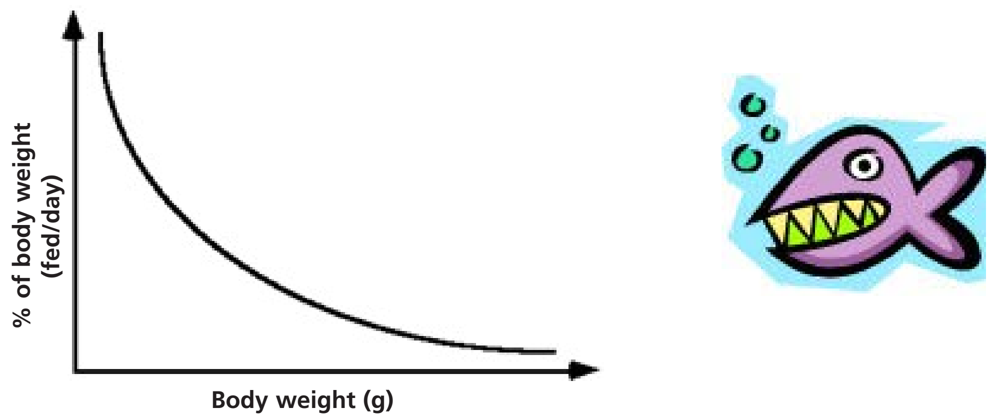
Size

The smaller the fish, the higher its relative growth potential but the lower its absolute growth potential. The larger the fish, the lower the relative growth potential and the higher its absolute growth potential.

The smaller the fish, the higher its basic metabolic rate. Thus, more food per unit of body weight is needed for a small fish to reach and maintain maximum growth capacity than for a larger fish (Figure 26). The following are some examples:

- **Fry** are fed 8 to 10 percent of body weight/day.
- **Fingerlings** (1 g to 100 g) are fed 5 percent of body weight/day.
- **Stockers** (100 g to 500 g) are fed 3 percent of body weight/day.
- **Food-sized** (500 g to 1 000 g) are fed 2 percent of body weight/day.

Figure 26: Relation between size and feeding requirements

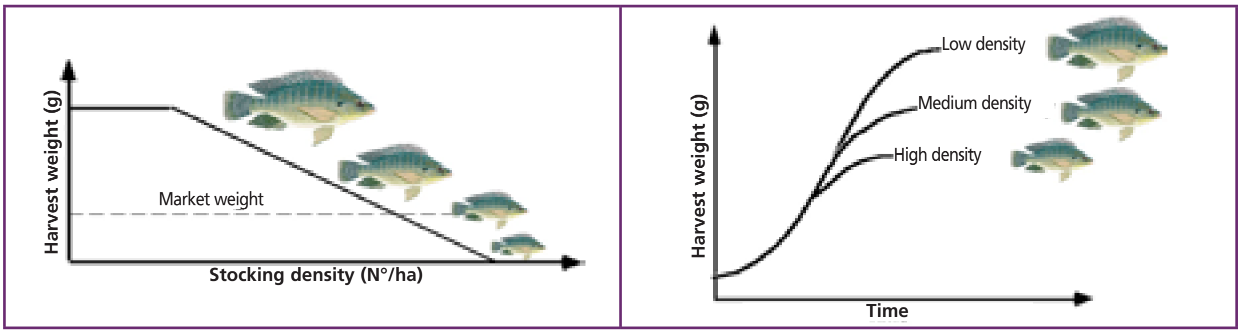


Stocking density

When the critical standing crop is reached, the following rule applies: The higher the stocking density, the lower the average weight of fish harvested.

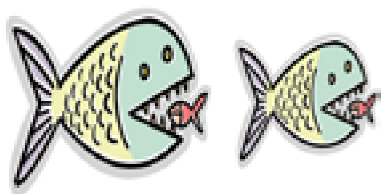
Figure 27 shows the relationship between average harvest weight and stocking density of a 50 g fish over time at one level of nutrient input.

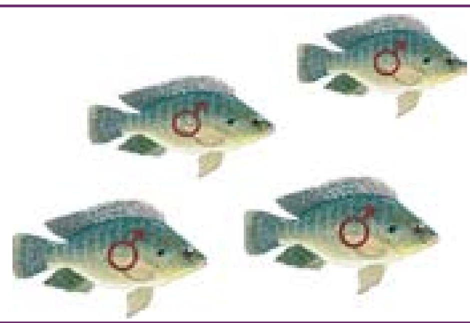
Figure 27: Relation between stocking density and fish size at harvest



This means the stocking density needs to be controlled; to do this, there are several techniques, as presented in the box below.

- Drain or sieve the pond or tank every one or two years to remove all the fish.
- Avoid fish to reach sexual maturity or be able to spawn in the culture unit.
- Polyculture with a predator (carnivorous fish) can be used to control density.
- Monosex culture:
  - limit spawning area or habitat,
  - sterile animals, and
  - spawning repression.





Where fish reproduce during the culture period, polyculture with a predator (carnivorous fish) can be used to control density. The use of carnivorous species to control fish density will increase the average growth rate and the percentage of harvestable fish but may decrease the total yield.

WARNING!
The use of carnivorous species to control fish density will increase average growth rate and the percentage of harvestable fish but may decrease the total yield.

Production rate

Above the critical standing crop, if the growth rate decreases at a smaller rate than the increase in stocking density, an increase in the production rate occurs. If the growth rate decreases at a higher rate than the increase in stocking rate, then the production rate drops. The maximum production rate is a point between the critical standing crop and carrying capacity.

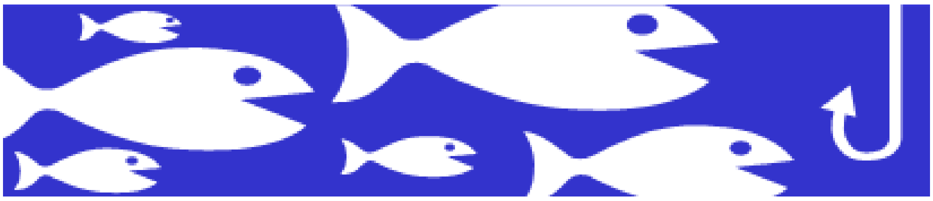
Table 2 provides an example of how the stocking density and individual fish growth influence the production rate.

Table 2: Influence of stocking density fish growth on production rate

Stocking rate (ha)	Growth (g/day)	Production rate (kg/ha/day)
1 000	2	2
3 000	2	6
5 000	2	10
10 000	2	20
15 000 = 50% increase	1.5 = 25% decline	22.5
20 000 = 33% increase	1.2 = 20% decline	24
25 000 = 25% increase	1.0 = 17% decline	25
30 000 = 20% increase	0.8 = 20% decline	24
35 000 = 17% increase	0.5 = 37% decline	17.5

Segment 4: Factors influencing yield and economics

Recalling key terminologies



Yield

When combining the carrying capacity (weight/area) and the individual fish growth rate (weight/time), we obtain the yield (weight/area/time). There are two types of yield: gross yield and net yield.

Gross yield is the total biomass of organisms harvested per unit of area (volume) in a given period of time (kg/ha/yr; lb/acre/yr; kg/m^3/yr). Net yield refers to the total weight of organisms harvested minus total weight of organisms stocked per unit of area (volume) in a given period of time.

The yield is dependent on a number of factors and their interactions. These factors are carrying capacity, growth period, harvest weight, survival and harvest frequency.

- ☑ Carrying capacity
- ☑ Growth period
- ☑ Harvest weight
- ☑ Survival
- ☑ Harvest frequency

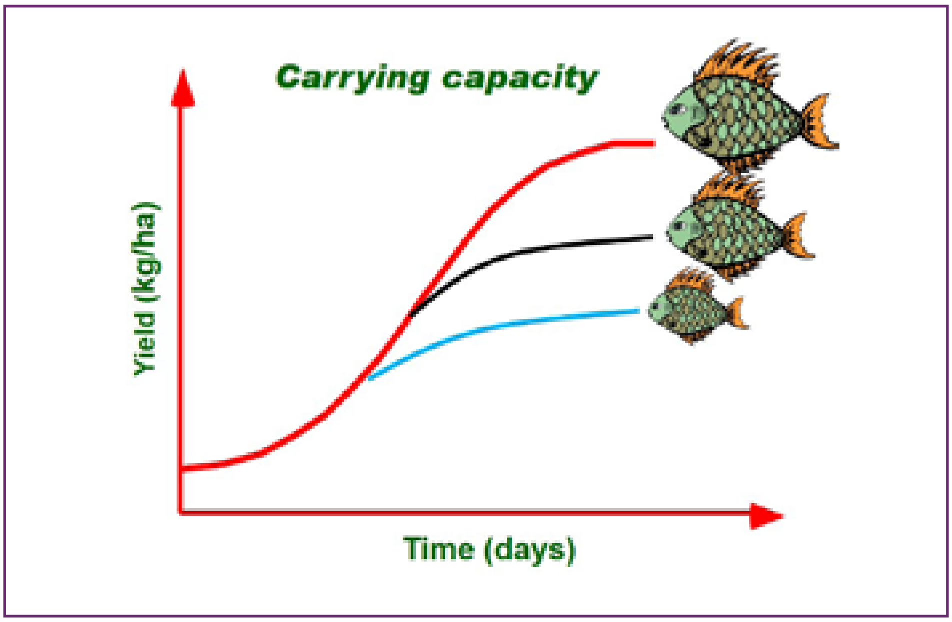
How does yield relate to carrying capacity?

The maximum potential yield is highest in water that has the highest carrying capacity per unit of water (Figure 28).

The smaller a marketable fish is at harvest, the higher the potential yield from a unit of water for a given period of time.

Yields per unit of area can be increased by increasing stocking densities (standing crop), stocking a wide range of fish sizes and partial harvesting.

Figure 28: Relation between yield and carrying capacity



Higher yields per unit area can be obtained by stocking optimum numbers of various-sized fingerlings, partial harvesting, and then restocking with a number of small fingerlings equivalent to the number of fish harvested.

Harvest weight

To raise two crops of fish a year instead of one crop, the following should be considered:

- Labour: more labour is needed.
- Water: more water is needed if ponds are drained to harvest fish.
- Fingerlings: more fingerlings are needed twice a year.

Survival

High yields are obtained by stocking the maximum number of fish per unit of area that allow the fish to grow to marketable size within the growing period. If mortality results in a reduction of fish below the optimum number per area, the yield will be reduced.

Causes of low survival are shown in the box below.

- Mortality due to handling stress at stocking
- Predators
- Disease
- Poor water quality
- Thievery

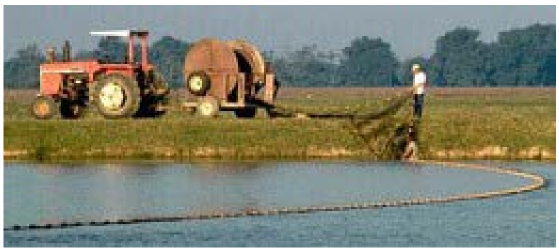
Aquatic birds

Bacterial disease

Dissolved oxygen kill

Photos: ©L. Lovshin.

Harvest frequency and restocking (of the yield)

Advantages	Disadvantages
➤ Partial harvesting and restocking can be continued for a number of years without draining the pond, conserving water, water fertility and chemical supplements to the ponds. ➤ Less effluent (flowing out) release compared with yearly draining. ➤ Fish yields per unit area per year are high. ➤ Fish are available for harvest year-round, improving farm cash flow and allowing processors to provide the consumer with fish year-round.	➤ Fish must be easily harvested with a seine. ➤ Fish should not reproduce in the grow-out pond or a predator fish will be needed.  Partial harvest of catfish. ©L. Lovshin.

Economics

Highest yields per unit of area are not the most economical in ponds receiving feeds and/or fertilization. Highest economic profits are achieved at a production level below the point of maximum yield (Figure 29 and Figure 30).

Figure 29: Economic profit and yield

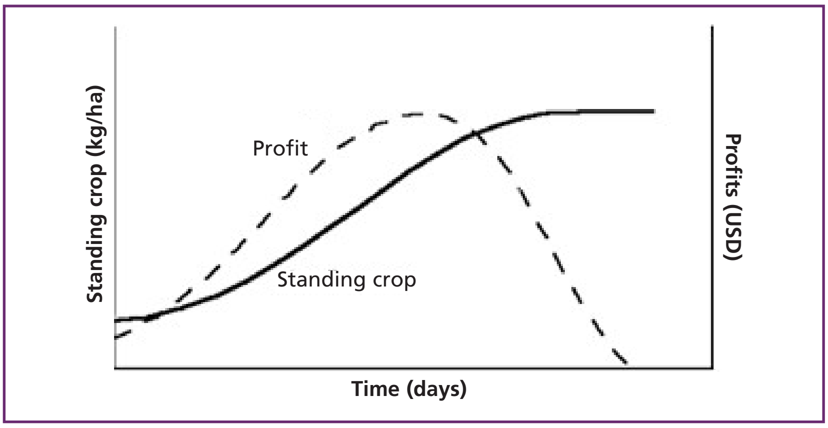
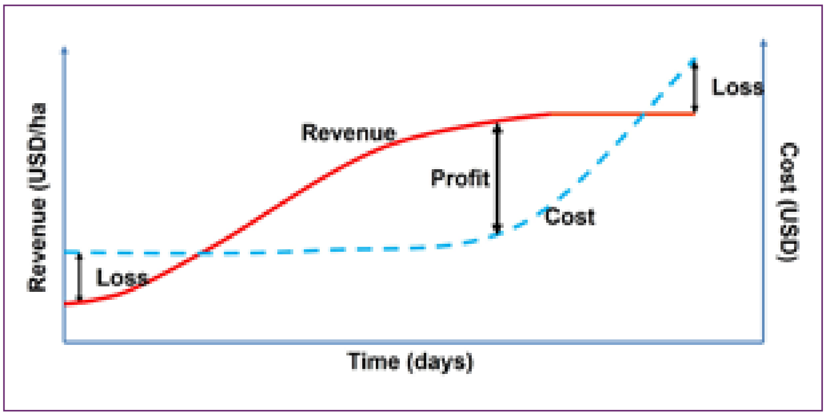


Figure 30: Harvest time and maximum profit



We must find the harvest time that will give us maximum profit (Figure 30). Normally, the point of maximum profit occurs between the critical standing crop and carrying capacity.

Subsistence scale pond culture

In Mbala District, Northern Province, some small fish ponds constructed close to Highway D1 by the nearby farmers of Kawala Village are clearly visible in this satellite image.

Using water from a small stream, the villagers practice extensive fish culture in their ponds with supplementary feeding.

With the ongoing campaign to improve seed and feed quality and supply and an extension programme to improve the skills of fish farmers, in particular the large number of owners of small fish ponds, the national capacity of farmed fish production stands for the opportunity for growth in the coming years.

©FAO/Xiaowei Zhou

Segment 5: Classification systems for aquaculture farms

Aquaculture farms come in all sizes, forms and materials, but management matters when attempting to classify the types of farms. In this segment, we will look at extensive, semi-intensive and intensive farming systems (FAO, 1999; FAO, 2017a), as well as the emerging aquaponics system (Somerville *et al.*, 2014).

Aquaculture systems are often classified according to the following:

- Salinity of water, i.e. mariculture (farm in seawater), freshwater and brackish-water.
- Business orientation, i.e. non-commercial and commercial aquaculture.[6]
- Type of farming system, e.g. pond, cage, pen, tank or raceway.
- Aquaculture product, e.g. trout, tilapia, shrimp, oysters and seaweed.
- Management intensity, i.e. extensive, semi-intensive and intensive.

The intensification of aquaculture includes complex interventions that often defy quantitative and qualitative categorization, making definitions regarding levels of intensity subjective.

Extensive systems rely on primary production in the water. The element of human control affects only a part of the life cycle of the cultured species. Fish seed is usually obtained from the wild. This system is characterized by a low input-output ratio, i.e. the proportion of inputs introduced in the farming system relative to the outputs produced because production inputs such as feed and fertilizer are seldom used.

Semi-intensive systems include some intentional human addition of fertilization and/or supplementary feed material, such as agro-industrial waste, in addition to the natural food from primary production. Fish seed is also purposely stocked.

In intensive systems, more output is produced from a specified production unit. In these systems, the farmer provides all of the nutritional requirements for the cultured species. In addition, all aspects of the system, including the physicochemical environment, are controlled.

In summary

Farm type by management intensity:

- Extensive management – no or some control of water quality; all of the nutritional requirements are derived from natural sources without conscious human intervention.
- Semi-intensive management – partial control of water quality; nutritional requirements are enhanced through intentional fertilization and/or supplemental feeding.
- Intensive management – (complete) control of water quality; all the nutritional requirements are met from external sources.

The sections below describe the characteristics per intensity level of management. Please note that within the intensive management type there are variations possible, with increased intensity of human interference (management).

[6] The concepts of commercial and non-commercial aquaculture are addressed in Module 3: The Economic Dimension of Sustainable Aquaculture.

Large-scale pond culture

About 20 large-scale pond-based aquaculture farms are active in Zambia. They are found in Copperbelt, Lusaka and Southern Provinces. These large fish farms usually have their own hatcheries for seed production for stocking their own ponds as well as for sale to other fish farmers.

In Lusaka Province, a large aquaculture farm adjacent to the Kafue River is captured by satellite camera. Established in the 1980s, the farm has over 130 earthen ponds in an area of more than 120 hectares. Fish farming on this farm is integrated with terrestrial animal husbandry. Some animal houses built on pond dykes are visible.

Polyculture of filter feeding carps and herbivorous grass carp, along with native tilapia species, was once practiced on this farm but was phased out later.

Today, the farm propagates and grows tilapias. Tilapia brooders used in its hatchery include some sourced from Southeast Asia.

©FAO/Xiaowei Zhou

Level 1 – Extensive farming

- No nutrients are added to stimulate, supplement or replace natural food.
- Earthen ponds exist with little modification of original topography and vegetation.
- Some control over quality/quantity of water supply and incomplete drainage and harvest are normal.

Marine shrimp pond managed extensively, ©L. Lovshin.

Extensive aquaculture involves low degree of control over environment, nutrition, predators, competitors and disease causing agents. Plant and animal seed stock is obtained from nature. Cost, technology, stocking rates and production levels are low.

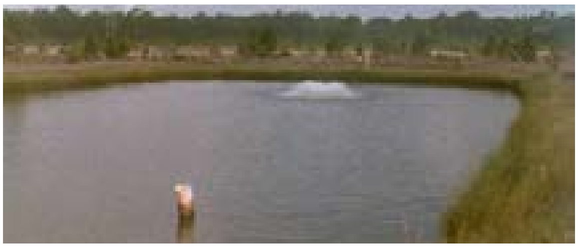
Level 2 – Semi-intensive farming (fertilization)

- Photosynthesis and food production are stimulated by addition of organic and inorganic fertilizers.
- Earthen ponds are suited to fertilization practices, e.g. deeper water than Level 1; complete drainage and harvest are common.
- Partial control over water quality/quantity, but whenever possible complete control of water quality should observed.

Duck manure fertilizes a fish pond in Thailand, ©L. Lovshin.

Level 3 – Feeding in semi-intensive farms

- Feed of often less than optimum quality and/or quantity is added for direct consumption to supplement natural foods – feeds are usually nutritionally incomplete.
- Earthen ponds are modified to magnitude where complete drainage and harvest are common.
- While most farmers do not apply complete control over water quality/quantity, it is advisable to do so whenever possible.



Photos: ©R. Roubach.

Semi-intensive aquaculture involves a combination of some attributes of extensive and intensive aquaculture. It is usually done in human-made ponds and raceways. Costs, technology, stocking rate and production levels are all intermediate.

Level 4 – Intensive farming (feeding with complete feeds)

©R. Roubach

©R. Roubach

Intensive aquaculture involves a high degree of control over the systems. Seed stock is produced from domestic broodstock within the system. Costs, technology, stocking density and production levels are all high.

- Feed is the primary source of nutrition although natural foods are often important; feeds are usually complete and balanced.
- Typically, earthen ponds are modified to allow complete drainage and harvest on demand.
- No aeration but periodic water exchange is recommended; the sun/photosynthesis is essential as the primary water quality maintenance system.

Level 5 – Intensive farming with additional interventions

©L. Lovshin

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Adding aeration and/or partial water exchange to the complete feeding:

- Feed is the primary source of nutrition although natural foods are often important; feeds are usually complete and balanced.
- Commonly, earthen ponds and, infrequently, tanks are modified to allow for complete drainage and harvest on demand.
- Water quality control should be greater than Level 4 with emergency aeration and/or partial flushing capability (not more than 25 percent of total volume per day). The sun/photosynthesis is essential as the primary water quality maintenance system.

Level 6 – Water reuse in intensive farms (feeding with water reuse)

- Feed is nutritionally complete and balanced; feed quantity is such that it essentially replaces natural foods (algae can be added).
- Culture environment is modified to allow complete drainage and harvest on demand.
- Water quality control through sedimentation, mechanical and bio-filtration, disinfection and aeration and/or pure oxygen supplementation; artificial light or sun, but photosynthesis is no longer the primary water quality maintenance system.
- Energy intensive.

Level 7 – Single-pass water exchange in intensive farms (raceways and cages)

- Feed is nutritionally complete and balanced; feed quantity is such that it essentially replaces natural foods (algae not added to water).
- Tanks, cages and small earthen ponds are modified for complete water replacement (up to numerous exchanges of water volume per hour) and rapid fish harvest (flow-through).
- Dissolved oxygen and nitrogenous wastes require constant management; the sun/photosynthesis is not essential as the primary water quality maintenance system.
- Suspended and dissolved nitrogenous wastes are flushed from the culture unit.
- Energy intensive; but gravity system possible; intensive disease control.

This is the end of the key principles and basic knowledge needed to set up a commercial aquaculture farm.

Level or type depends on local conditions to conduct aquaculture as a business.

Tip for trainers:

Show the series of photos below "recapping" the topics and process, "from site selection, type of farming systems and seed production from the hatchery to the consumer". Show the photos in a slide show with one photo per slide, so that participants can see the details in the photos.

If time allows, ask the participants to provide comments to the photos, applying the theoretical principles.

Examples of farming systems: concrete tanks, earthen ponds, cage culture, irrigation schemes and natural depressions




Photos: ©V. Schmidt.

From the seed to the table

Hatchery: incubation

Nursery: larval rearing in concrete tanks

Nursery: larval rearing

Nursery: fingerlings in hapas

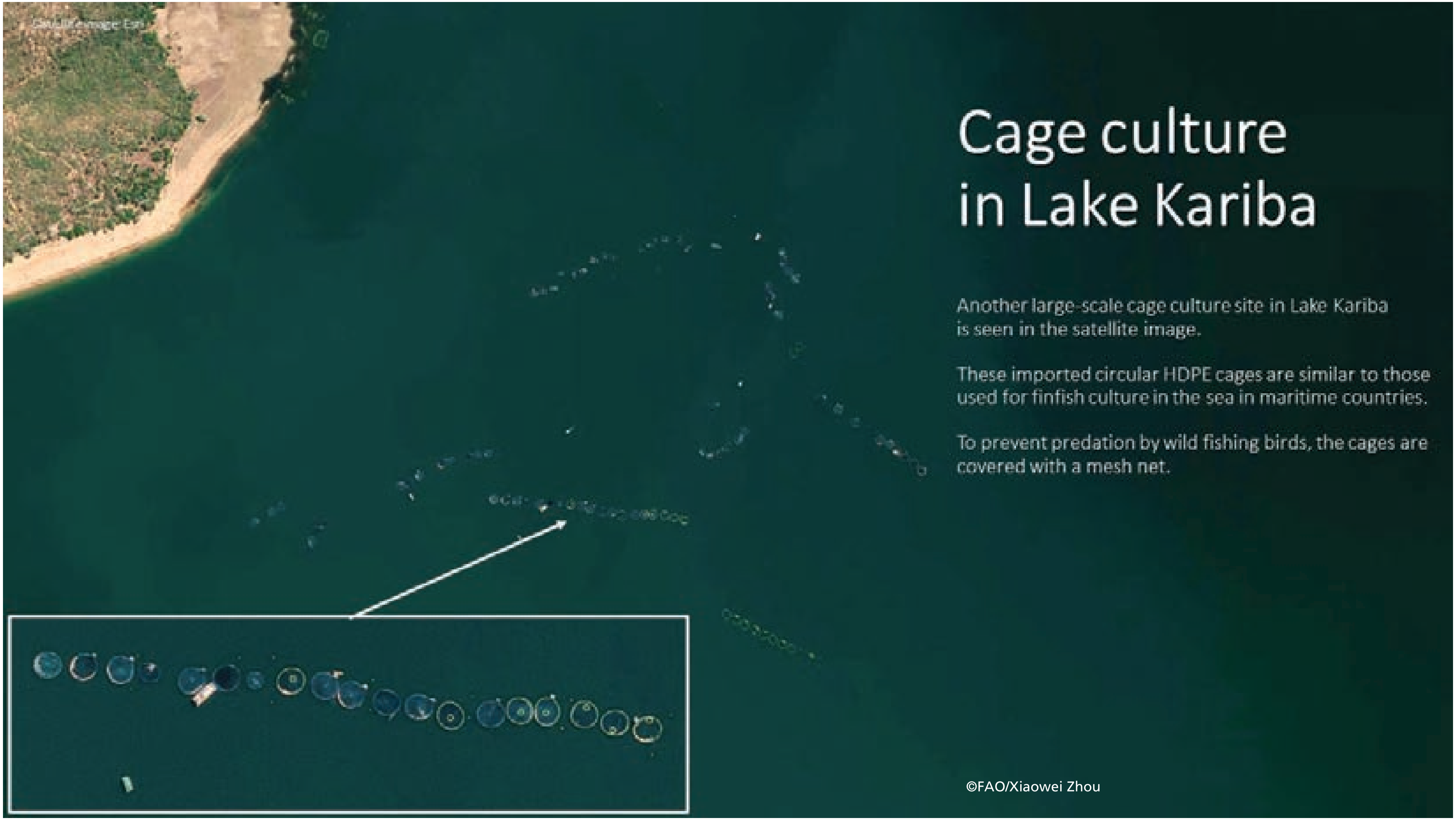
Manual feeding in small operations

Feeding platform in industrial operations

Partial or complete harvest: labour intensive

Partial or complete harvest in industrial operations

From the pond to the table



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POND, CAGE AND AQUAPONIC SYSTEMS

Pond-based aquaculture

Pond-based fish farming systems are characterized by depressions in a piece of land, filled with water, and contain the culture species under various levels of management intensity (FAO, 2010).

Pond-based systems can be classified in several ways, including management intensity, salinity, and elevation or temperature. The general principles of pond culture are similar for all these categorizations.

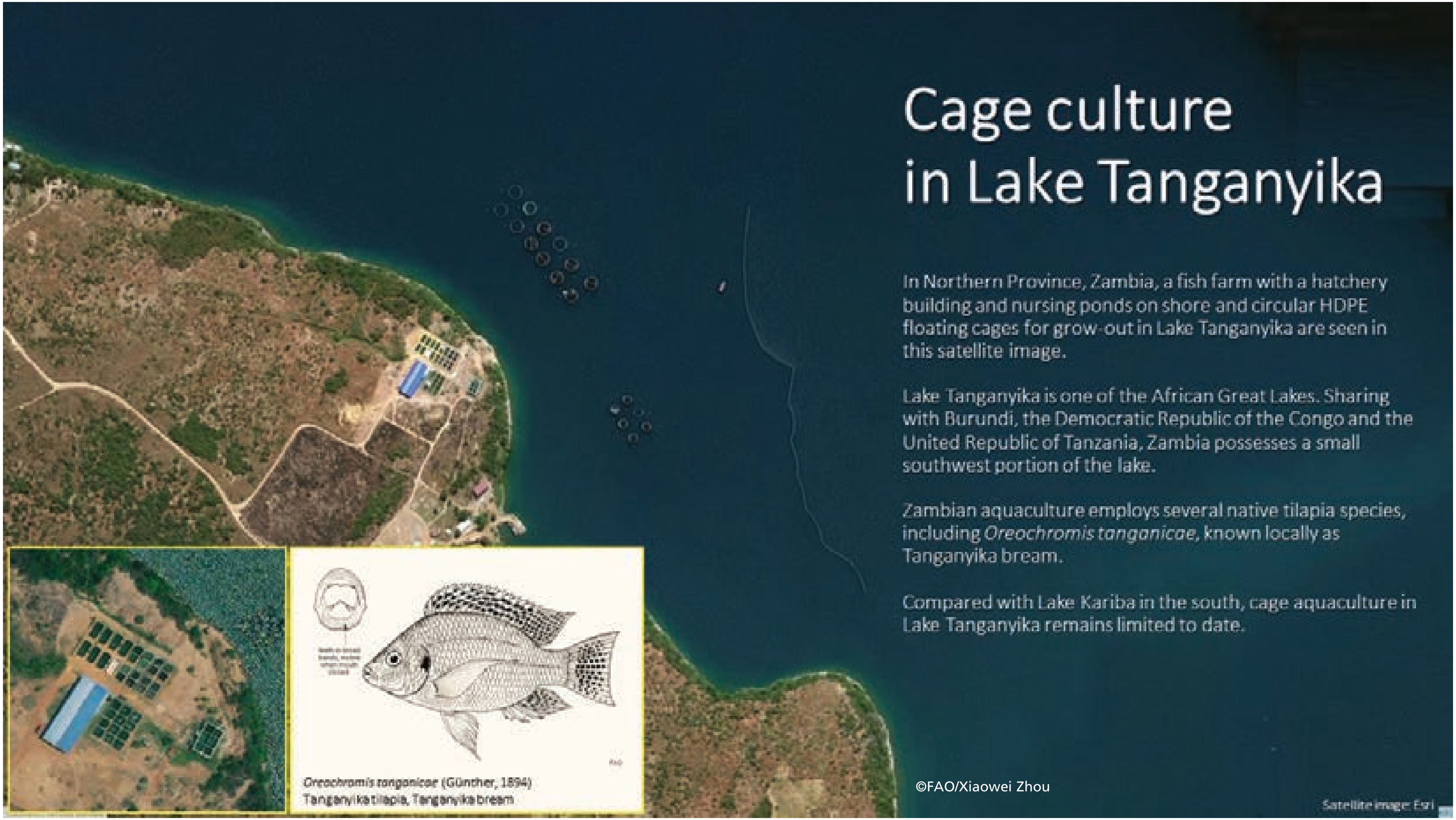
A typical pond farm should be located close to a reliable water source, on a soil type that can hold water. In order to reduce pumping costs, the farm should be sited on a gentle slope to allow water to flow into and out of ponds by gravity, and ideally not too far from the farmer's residence.

Ponds need to have an average depth of approximately 1.5 m to allow for adequate cover from predatory birds and hot surface water during the day.

The most basic inputs in a pond-based farm are water and land. Without a good supply of good quality water, all the other processes or management units will come to a standstill. Other important factors for production include good-quality feed and seed (fingerlings); well-trained labour is also essential.

Equipment and machinery used include aerators, seine nets, chemical application boats and water-quality testing kits. A farm shed is required to store the equipment, feed and other inputs, in addition to farm records.


These photos are tilapia earthen pond farms showing gravitational water in-flow, Rwanda, ©FAO/Yaw Ansah.


Cage culture
in Lake Tanganyika
In Northern Province, Zambia, a fish farm with a hatchery building and nursing ponds on shore and circular HDPE floating cages for grow-out in Lake Tanganyika are seen in this satellite image.
Lake Tanganyika is one of the African Great Lakes. Sharing with Burundi, the Democratic Republic of the Congo and the United Republic of Tanzania, Zambia possesses a small southwest portion of the lake.
Zambian aquaculture employs several native tilapia species, including *Oreochromis tanganicae*, known locally as Tanganyika bream.
Compared with Lake Kariba in the south, cage aquaculture in Lake Tanganyika remains limited to date.
Oreochromis tanganicae (Günther, 1894)
Tanganyika tilapia, Tanganyika bream
©FAO/Xiaowei Zhou
Satellite image: Esri

Cage-based aquaculture

A cage-based fish farming system refers to the farming of fish in culturing units consisting of a framed net that is open at the top and floating on the surface. Otherwise, when completely enclosed, the cage is kept below the water surface by adjustable buoyancy or suspended from the surface (FAO, 1984). Cages are usually employed in bodies of water such as rivers, deep lakes and the sea.

Given the relatively small size of cages, harvesting is simple and quick to perform. The investment per unit weight of fish produced is relatively low compared to pond-based farming systems (FAO, 1984). Moreover, cage construction is cheaper and easier to execute in contrast to that of a pond.

One major characteristic of a cage-based system is that the farmer has little control over the physical and chemical parameters of a chosen site. Therefore, site selection needs to ensure that factors such as water current, quality and depth, wind and wave action are all conducive to cage farming.

The main inputs into a cage-based system are feed and fingerlings. All the nutrient requirements for the fish must be provided by the farmer.

Equipment includes the cage system, which is made up of materials such as netting, floats and the frame. A farm shed is also needed on shore for storing feed and other inputs, as well as serving as an office for record-keeping and other management activities. A canoe or boat is required for feeding and harvesting activities.


Tilapia cage farm on Lake Kivu, Rwanda, ©Yaw Ansah.


Tilapia cage farm Siavonga Harvest, Zambia, ©Boniface Mulonda.

Aquaponics

What is aquaponics?

Aquaponics[7] is a modern way of farming, using fish faeces to fertilize plants in a closed production system that integrates aquaculture with hydroponics, the soilless cultivation of plants. Aquaponics has three main components: fish, bacteria and plants.

The fish supply nutrients to plants; bacteria help to process waste and make nutrients available to plants and eliminate metabolites that are toxic to fish. The plants clean the water by taking in dissolved wastes. At the end of the cycle, the water returns to the fish tank (Figure 31 and Figure 32).

Figure 31: Schematic representation of an aquaponic system

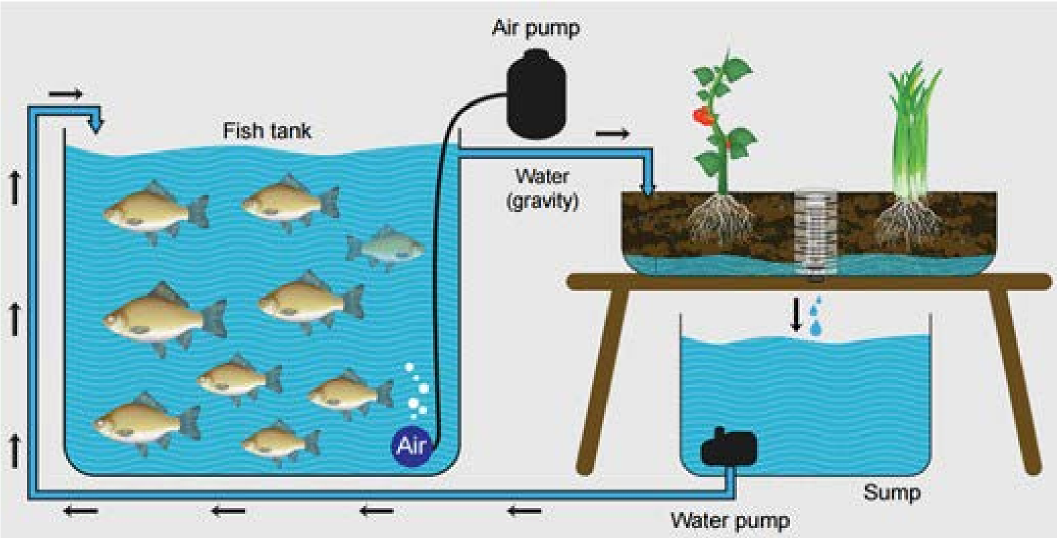


Figure 32: Examples of aquaponic farms with various vegetables

Photos: ©Austin Stankus.

7 Austin Stankus, personal communication ©FAO-NFI, 2018.

Uses and benefits of aquaponics

- Both small-scale and commercial operations.
- Aquaponics allows intense production of large quantities of fish and vegetables using minimal space and resources.
- Efficient use of water, space and other resources.
- Provides a cheap source of fertilizer for hydroponic plants – good for commercial vegetable producers.
- A value-added way to filter fish tanks – good for commercial aquaculture producers.
- Sustainable and intensive food production system.
- Two agriculture products (fresh fish and vegetables).
- Extremely water efficient.
- Does not require soil.
- Does not use fertilizer or chemical pesticides.
- Higher yields.
- Higher production control means fewer losses.
- Can be used on non-arable land, such as deserts, degraded soil or salt-inundated lands.
- Creates little waste.
- Economical production.
- Daily tasks are labour-saving and inclusive of people from all ages and gender.
- Construction materials and information are widely available.

Shortcomings of aquaponics

As in the other aquaculture farming systems, aquaponics also has its pros and cons. Some of the shortcomings are the following:

- Expensive initial start-up costs compared with soil production or traditional hydroponics.
- Knowledge of fish, plants and bacteria is required for this type of farming.
- Not recommended where the environmental conditions do not match the needs of the fish or plants (too hot or too cold).
- Reduced choices to manage pests and diseases.
- Mistakes can cause catastrophic collapse.
- Requires high input of energy.
- Needs reliable access to electricity, fish seed and plant seed.
- Requires careful financial and market analysis for a successful business.

In summary, aquaponics is a combination of aquaculture (growing aquatic organisms in a controlled environment) and hydroponics (growing plants without soil).

- Aquaculture: The water becomes nutrient rich – fish eat food and excrete waste.
- Hydroponics: The plants require a nutrient-rich solution.
- Aquaponics: Combining aquaculture and hydroponics is a natural union – fish waste provides a food source for the plants, and the plants help to purify the water for the fish.

FEEDING AND NUTRITION

Unlike plants, fish cannot combine sunlight and nutrients to synthesize body tissue. Instead, fish require organic material (Figure 33) – such as other animals and plants, or formulated feed containing these materials – to survive, grow and reproduce (Gopalakrishnan and Coche, 1994). The efficiency with which feed is converted by fish into flesh is known as the feed conversion ratio (FCR). An FCR of 1.2 implies that 1.2 kg of feed is required to produce 1 kg of fish. A lower FCR refers to a higher efficiency.

Fish food can be grouped into three main categories: natural food, supplementary feed and complete feeds (Hasan and New, 2013).

Natural food is created by natural processes in the pond, and includes phytoplankton and zooplankton, detritus, snails, insects, worms, other fish and aquatic plants. The abundance of these food items depends directly on the concentration of various levels of water quality parameters and can be improved by pond liming and fertilization.

Supplementary feed is used to compensate for nutrient and quantity deficiencies in natural food. This is the most common feeding method in semi-intensive systems. Supplemental feed is usually made up of agro-industrial by-products such as wheat, maize and rice brans, as well as kitchen wastes such as leftovers (Gopalakrishnan and Coche, 1994). Leaves (e.g. cocoyam and potato leaves) and grass, chopped or administered whole, can also be used for herbivorous species, such as *Tilapia zillii* (Mulonga, 2014). Commercially formulated feeds are considered supplementary when used in combination with pond fertilization. In several cases, dry agro-industrial by-products are mixed together and pelletized with a feed machine; the feed is then dried before being fed to fish.

Complete feeds are formulated to meet all nutritional needs to enable the fish to grow well. It is usually made commercially and is expensive.

The major nutrients targeted for fish feed are carbohydrates, protein, lipids, vitamins and minerals. It is essential for feed milling companies to have laboratory facilities to conduct a proximate analysis of both the raw materials and the finished feeds as a way of ensuring quality. However, the types and quantities of nutrients needed by fish differ based on species and size.

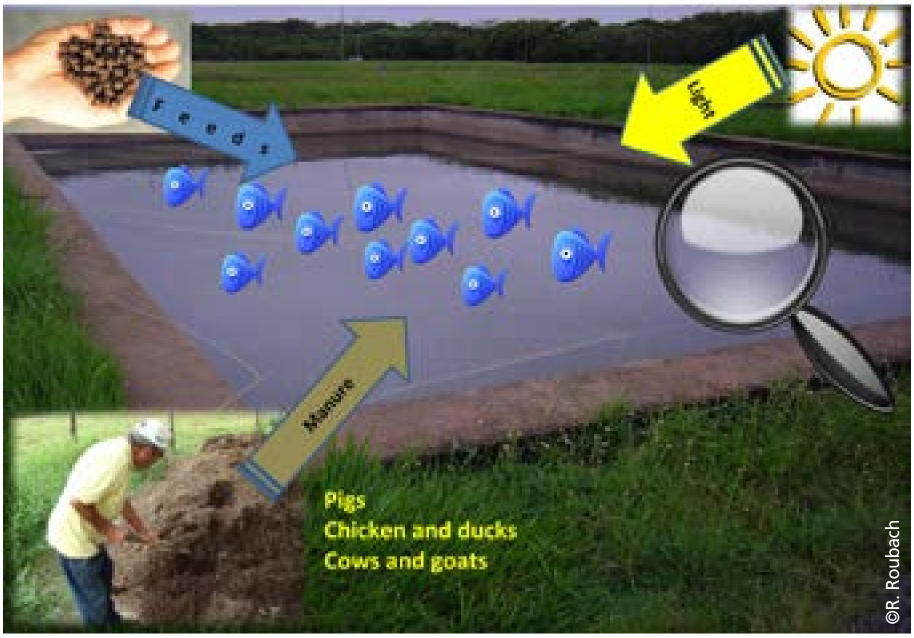
Nutrition

Supplement the nutritional needs of the fish

REMEMBER

Natural water productivity is always the first feed!

Figure 33: Basic requirements of a fish pond (water, light and nutrients)



Adequate nutrition

Adequate nutrition[8] depends on the species that is grown and the choice of management intensity.

Objective: adequate nutrition	
Note: For good results in aquaculture, you need knowledge about each species and of the growth phase.	
Good quality feeds are necessary for: ➤ Increased performance ➤ Improved nutrition (reduced cost) ➤ Improved resistance (winter, management) ➤ Reduced effluents ➤ Improved fish appearance	
➤ Supply of energy and nutrients: – Amino acids (proteins) – Fatty acids – Carbohydrates – Vitamins – Minerals	

Nutritional requirements depend on these factors:	
➤ Species ➤ Size ➤ Age ➤ Sex ➤ Reproductive stage/maturity ➤ Water temperature ➤ Water quality (environmental conditions)	

[8] Rodrigo Roubach, personal communication ©FAO-NFI, 2018.

Feeding tilapia

The form of feeding, frequency and the amount needed for tilapia depends on the size and growth phase of the fish. Table 3 provides an example of good practice feeding for use in tilapia farms.

Table 4 shows the appropriate types of raw ingredients that can be used for tilapia feed. In the case of tilapia, fry are fed at a daily rate of 15 percent of their body weight. By the end of the culture period, the feeding rate should be decreased to 6 percent of their body weight. Looking at tilapia specifically, the feeding table using formulated feed under semi-intensive pond farming is shown in Table 3.

Table 3: Example of fish feeding practice for tilapia

<table>
<tr><th>Life stage</th><th>Fish size (g)</th><th>Stocking density (No./ha)</th><th>Feed type</th><th>Feed size (mm)</th><th>Feeding rate (% body weight)</th><th>Feeding frequency (No./day)</th></tr>
<tr><td>Early fry</td><td>0–1</td><td rowspan="3">10 000–30 000</td><td>Powder</td><td>0.2–1</td><td>15–10</td><td>4</td></tr>
<tr><td>Fry</td><td>1–5</td><td>Crumble</td><td>1–1.5</td><td>10–5</td><td rowspan="2">2</td></tr>
<tr><td>Fingerling</td><td>5–20</td><td rowspan="4">Sinking pellets, balls</td><td>1.5–2</td><td>5–3</td></tr>
<tr><td>Juvenile</td><td>20–100</td><td rowspan="3"><10 000</td><td>2</td><td>3–2</td><td rowspan="3">1–2</td></tr>
<tr><td>Grower</td><td>>100</td><td>3–4</td><td rowspan="2">2</td></tr>
<tr><td>Broodstock</td><td>150–300</td><td>4</td></tr>
</table>

It is important to know the total weight of fish in a pond in order to calculate the daily feed ration. A few individual fish can be caught randomly and weighed for an estimate.

Table 4: Example of common tilapia feed raw ingredients

Cereals and by-products	Vegetable protein sources	Animal protein sources	Other additives
Maize	Soya meal (solvent)	Meat and bone meal	**Vitamins**
Maize bran	Soya meal (full fat)	Blood meal	**Other additions**
Wheat	Soya meal (mechanical)	**Fishmeal**	Anti-salmonella
Wheat bran	Corn gluten meal	Fish oil	Toxin binders
Sorghum	**Added amino acids**	**Mineral sources**	**Antioxidants**
Barley	Methionine	Limestone flour	Growth promoters
	Lysine	Monocalcium phosphate	Molasses
	Threonine	Dicalcium phosphate	
	Tryptophan	Trace minerals	

Types of feed

When natural fish food organisms are reduced, a complete ration containing essential nutrients must be provided to gain an increase in carrying capacity. There are many types of feeds.

What is essential to retain is that a nutritionally complete feed contains all the amino acids, lipids, carbohydrates (energy), vitamins and minerals to allow fish to grow well in the absence of natural foods.

Commercially formulated feeds are considered supplementary when used in combination with pond fertilization. In several cases, dry agro-industrial by-products are mixed together and pelletized with a feed machine; the feed is then dried before being fed to fish.

Complete feeds are formulated to meet all nutritional needs to enable fish to grow well. It is usually made commercially and is expensive.

The major nutrients targeted for fish feed are carbohydrates, protein, lipids, vitamins and minerals. It is essential for feed milling companies to have laboratory facilities to conduct proximate analysis of both the raw materials and the finished feeds as a way of ensuring quality. However, the types and quantities of nutrients needed by fish differ based on species and size.

It should be noted that commercial feeds can be extruded, pelletized, sinking or floating. Each type is manufactured following different processes, as per Figure 34, and contains different characteristics, as described in Table 5 and Table 6 and shown in Figure 35.

Figure 34: Feed manufacturing process

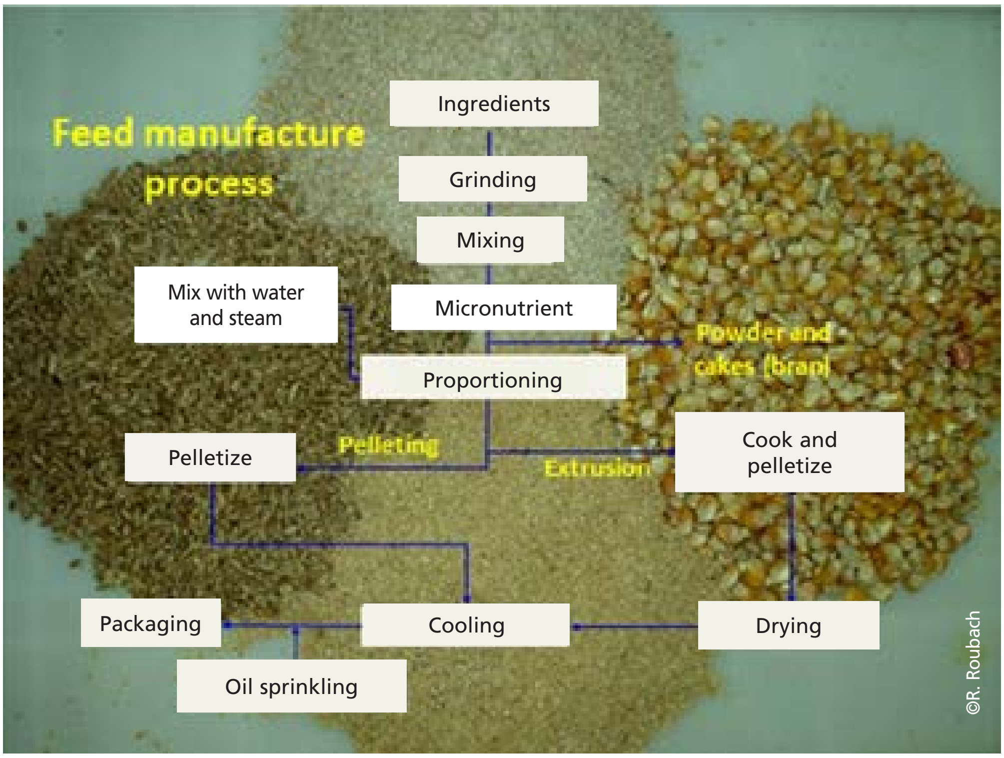


Table 5: Extruded versus pelletized feeds

Characteristics	Extruded feeds	Pelletized feeds
Floating	Float	Sink
Feeding observation	Easier	Difficult
Stability in water	High	Low to medium
Waste (potential for losses)	Lower	Higher
Feeding efficiency	Higher	Lower
Pollution (potential)	Lower	Higher
Cost	Higher	Lower

Figure 35: Cage feeding

Table 6: Examples of ingredients

Animal origin	Vegetal origin
Meat and bone meal	Soybean meal
Fishmeal	Cotton bran
Shrimp head meal	Peanut bran
Poultry by-products meal	Sunflower bran
Blood meal	Corn/cassava bran
Fish oils	Sorghum bran
	Wheat bran
	Vegetable oils

Note:
The operation of equipment is highly specialized and more costly. An extruder is not easy to operate.

IMPORTANT TECHNICAL ASPECTS OF AQUACULTURE FARMING

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The second part of this module lays out the different types of aquaculture, seed production, farm management, feeds and nutrition, as well as the required basic knowledge on site selection and pond construction.

SITE SELECTION, CONSTRUCTION OF PONDS AND WATER RESERVOIRS

This section introduces the most important principles to consider for site selection and pond construction. Crucial elements include the following points.

- Pond-based fish farming systems are characterized by depressions in a piece of land, filled with water, containing the culture species under various levels of management intensity.
- A typical pond farm should be located close to a reliable water source, on a soil type that can hold water. In order to reduce pumping costs, the farm should be sited on a gentle slope to allow water to flow into and out of ponds by gravity, and ideally not located too far from the farmer's residence.
- Ponds need to have an average depth of approximately 1.5 m to allow for adequate cover from predatory birds and hot surface water during the day.
- The most basic inputs in a pond-based farm are water and land. Without a good supply of good quality water, all other processes or management units will come to a standstill.
- Much like any fish farming system, the most important factor to be considered when selecting a site for a pond farm is the availability of a constant supply of good-quality water (FAO, 2006a). Examples of water sources include natural springs, rainfall, irrigation canals, reservoirs, dug wells, and streams and rivers. Chemical properties such as pH, dissolved oxygen, ammonia and biological factors (e.g. primary production potential) and physical characteristics such as temperature and turbidity must all be favourable year-round, or within the growing cycle (FAO, 2006b).
- The suitability of the selected land must be confirmed. However, land that is considered wasteland or unsuitable for agriculture will be cheaper. Sandy clay or clay loam soils are recommended, both for their water retention and their abilities to support primary production (FAO, 2006c). Laboratory analysis of the chemical characteristics of the soil (pH, phosphorus, etc.) is also recommended. Hydrological factors such as the susceptibility to flooding by virtue of adequate elevation and slope — 2 percent steepness or less — must also be considered. The water table level should be checked to allow for complete drainage and avoid flooding due to rainfall events (FAO, 2006c).
- Several social, economic and even cultural factors could affect either farm operation or marketing of products. Some of these factors include political climate, land tenure systems, credit and financing facilities, area development plans, location of

markets, acceptability of fish (or particular species) in the wider area, and proximity to amenities such as major roads and electricity. In order to decide on a site for any aquaculture operation, the farmer needs to consider the scale and intensity of production, whether it should be monoculture or polyculture, and the production target. All these factors are used when calculating the area of land required for the operation (FAO, 2006b).

- Design and construction of ponds, which includes the pond size, depth and shape:
  - A pond could have a surface area of between 1 000 m^2 and 2 000 m^2 (and no less than 300 m^2) (Mulonda, 2014). In general, pond dimensions should not allow for a total production exceeding 100 tonnes per pond, for ease of management and to reduce potential risks. Ideally, it should take no more than 10 days to fill a pond. For intensive operations, complete drainage is essential.
  - The maximum depth should range between 1.2 and 2 m. In regions with elevated temperatures, ponds should be deeper, between 1.8 and 2 m. Square or rectangular shapes are easiest to construct and manage. However, any shape can be chosen based on the layout of the land.
- Concerning the farm layout design, the following factors should be considered when laying out the locations of the farm (FAO, 2006d):
  - The distances to be covered when transporting feed from storage to ponds, and hauling harvested products to the holding facilities, should be as short as possible.
  - A farm shed is required to store equipment, feed and other inputs, in addition to farm records.
  - The farm buildings should be accessible by road.
  - Areas that require attention or frequent attendance, such as hatcheries, should be close to the farm operating buildings.
  - Each pond should have its own filling and draining system, if possible, independent from other ponds.
  - The dyke crests used as unpaved roadways should be at least 3 m wide. Paved roadways on dyke crests should also have 1-m-wide unpaved shoulders.
  - The dimensions of the canals that carry water from the intake to the individual ponds should allow all ponds to be filled within the recommended time. All ponds on a farm should be filled within 50 days.
  - The drain (outlet) ditches should be at least 0.3 m below the surrounding terrain, and not be allowed to overflow. Drain ditches serve as conduits for seepage and external runoff, as well as a mechanism to prevent this water from entering directly into surrounding waterbodies.


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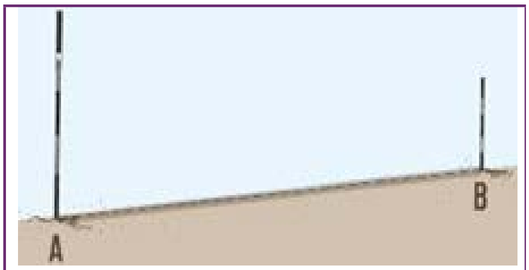
The first steps

Surveying: a definition	Surveying is the science of measuring the Earth and its features, and of making maps and charts to show them. Applied surveying is sometimes also called applied topography. The type, number and shape of the ponds to build depend on the topographical profile of a site.
Topography	In order to choose a good site for a fish pond, there is a need to measure several things, including: ➤ The area of land available; ➤ The slope of the land; ➤ The elevation (height) of the land in relation to the source of water that will be used; ➤ The distance between the source of water and the location of the ponds.
Measuring and more steps	The following steps are essential to set up the construction work: ➤ The distance between the source of water and the location of the ponds; ➤ The best way to supply water to the ponds; ➤ The easiest way of draining the ponds.

Lines of measurement

To measure and master distance, the area of land available, the slope of land, the elevation (height), etc., it is important to first understand the different kind of lines that exist and how to use them. Measurements are important in fish farming.



A line is a space between two points (for example, in this drawing, AB is a line).

Lines of measurement are either horizontal or vertical and may follow the level of the ground. These lines are clearly plotted in the field with markers to show the exact path along which you will measure. It can be a straight line, a crooked line or a curved line (see Figure 36 and Figure 37).

Figure 36: Different lines of measurement

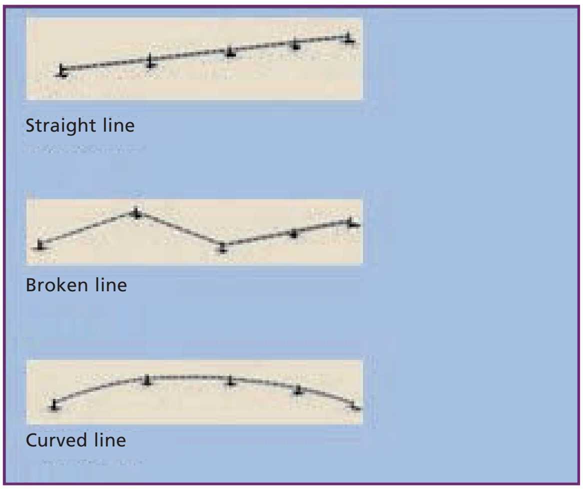
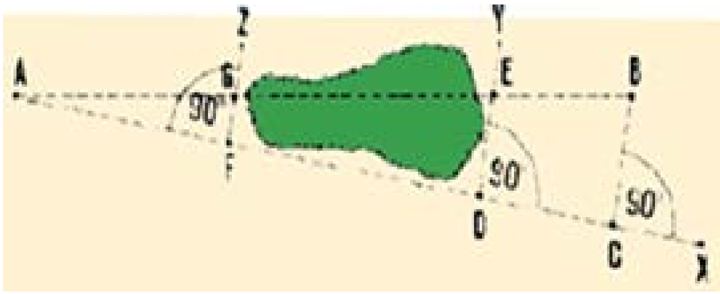


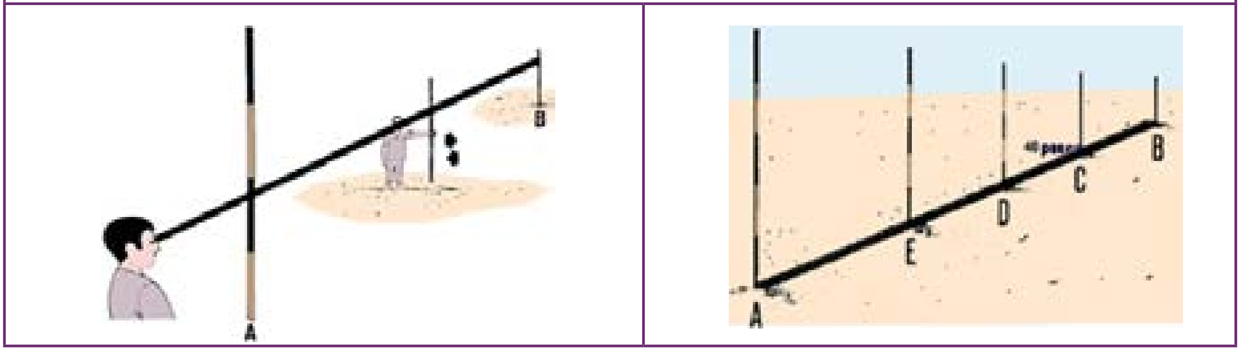
Figure 37: Setting a straight line between two points



Setting out line AB that runs through a forest

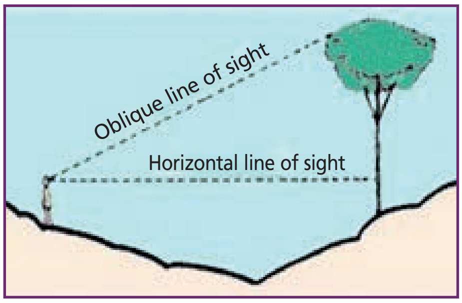
Mark points A and B with ranging poles. Choose a point X, which is beyond point B, and which you can see clearly from point A. Mark point X with a ranging pole or a marking peg. Then set out a line as above from point A to point X, avoiding the forest.

Setting out a straight line between two points visible from each other



Note: To draw a straight line, always make sure that the ranging poles are vertical.

Figure 38: Lines of sight



A line of sight is an imaginary line that begins at the eye of the surveyor and runs toward a fixed point. Lines of sight are either horizontal or oblique (between horizontal and vertical) (Figure 38).

Note: To evaluate a fish farming site, both lines of measurement (following the ground) and lines of sight (from your eye) will be used to determine distances and slope.

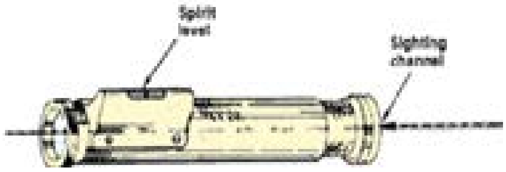
Surveying tools and types of measurement

Surveying tools include GPS, hand level, theodolites, Mason's level, measuring tape, rulers, string or twine (ropes), dumpy level and pegs. These tools can be used mostly for measuring horizontal and vertical distances, height differences and slopes (Figure 39).

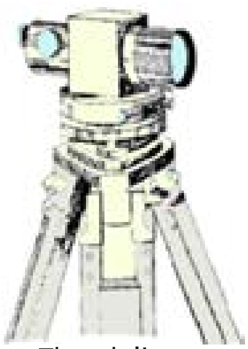
Figure 39: Equipment used for surveying and pond construction

Tools used for surveying GPS

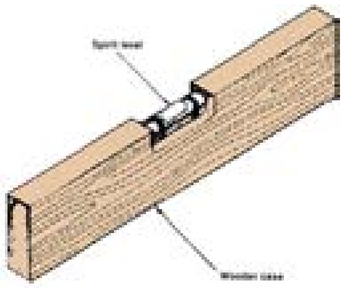
Line level



Tools used for surveying GPS



Theodolite

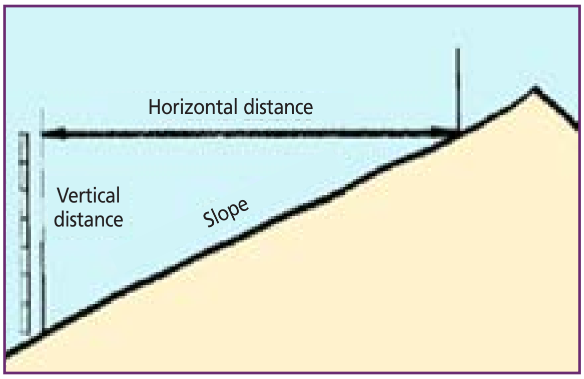


Mason's level

Measuring distance and surface area

In topographical surveys, the distance must be measured along straight lines. These lines either join two fixed points or run in one direction starting from one fixed point. They are plotted in the field with pegs, pillars or ranging poles. In topography or surveying, the distance is always horizontal (as the water level of a pond or a lake; see Figure 40). This situation will be applied up to the slope of terrain that is less than 5 percent. But when the slope of the terrain is greater than 5 percent, you will have to find the vertical distance.

Figure 40: Measuring distance with slope



> **Note:** Measuring lines must always be straight and horizontal even if the ground is not levelled.

Measuring distance along straight lines

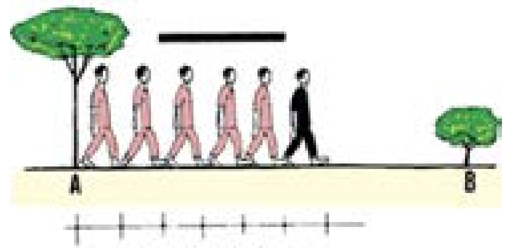
How to measure distance

You can measure distances roughly by:

- Pacing.
- By rope (show a rope).
- Measuring tape (show twine or other rope).
- Estimation by eyes (demonstrate).
- GPS (need more experience and show an example or photo).
- Line level (show an example and the dumpy level and theodolite).

> **Note:** Be aware that your pace will be shorter in tall vegetation than in short vegetation, shorter walking uphill than downhill, shorter walking on sloping ground than flat ground, and shorter walking on soft ground than hard ground. Same goes for the size of the person measuring: If you are a tall person, your pace will be different from a shorter individual. That is why measurements should be done by the same individual to minimize errors; and they should also measure their own pace under different circumstances.

Using steps and a formula to measure distance



Tip: Count the number of your normal steps and determine the correct measurement in metres.

Count the number of normal steps that will cover a fixed distance along a straight line, then calculate the average length of your step when you walk normally (called your "normal pace").

For example, take 100 normal steps on horizontal ground in a straight line. Measure the distance between your starting points (from your toes) to your ending point (at your toes). Divide by 100 to get your "pace factor" (alternatively, you can measure out 100 m and count the number of steps it takes to walk it).

Formula and surface area calculation

To calculate the surface area of an irregular pond, it is better to imagine a regular pond by calculating the average of sides and apply the classic formula (for instance, for rectangular: length × width; for square: side × side).

Formula for measuring distance with number of paces

Distance (metre) = N × PF

N = Number of paces

PF = Pace factor

Example: To measure ABCD. Pace distance AB = 127 steps; BC = 214 steps; and CD = 83 steps. ABCD = 127 + 214 + 83 = 424 steps. If PF = 0.75 m; ABCD = 424 × 0.75 = 318 m.

Note: Each person has his or her own specific pace value or pace factor which he or she should determine by getting the average on a given distance. The pace value is often below 1, such as 0.7, 0.8 and 0.9.

Example:

Imagine you have a pond with the following measurements: width 1 = 20 m, width 2 = 25 m, length 1 = 40 m and length 2 = 45 m.

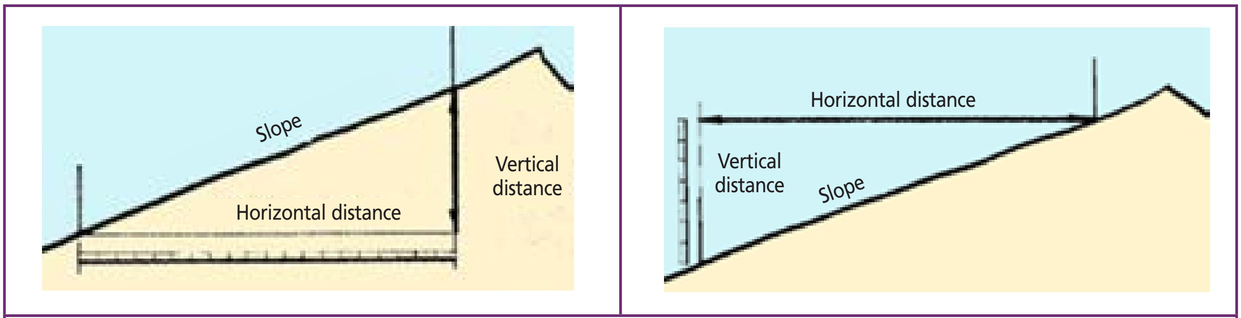
What is the surface area of the pond?

Average length: 40 m + 44 m = 84/2 and average width = 20 m + 24 m = 44 m/2. Therefore, the surface area is 924 m^2.

Measurement of height differences and slope determination

The height difference is the vertical space between two points. A slope is the vertical rise or drop of two points divided by the horizontal run (see Figure 41).

Figure 41: Measurement of height differences



Establishing the slope is one of the most critical aspects of surveying and site selection because you will rely on gravity to get water into and out of your ponds.

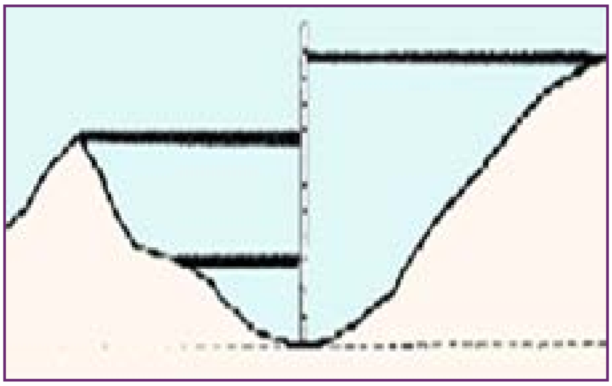
How to deal with height differences on your land (surface)

In pond culture, you must often measure the difference in height between two points, such as the following:

- To construct a pond, you need to determine the heights of the dykes you will build and the depths of the pond bottoms you will dig.
- To choose the routes of water-supply canals from the source to the ponds, you will also need height and depth measurements.
- When you plan a reservoir, you will also need to make height measurements to determine where its shoreline will be.

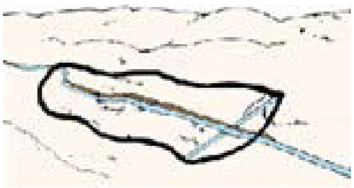
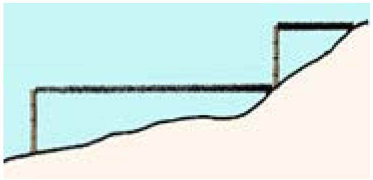
Measure any differences in height among a series of points on the ground and compare them. From the results of this comparison, calculate the heights of given points when making an accurate map. This is called surveying the levels of the points, or levelling (Figure 42).

Figure 42: Height differences



Calculating height differences

To locate points that are at the same height is called laying out contour lines, or contouring (see Figure 43).

Figure 43: Contour line	Figure 44: Setting out a slope
	

To locate points that have a given difference in height, you will set out lines of slope with a definite gradient calculating height difference.

The height difference between two points equals the difference in elevation between two points (see the diagram in Figure 42 and Figure 44).

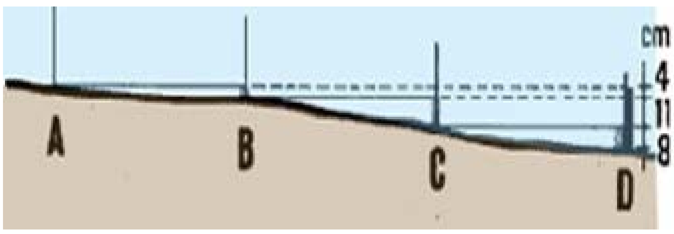
Measuring height differences in stages

Measuring height differences in stages requires obtaining the sum of the height difference of intermediate points, in other words, adding the measurements of the intermediate points to find the total distance.

In the example in Figure 45, the calculation would be the following:

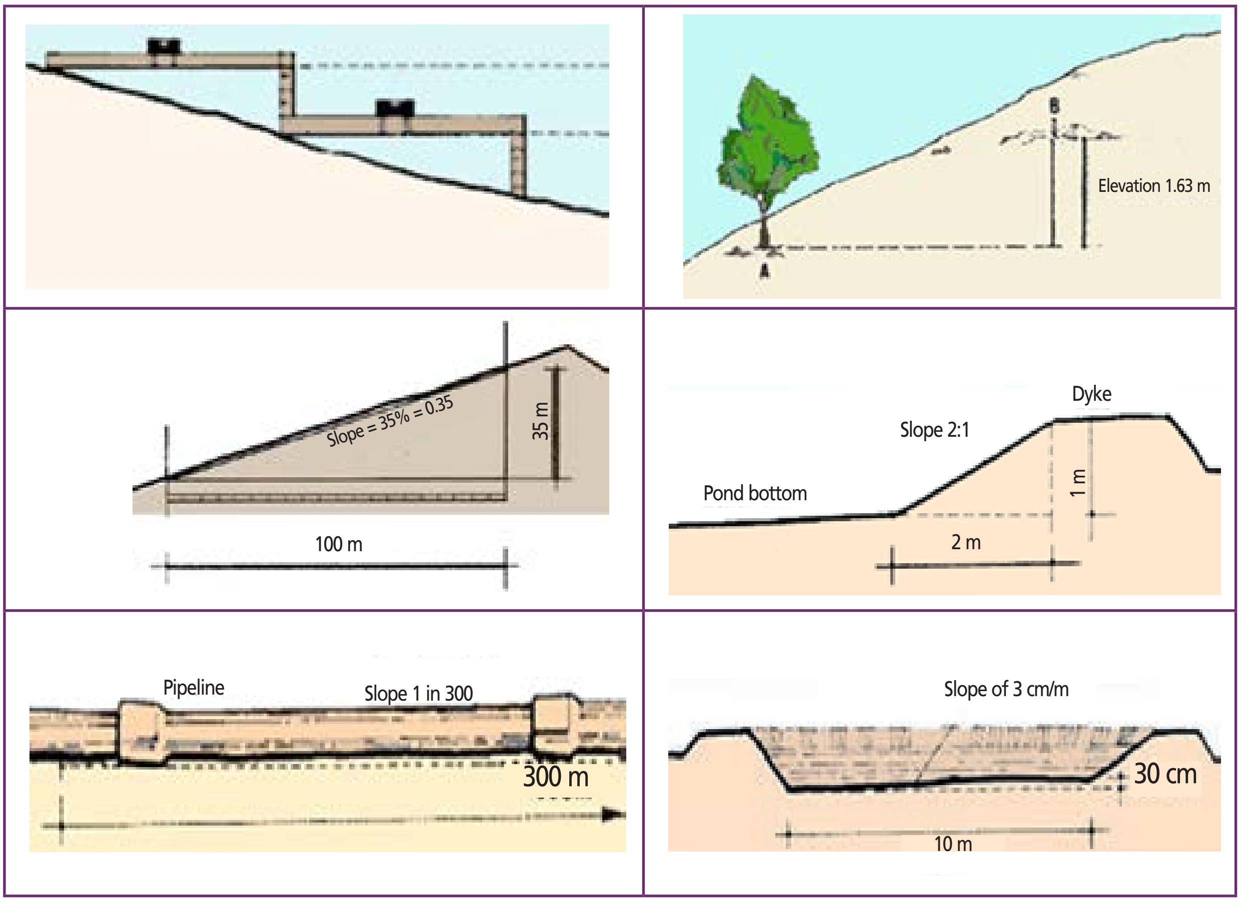
4 cm + 11 cm + 8 cm = 23 cm and is the height difference between A and D.

Figure 45: Measuring in stages



Slope determination and calculation

In fish culture, to determine the slope in a pond or reservoir, you will first need to measure the height difference between two points.



How to calculate a slope

To calculate a slope, measure the vertical distance (the difference in elevation) between one point of interest and another (called the rise or drop) and divide it by the horizontal distance between the same two points. Multiply the final product by 100 to get the percentage slope. For example, the difference in elevation from the top of Victoria Falls, in Southern Africa, to the bottom of the falls is about 100 m, and the horizontal distance is also about 100 m. Therefore, 100 m/100 m = 1 × 100 = 100 percent. That is one steep slope, indeed.

Formula = 100 × elevation/distance

To calculate a slope ratio, measure the vertical distance between two points (i.e. the difference in elevation), cut a stick of the same measurement, and count out how many sticks it takes to traverse the horizontal distance. The final product is expressed as X: 1, with X representing the number of sticks it takes to traverse the horizontal distance.

An ideal slope for fish farming is a 2–8 percent cross-section profile and a longitudinal profile of 1–5 percent.

Once you know the average slope between two points, you can calculate the height difference between the two points. The formula to do this is the following:

D × S = H (horizontal distance multiplied by slope equals height difference).

D = Horizontal distance

H = Height

S = Slope

Example:

You measure
D = 20 m (this is the horizontal distance); S = 5% = 0.05; H = 20 m × 0.05 = 1 m.

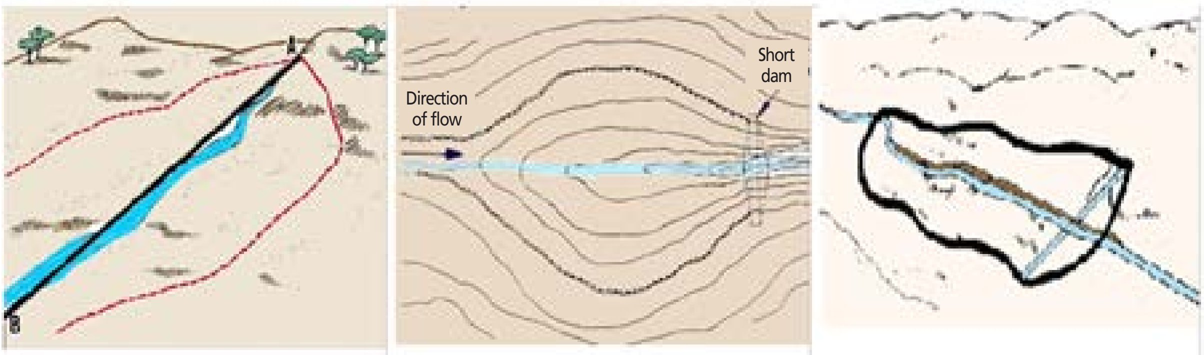
Contour lines or contouring

During the surveying of a fish farm site selection, the location of points that are at the same height is called laying out contour lines, or contouring (Figure 46).

Contour lines are often used to:

- Create terraces in agricultural fields.
- Demarcate the location of main barrage/reservoir, etc.

Figure 46: Examples of contour lines



Levelling an inlet main canal from the water capture point without dam.

Selecting site for barrage/dam construction using contouring techniques.

Contouring water level of a dam before constructing the barrage

Note: All the physical features of your fish farm depend directly on the topography of the site. These features include the type, number, size and shape of the fish ponds and how they are placed in relation to each other. The supply of water and the type of drainage also depend on the topography of the site.

Practice session with this section; please refer to Module 5 for details.

1. Measurement of the distance;
2. Slope calculation on a given site;
3. Pace factors calculation;
4. Contour line making.

Pond construction plan

Construction materials are selected in reference to the type of pond and water sources. Depending on the construction materials used, there are several types of commercial fish ponds: concrete ponds, earthen ponds, and ponds with polyvinyl chloride (PVC) liner (see examples in Figure 47).

Figure 47: Examples of ponds

Concrete pond, Zambia, ©Donard Namwisi.

Earthen pond, Uganda, ©Mulonda Boniface.

Liner pond, Zambia, ©Donard Namwisi.

Planning of the fish pond layout design

This session focuses on the construction of earthen ponds.

Planning pond layout

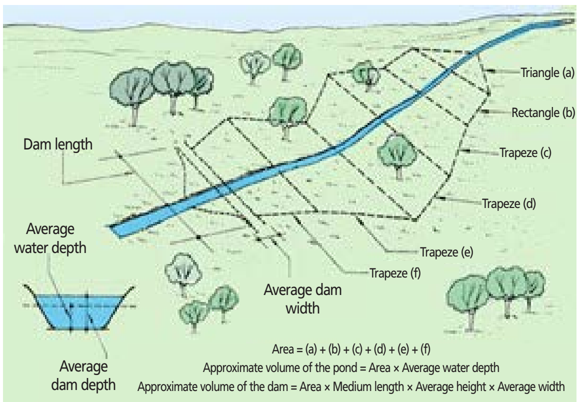
Before starting the demarcation of a pond, it is imperative to make a plan on paper, detailing the following:

- Organizational planning: defining materials for construction, and how, where, and in which order the farm will be built.
- Physical planning: deciding the layout and providing a detailed design and construction.

Figure 48 shows an example of a suitable site for fish farming in Eastern Zambia.

Figure 48: Identified site of a pond in Eastern Zambia and diagram

Identified site in Eastern Zambia, ©Donard Namwisi.



Selected and surveyed site for fish pond (FAO, 2006d).

Note: Technical assistance is needed for pond layout planning, design and construction.

To devise a good site planning or pond layout, a more detailed study should confirm the choice, based on the longitudinal profile and on the cross-section profile of the valley (see Site selection, construction of ponds and water reservoirs). Selection of the type of pond to build will also depend on the result of the longitudinal and cross-section of the valley survey.

Example diagrams of general layouts for fish farms are shown in Figure 49, Figure 50, Figure 51 and Figure 52 (FAO, 2006d).

Figure 49: General layout for a small fish farm

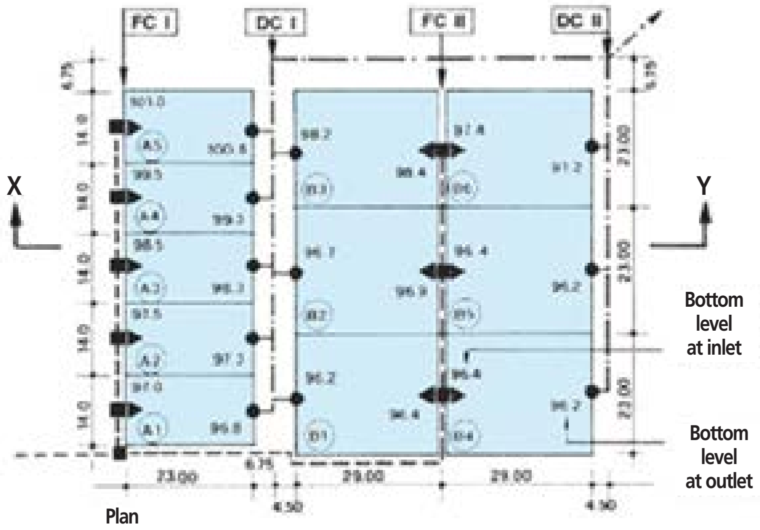


Figure 50: Pond layout plan with derivation system from one side

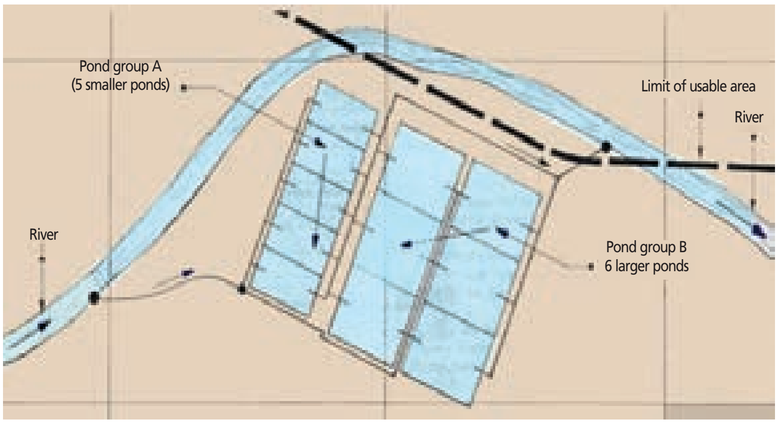


Figure 51: Pond layout plan with derivation system from both sides (parallel ponds)

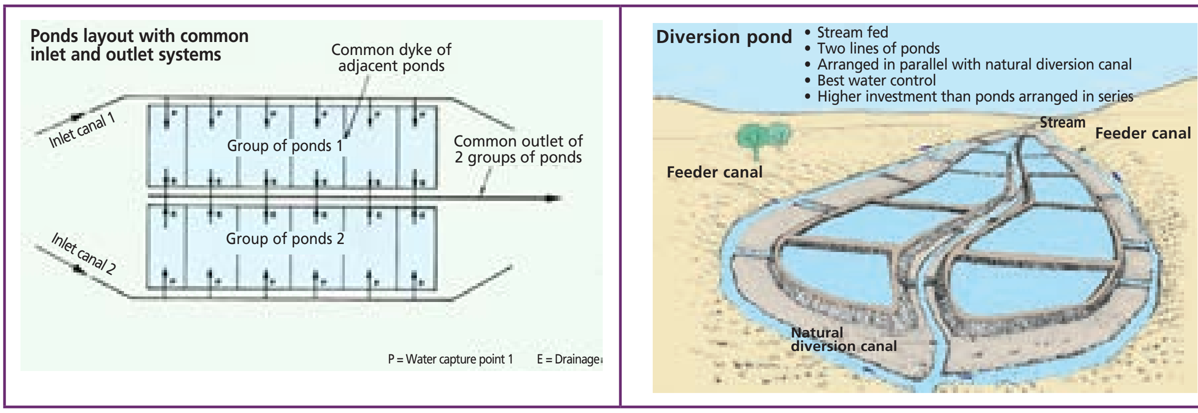
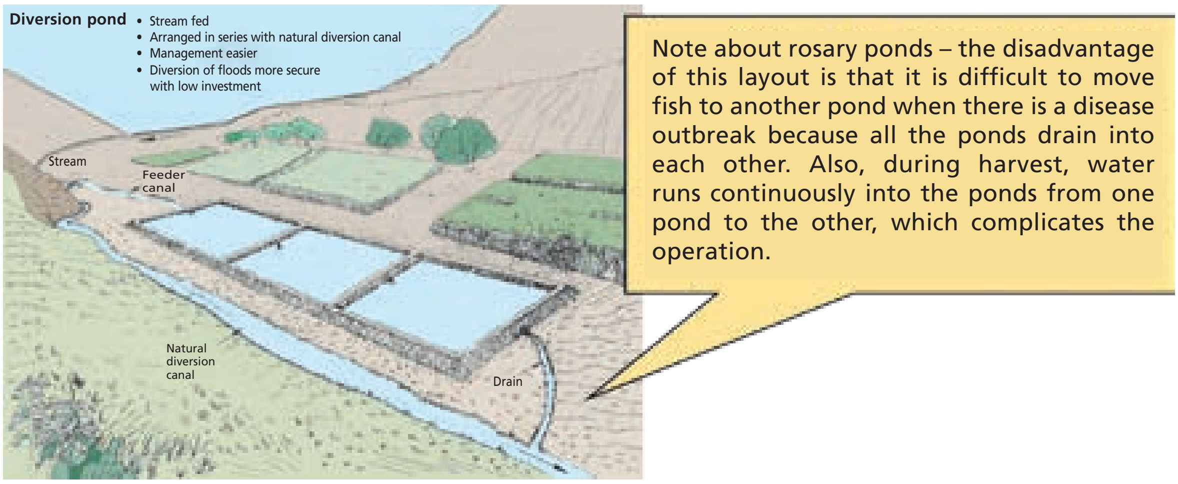


Figure 52: Example showing the layout of a rosary pond



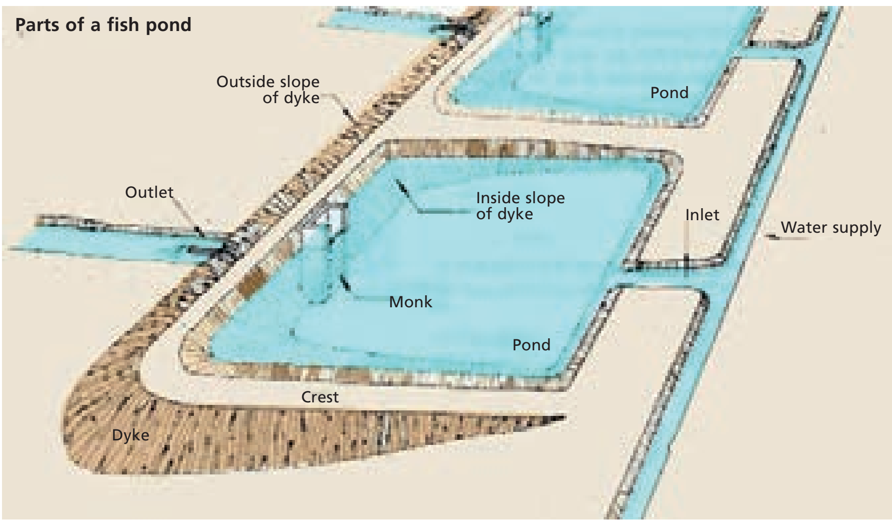
Good Pond layout (both sides of the valley) without a reservoir

After planning the layout of the pond and its inlet and outlet systems, it is easy to pass to the demarcation/measurement inlet and outlet systems, pond dykes and bottom.

A good farm layout comprises an inlet system, outlet system and pond demarcation/ measurement.

The parts of an earthen pond are dykes, pond bottom, inlet canal, outlet canal, inlet pipes, outlet pipes, the freeboard and capture area or the monk pond layout (both sides of the valley) without a reservoir (Figure 53).

Figure 53: Overview of parts of an earthen pond



Inlet and outlet systems demarcation/staking out/measurement

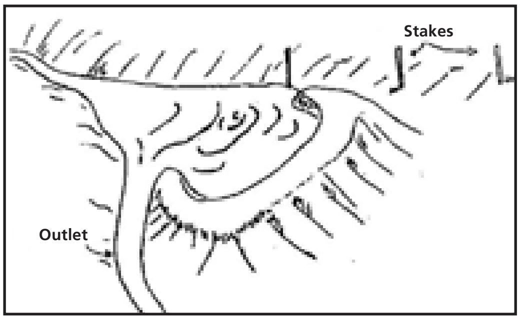
Inlet system (taking water to the pond): The system includes a water reservoir/dam, supply water furrow and inlet pipes.

Demarcating the inlet system should follow this process:

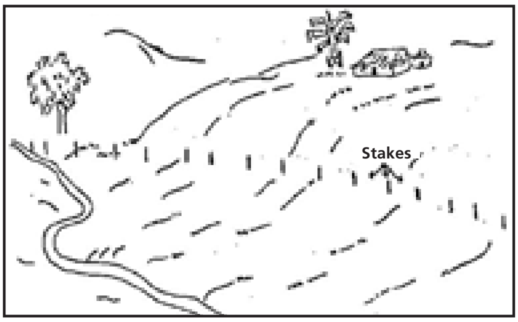
- First identify the water capture point/dam or barrage for reservoir and demarcate/stake the area (Figure 54) (see Dams for fish pond construction).
- Demarcate/stake out the water supply furrow/derivation canal from the water capture point (barrage/dam/reservoir). Staking out a water supply canal for construction involves creating a contouring or contour line, which means levelling points that are at the same level (see Contour lines or contouring).

Note: This task requires expertise from the technical team. Therefore, to achieve this task correctly, seek assistance from the technical support team.

Figure 54: Dam as source of water: inlet system demarcation



Dam/reservoir (RAP Zambia, 1998)



Inlet canal staking out (RAP Zambia, 1998)

Outlet system (for pond drainage system) demarcation/staking out

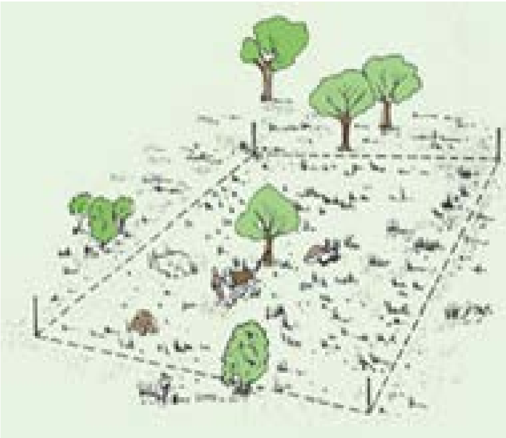
A drainage system located at the deep end of the pond and the drainage area includes:

- Implantation of drainage pipes with monk or without monk.
- Construction of a drainage canal:
  - identify the drainage point of the pond at the deep end inside the pond;
  - identify the drainage point of the pond at the outside deep end (this should at least show a difference in height with the inside deep end point at least 20 cm below the inside deep end of the pond);
  - determine the longitudinal profile of the drainage canal. The slope of this longitudinal profile should be at least 2 percent up to the drainage area; and
  - ideally, the drainage areas should be a running river and not a small swamp that can be filled up during harvesting.

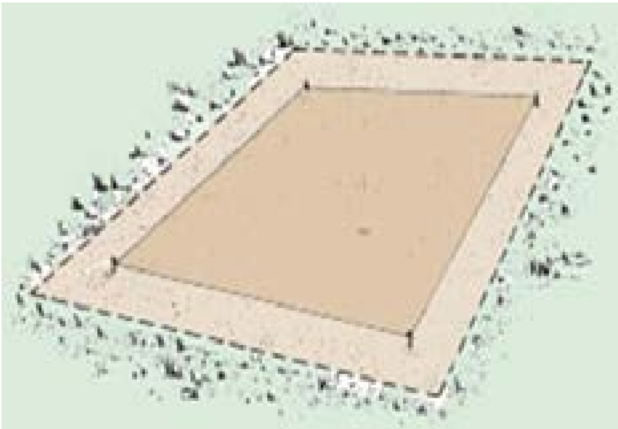
Demarcation and staking out

After selecting the site and making a pond plan, it is necessary to demarcate the size of the pond by indicating the outside toes (external borders) and cleaning the site for pond, dyke and bottom demarcation, as shown in Figure 55 (FAO, 2006c), the dyke and pond bottom demarcation/staking out (Figure 56) and the drainage system at the bottom (Figure 57), the cross-section of a pond (Figure 58), and the desired level of water depth (Figure 59).

Figure 55: Demarcation and staking out a pond



Measuring the outside size of a pond (FAO, 2006c).

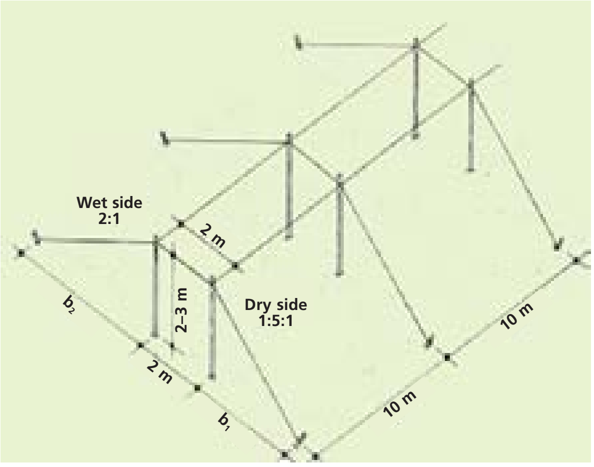


Stake out site as a guide for soil surface removal.

Pond dyke demarcation

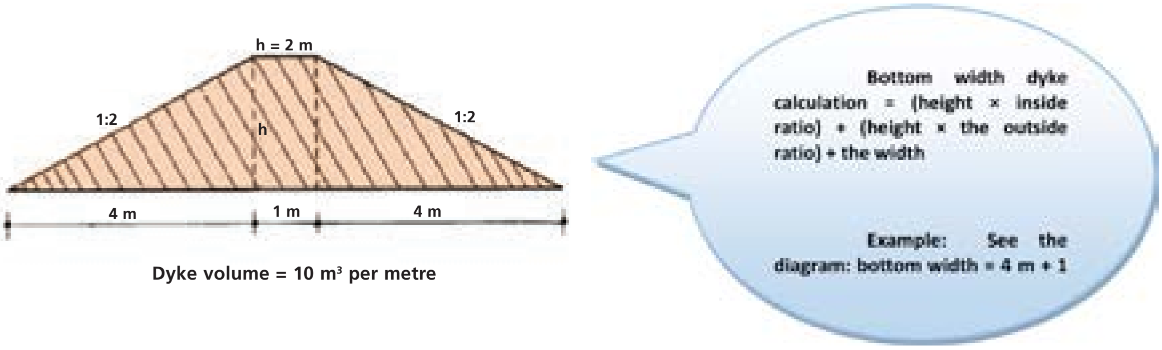
- Where to remove soil and where to add soil for each pond
- Dyke dimension
- The height of the dyke
- The top width of the dyke
- The bottom width of the dyke as well as its slopes
- Define the inside and outside slopes of the dyke

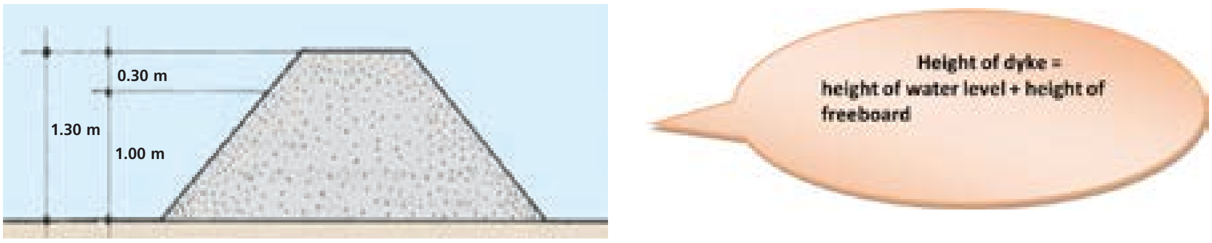
Figure 56: Diagram of the staking out process and staking out a pond in Uganda

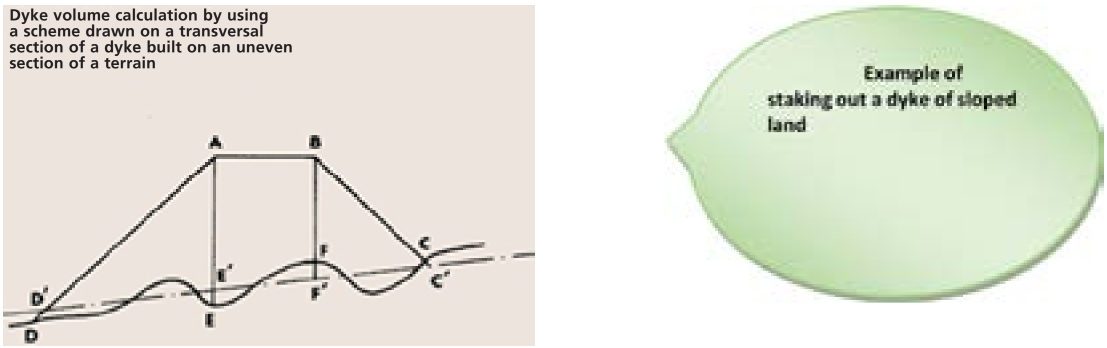


Source: FAO, 2006c.

The process of staking out a pond using a rope and pegs, Uganda. ©FAO/Mulonda Boniface.





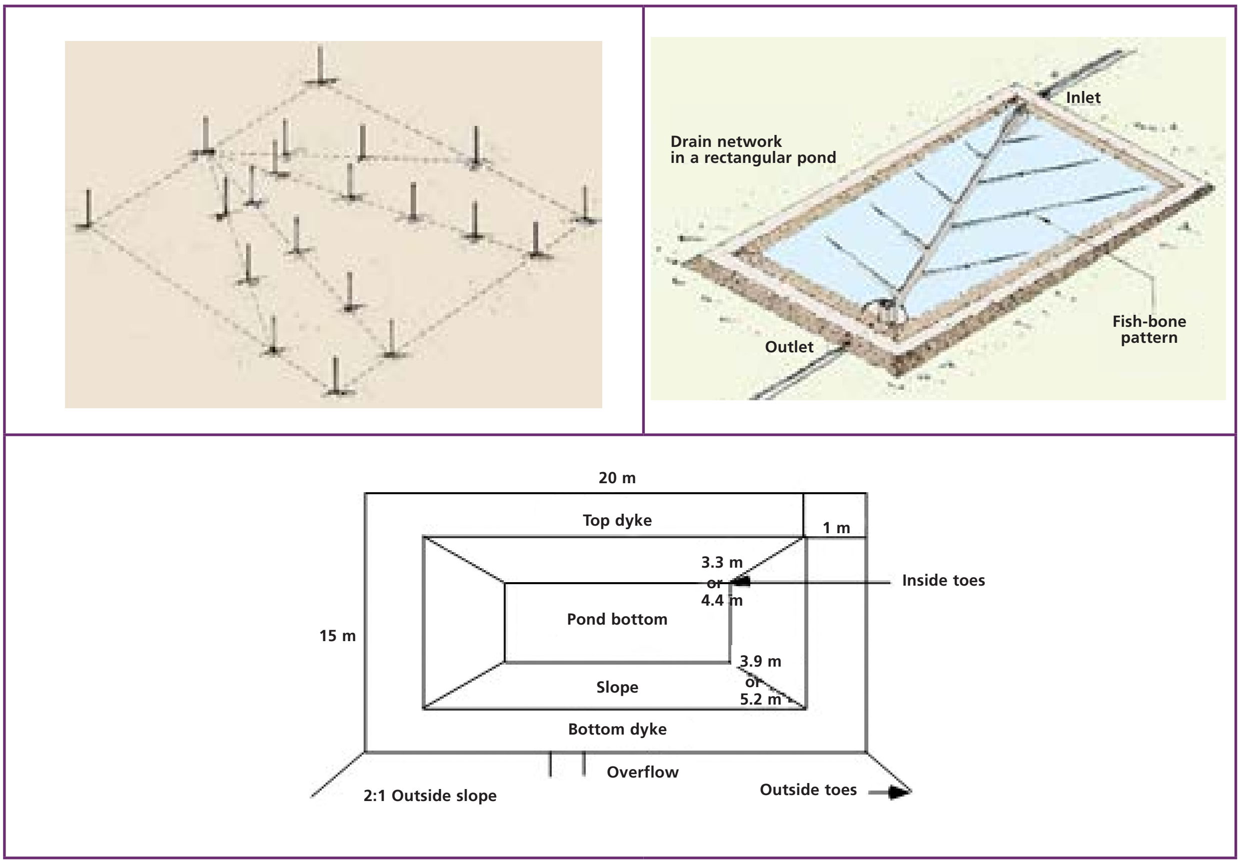


Staking out a pond bottom before construction

- To stake out the pond bottom area of each pond, it is helpful to get information on how much earth to remove and where to transport it (cut and fill).
- If the pond is full of water, it should be drained before demarcating.
- The process requires expertise and will depend on the slope of the pond bottom (use surveying tools).

Note: It is important to maintain an average of 1 m depth of water in the pond for the rapid growth of fish and to avoid predation.

Figure 57: Example of designing a drain network in a bottom pond



Source: FAO, 2006c.
Note: These schemes show an overhead view of a pond; a cross-section view of a production pond; and the cross-section of a United States Peace Corps project staked pond in Zambia.

Figure 58: Cross-section of a production pond

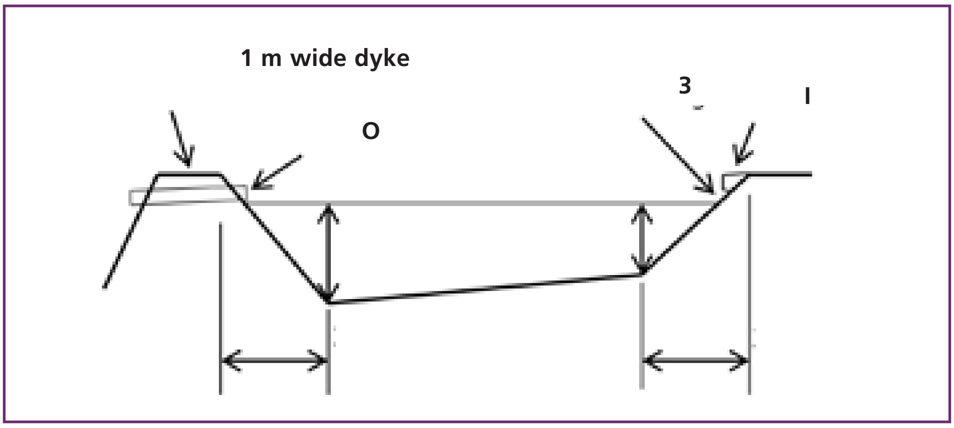
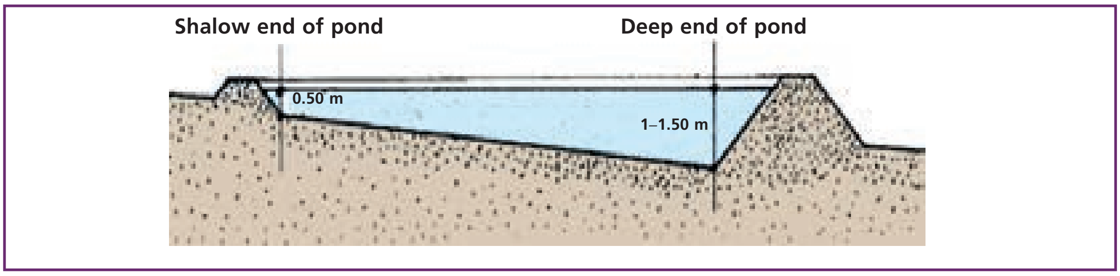


Figure 59: Diagram showing shallow end and deep end of water level in a pond



Source: FAO, 2006d.

Note: A sufficient water depth is needed for fast fish growth and to reduce aquatic vegetation proliferation.

Standard commercial fish pond

Appropriate site selection and pond construction are essential elements, particularly when planning and operating a commercial fish farm. Based on some observations in sub-Saharan Africa, a pond could have a surface area of between 1 000–2 000 m^2 (and no less than 300 m^2) (Mulonda, 2014). In general, pond dimensions should not allow for a total production exceeding 100 tonnes per pond, for ease of management and to reduce potential risks. Ideally, it should take no more than 10 days to fill a pond. For intensive operations, complete drainage is essential. The following are some general recommendations based on those observations (FAO, 1984).

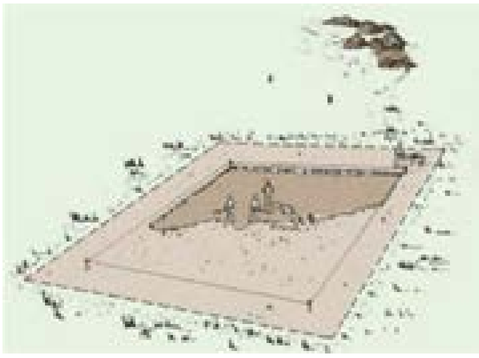
The recommended characteristics of a standard commercial fish pond are:

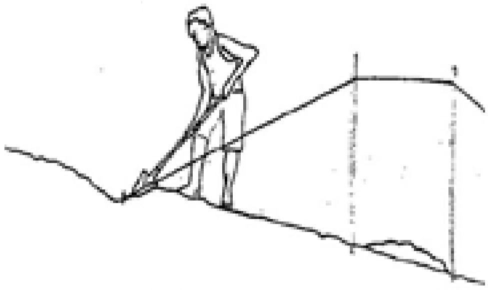
- Size of pond: 500–1 500 m^2 or more.
- Maximum depth of the pond: 1.5 m.
- Pond shallow end: 0.80–1.00 m.
- Pond deep end 1–1.80 m.
- Dyke width top: 1–3 m.
- Height of dyke: 1.8–2.20 m.
- Dyke bottom slope/ratio of 2–3:1 for inside dyke slopes and 1.5–2:1 for outside slopes.
- One or several overflow facilities, which can facilitate arming.
- Water depth at the shallow part may be 80–100 cm and at the deeper end 100–120 cm.
- Overflow pipe placed near the top of the dyke (freeboard 0.5 m).
- The outlet furrow: 1 m wide at the bottom and 40 cm deep. The slope should be between 1 and 2 percent.

Building the pond

Building a pond requires thoughtful planning and preparation. Some very practical insights and guidance for consideration based on the site and farm specific contexts are noted below.

Preparation of the construction site





Pond dyke and bottom construction

- Remove surface soil to the outside limits of pond dykes.
- Cut and fill during pond construction (FAO, 2006c) by cutting, carving or shaving the top dyke out of the hillside, and then reusing the soil that you remove to build up the dyke.
- Realistically, all ponds require some cutting (soil removal) and some filling (soil addition). See the photos below and the drawings on the left.
- To obtain a rough estimation of how much earth you must move to build the pond, the amount of soil can be calculated in m^3 by looking at the measurements of your staked-out pond (see the photos below).

Cut and fill, Ghana, ©FAO/M. Boniface.

Construction of a dyke, Uganda, ©FAO/M. Boniface.

Pond construction using a bulldozer, Uganda, ©FAO/M. Boniface.

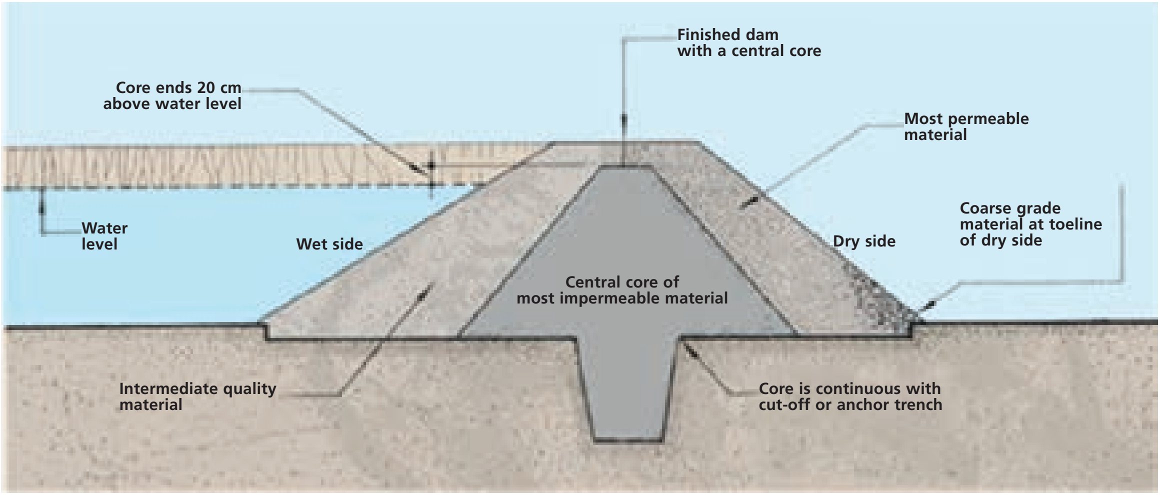
Note: Dyke construction should be progressive – step by step.

Why a core trench?

In areas with sandy soil, you should begin pond construction with something called a “core trench” (Figure 60).

- A core trench is a trench about 50 cm wide, which runs from one end of a dyke to the other.
- It should be dug as deep as necessary, until finding an impermeable clay layer, and then filling the entire trench with clay.
- The purpose of a core trench is to make the dyke stronger and less permeable to water, and thus less likely to leak or seep.

Figure 60: Diagram showing a core trench in a dyke

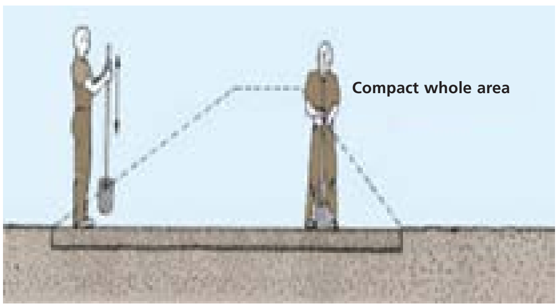


Source: FAO, 2006c.

Compacting and shaving dykes (Figure 61 and Figure 62) are necessary processes to complete the construction of a pond (Figure 63)

- To reduce leaks and seepage, when you add soil to build a dyke or dyke slopes, you should compact each layer 30–40 cm.
- In areas where the water has been raised quite high above the natural water table (common with village furrows), ponds will leak through the pond bottom. To reduce the amount of seepage, use soil from termite mounds.
- Uptake out all roots and other wooden material, and after each layer of 30–40 cm of soil, compact it with compactors (see illustration and photo in Figure 61).

Figure 61: Shape of dyke after compacting and before shaving



Compacting dyke (FAO, 2006d).

Compacting soil during pond construction, Guinea-Bissau, ©FAO/M. Boniface.

Figure 62: Slopes and shaving of dyke

- Respect the pond bottom slope. Follow the maximum/minimum of 2 percent for the pond bottom slope.
- A very steep slope of pond bottom will lead to less depth of water in the pond and increase proliferation of aquatic vegetation.
- The dyke must be shaved to give it good shape and to avoid erosion (FAO, 2006d).

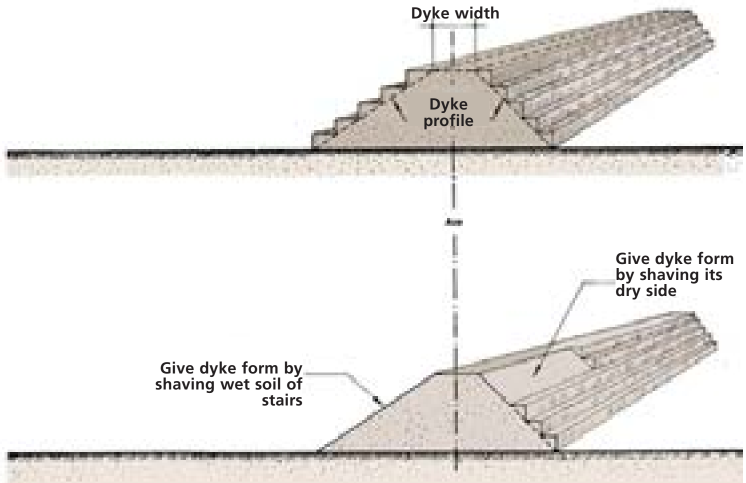
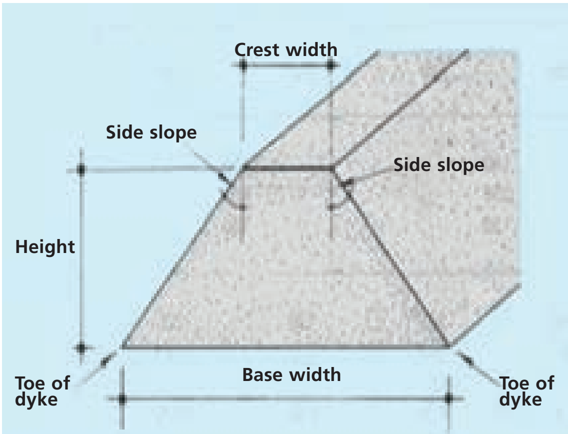


Figure 63: Pond construction process



Pond construction process, Eastern Zambia, ©Donard Namwisi,

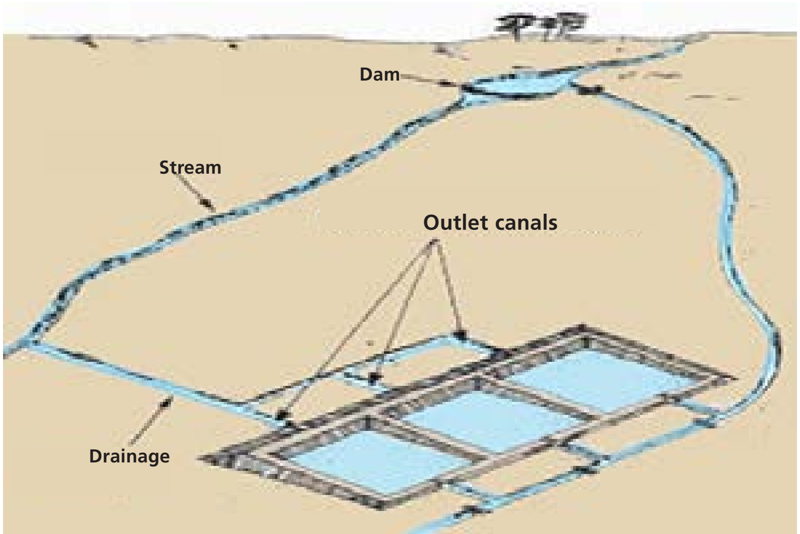
Don't ignore the slope!

Building the inlet and outlet systems

The construction of an inlet system includes the following:

- Inlet or derivation canal construction.
- The inlet canal should be well designed (see Figure 64).
- The inlet canal or derivation should be constructed with cement or PVC pipes (see Figure 65 of the various canals).

Figure 64: Diagram showing the network of inlet and outlet systems



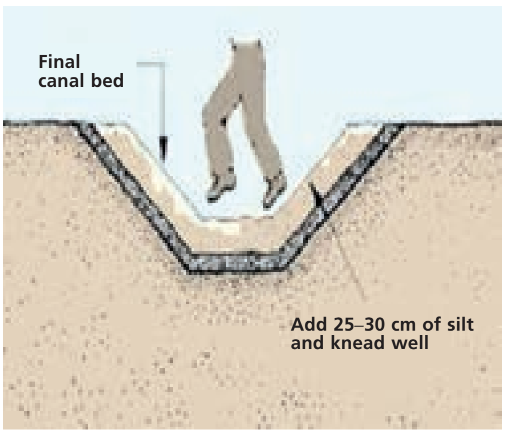
Source: FAO, 2006d.

Figure 65: Different examples of inlet canals

Concrete main inlet canal, Guinea-Bissau, ©FAO/M. Boniface.

Concrete main inlet canal constructed of an earthen dyke, Chad, ©FAO/M. Boniface.

Earthen inlet and outlet canal badly constructed, Uganda, ©FAO/M. Boniface.



Outlet system or drainage system

An outlet or drainage system can be made from a piece of a pipe with elbow (Figure 66 and Figure 67). The evacuation pipe should be installed 10 or 20 cm above the inlet furrow (see Pond design/demarcation).

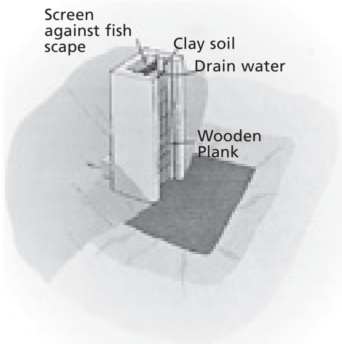
In some cases, the harvest basin can be constructed in a pond for easy catching of fish. This can be constructed with concrete, cement or bricks. It can be inside or outside of the pond bottom.

Finishing touches include:

- Placement of inlet pipes and screen so "trash fish" do not enter the pond and your fish do not escape.
- Placement of outlet pipes and overflow pipes with screen.

Figure 66: Example of drainage system


Open monk for drainage, Senegal, ©Mammina.



Concrete monk for drainage.


PVC pipe for drainage, Uganda, ©FAO/M. Boniface.

Figure 67: Inlets and outlets


Outlet PVC layout, Guinea-Bissau, ©M. Boniface.


Inlet PVC pipe and pond layout, Chad, ©M. Boniface


Using stones when filling a pond by PVC inlet pipe, Guinea-Bissau, ©I. Barry.


Bad fixing of inlet PVC pipe, Zambia, ©M. Boniface.


Planting grass on a finished dyke, Zambia. ©D. Namwisi.


Pond dyke wheel covered by grass, Gabon, ©K. Lionel

Filling the pond

Filling the pond with water needs to be done progressively and be monitored because there is risk that the dyke will collapse. Note that there will be natural compacting during pond filling. Note also that the quantity of water in the pond can be estimated as well as the number of days it will take to fill the pond; and the planting of grass along dykes decreases erosion and increases the dyke longevity screen of these pipes so that “trash fish” do not enter the pond.

Do not do the following:

Photos: ©D. Namwisi.

In summary

The pond should:

- Be greater than 300 m^2 to produce fish for food and income.
- Have a square or rectangular shape.
- Be shallow, with water depth from 80 cm (upper end) to 120 cm (lower end).

The dykes should:

- Be 50 cm higher than the water on top (freeboard).
- Have a good slope on the sides.
- Be built with soil tightly packed.

Build your pond in successive steps:

- Clear all vegetation, rocks, etc., from the area.
- Remove the topsoil and keep it aside.
- Mark the limits of the inside banks at ground level.
- Mark the limits of the inside banks at bottom level.
- Dig inside these last limits by layers of 20 cm (upper end) to 30 cm (lower end).
- Use this soil to build up the banks, layer by layer and tightly packed.
- Form the inside slopes of the dyke.
- Form the outside slopes of the dyke.
- Add topsoil on top and on the outside slopes of the dyke.
- Dig a small draining canal inside the pond.

Dams for fish pond construction

Why a dam/reservoir?

There are only two reasons to construct a dam:

- To raise the level of a water source so that a main inlet canal can be built;
- To create a reservoir for water storage (for mitigating the effects of the dry season); this applies to some areas in Zambia (Figure 68).

Figure 68: Construction of water reservoirs/dams

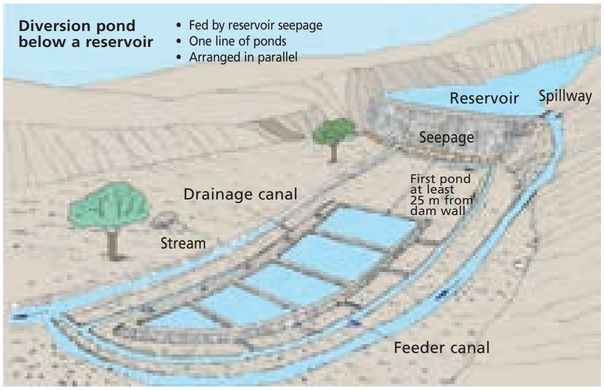


Diagram of dam serving a fish farm (FAO, 2006c).


Earthen dam, Copperbelt, Zambia ©Donard Namwisi.

Identifying and selecting a site for dam/reservoir construction

Identifying and selecting a good site for dam/reservoir construction is essential. Sound procedures to follow are the following:

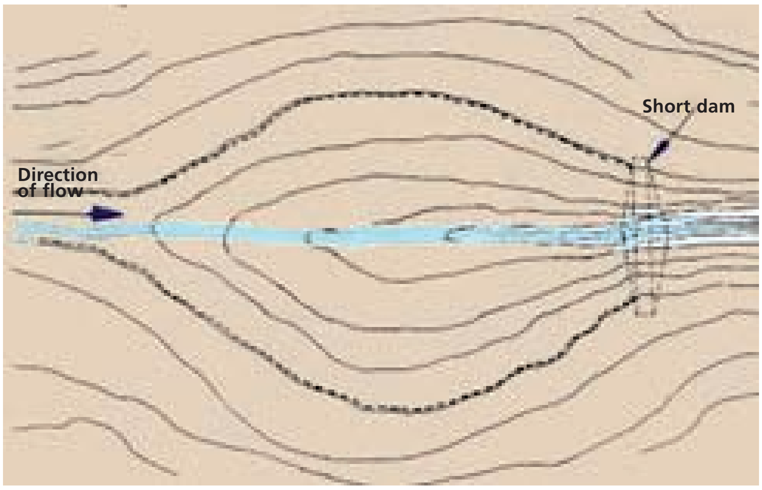
- Walk down the valley along the stream and find a place where the water level is relatively high in the stream bed.
- Check if the site (soil and topography) can allow for retention of the greatest volume of water from the top of the stream.
- Look for a place that will be the easiest to constrain a lot of water and easiest to construct, that is, a place where the stream is narrow or has narrowed, i.e. short length of dam dykes.
- Make sure there is good material (soil) around the place where the dam will be constructed and little vegetation, especially trees.
- Carefully check for areas of possible flooding: the smaller the drainage area, the higher potential for floods.

Surveying the identified area

Determine how high the water could feasibly be raised with a dam of moderate size (1–2 m) (Figure 69 and Figure 70). Keep in mind that the water at the point of the dam cannot be raised higher than the level of the source up the valley.

Determine the location from which the inlet canal could originate based on the height of the proposed dam.

Figure 69: Trace the fill canal along a contour line



Wide valley with narrow end, a suitable place for dam construction (FAO, 2006d).

Figure 70: Concrete dam and liner dam

Concrete dam, Gabon. ©Mulonda Boniface

Liner dam, Zambia. ©Donard Namwisi.

Dam/reservoir staking out and construction steps

- Clear the area completely of bush, trees, stumps, grass and all other debris, such that only soil and water remain to be dealt with.
- Demarcate the dam with the appropriate measurements of height, length and width (depending on the power of the stream, the width/slope of the dam will vary between 2:1 and 4:1, and the top of the dam 1.5 m).

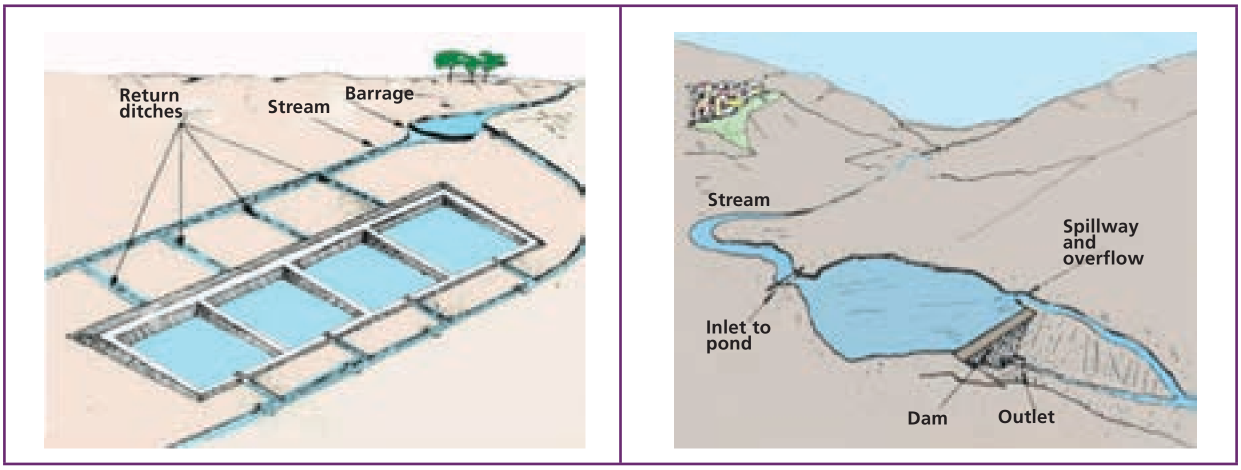
Avoid damming the stream very close to the source (e.g. spring or well).

Procedures for constructing the dam:

- As a first step, deviate the water stream on one site and dig away all the organic matter/soil that will not be used for construction. Once construction is completed, use the soil to cover the top of the dyke and plant grass to protect it from erosion.
- Leave the middle part of the dam open to allow water passage (it is usually impossible to stop all the water from flowing into the stream bed, even with a spillway and temporary furrow).
- Use clay or anthill soil (in Zambia). There should be no stones, sticks or other organic material in the soil.
- The soil should be placed and compacted every 20–30 cm (see pond construction steps).
- The middle section of the dam should be constructed last to allow the stream to continue flowing through.
- When it is time to build the middle part, notify potential users in the area that there may be some interruptions of water supply to allow safe construction of the pond without flooding in the area.
- The middle should be built quickly while compacting well. If the stream is not diverted completely, the running water will make the soil impossible to compact.
- In sandy soil, build a core trench, which is incorporated in the dam in order to avoid the problem of erosion in the body of an earthen dam. A core trench is tightly packed clay soil that is deeply anchored in the regular soil.
- Dig a spillway/temporary furrow to pass water from the stream around the construction site. It allows excess water from rainfall to pass around the dam instead of filling it. If too much pressure is applied, it may possibly burst the dam.
- The spillway of a dam is the passage through which excess water from a lake or reservoir flows.
- A spillway should be constructed just below the level of the dam to accommodate an access of water in the rainy season.
- The water level should never exceed the height of the dam as the intense pressure will cause the dam to break.
- Make the spillway wide enough to carry excess water.
- Strengthen different parts of the spillway because this is where your water will be rushing out.
- Construct the spillways with cement or put down some rocks or wooden planks.
- When the dam is complete, the temporary furrow/canal must be closed so that the water now fills behind the dam and enters the derivation canal. This canal may be located near the original location of the temporary furrow, and it must be at a level lower than the spillway so that it fills first. Figure 71 shows a diagram of a dam, inlet and outlet channels from the dam to the pond system (FAO, 2006d).

©C. Byakusenge

Figure 71: Diagram of viewing dams and inlet and outlet systems



Source: FAO, 2006d.

Pond renovation

This section helps to identify the problems for ponds that need to be renovated in order to meet the technical requirements for commercial aquaculture. It also discusses how to apply appropriate techniques to renovate a dyke, pond bottom, and the inlet and outlet systems of an old pond.

General and technical problems of most existing ponds

Past experience

Past experience shows that renovating a fish pond is often difficult because the fact of its prior construction and design factors (size of pond, dyke dimension, slope, depth of pond, lack of inlet and outlet systems, pond layout, etc.) makes it necessary to try and reshape the pond to the required standard at that location.

Problems of most existing fish ponds before renovation

- Existing dykes are often built with decomposable organic matter; therefore, it is usually wise to take the dykes apart and rebuild them.
- Most traditional ponds have narrow dyke tops and no slopes, so abundant fill dirt (soil) is needed.
- Most traditional ponds are shallow. You need to sink them to the required depth.
- A drainage canal needs to be constructed if it does not exist.
- Some ponds are too large or small or do not meet the standards of a commercial pond; it is necessary to rebuild them to a manageable size.


Hatcheries and nursing farms on the shore of Lake Kariba
Hatcheries and nursing ponds on the shore of Lake Kariba owned by large cage culture companies are revealed by satellite image.
Nile tilapia, *Oreochromis niloticus*, is the dominating species in Zambian aquaculture. In 2020, it accounted for 67 percent in the total production of farmed fish in the country.
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SEED PRODUCTION, NUTRITION AND FEEDS

The choice of a particular seed production method is dependent on available facilities, the reproductive biology of the fish and on local conditions. There are three main methods for reproducing culture species: natural, semi-natural and artificial (FAO, 2006b). In each of these methods male and female fish (the broodstock), or their sperm and eggs, are brought together for the purpose of propagation.

Natural reproduction is especially used to propagate tilapia. A set ratio of males and females are placed together in a breeding pond or other enclosure and allowed to spawn naturally. Other species might require additional changes to the environment. For example, African catfish (*Clarias*) will only spawn with a sudden rise in pond level; American and European catfishes (*Ictalurus* and *Silurus*, respectively) require the presence of artificial nests; and common carp requires grassy vegetation. Due to the ecology and ethology of some species, catfish and Nile tilapia have been the most selected farming species in sub-Saharan Africa. The culture of a monosex tilapia has been shown to be more profitable than that of a mixed-sex culture. For African catfish (*Clarias* spp.), artificial reproduction is required.

In semi-natural reproduction, female fish are injected with pituitary hormones to instigate spawning before males and females are placed together. Fertilized eggs are then collected for hatchery procedures.

In artificial reproduction, female fish are injected with chemicals to ripen the eggs in their ovaries, after which they are stripped of the ripe eggs. The eggs are then fertilized artificially with male sperm and then sent through hatchery procedures.

Broodstock can either be obtained from the wild or transported into the farm, or the broodstock can be specially raised in the farm through selective breeding, which allows for progressive stock improvement. Broodstock pond conditions should be conducive to the particular farmed species. Temperature, dissolved oxygen and natural food suited to the species contribute to successful reproduction (FAO, 2006b).

Relatively small-sized, young broodstock is preferred to bigger-sized older ones. The former produces better quality eggs that have higher food utilization efficiency. Broodstock should be replaced regularly to improve spawning synchrony (Badiane, 2015).

This section includes practical exercises both for the classroom and on the farms. Please refer to exercises and instructions in Module 5 – Practical Hands-On Training.

What is seed production?

To start a fish farm with the objective of growing fish to a mature size for consumption, the farmer needs to acquire "seed" out of a production of small fish/crustaceans for grow-out and to follow the different steps of seed production, such as broodstock selection, breeding, eggs incubation, hatching, larval rearing and nursing.

It should be noted that seed production is a specialized field within the aquaculture value chain and should be performed only by farmers who have the correct skills and competencies; otherwise, it can be non-cost effective and lead to the production of bad quality seed.

Different farming phases from seed production to grow-out are shown in the following overview.

Seed production steps in ponds	
Spawning • Securing and spawning of broodstock. • Hatching of eggs.	Spawning 0.1 hectare
Growing fry to produce fingerlings.	Fingerlings 1 hectare
Grow-out to market size • Stocking and grow-out of fingerlings to marketable size.	Food size 20 hectares
There is a need to determine the unit size and requirements of each phase.	

Management of seed production

The choice of a particular seed production method depends on the available facilities, the reproductive biology of the fish, and the local conditions. There are three main methods for reproducing culture species: natural, semi-natural, and artificial (FAO, 2006b). In each of these methods, male and female fish (the broodstock), or their sperm and eggs, are brought together for the purpose of propagation.

For example, African catfish (*Clarias*) will only spawn with a sudden rise in the pond level; American and European catfishes (*Ictalurus* and *Silurus*, respectively) require the presence of artificial nest containers; and the common carp requires grassy vegetation. Natural reproduction is especially used to propagate tilapia. A set ratio of males and females are placed together in a breeding pond or other enclosure and allowed to spawn naturally. Other species might require additional changes to the environment (FAO, 2017a).

Facilities and material preparation for hatchery seed production

Before and after use, all materials and facilities should be cleaned and disinfected.

Materials needed:

- **Cleaning:** brush, mops, squeegee (to clean liquids from a flat surface), powder soap, basins.
- **Disinfection:** 12 percent bleach or other appropriate disinfectant.
- Basins can then be filled with water and parameters measured in order to readjust those that are not within the recommended range:
  - **Water parameters kit:** pH meter; alkalinity, hardness, nitrite and ammonia solution test; oxymeter.
  - **Chemical products for readjustment:** calcium chloride (alkalinity), soda bicarbonate (pH and hardness), non-ionized salt (conductivity), buckets of 10 litres.

Photos: ©Abdoul Aziz Badiane.

Producing catfish seed

For African catfish (*Clarias* spp.), artificial reproduction is required. A hormone (Ovaprim) is used to stimulate eggs maturation in females at 0.5 ml/kg. After eggs are stripped, incubation is done in an aquarium. Larvae are initially fed with *Artemia* for one week after hatching, and then transitioned to industrial catfish feed (Badiane, 2015).

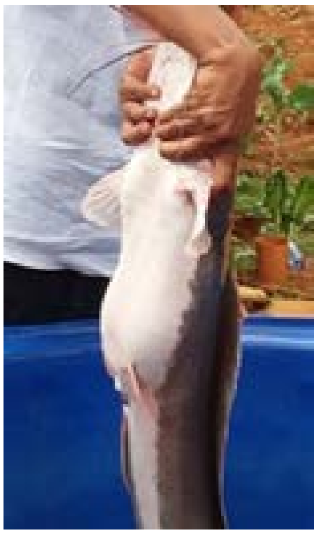
Broodstock

Broodstock selection

A good broodstock quality is essential to ensure good egg quality and thus a good hatching rate.

Materials needed:

- Broodstock male and female: >1 year old; body weight >1 kg; female belly should be well rounded, soft and swollen; male with well-developed genital papilla.
- Scale of 50 kg capacity ± 1 g.
- Scoop net for broodstock.
- Basins of 40 to 60 litres.
- Towels.
- Notebook and pen for data recording (body weight, tank number, etc.).



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Hormones

Hormone injection
The most common method of administrating the hormone is with an intramuscular injection into the dorsal muscle. Selected females will be injected with hormones or pituitary gland to induce eggs maturation.

Materials needed:

- Hormone or pituitary gland to induce final maturation. Synthetic hormone (Ovaprim) at a dose of 0.5 ml/kg.
- Syringe 5 ml with graduation of 0.2 ml.
- Towels.
- Zatch.
- Notebook and pen for data recording (body weight, volume of hormone, time injected, basin number).

Harvest of eggs and milt

Eggs and milt harvest

Average temperature (°C)	Latency time (hours)
26	13
27	12
28	11
29	10
30	8

Eggs should be harvested from 10 to 30 hours after hormone injection according to water temperature.

To harvest the eggs, apply smooth abdominal pressure until all the eggs are collected.

Materials needed:

Egg harvest (Figure 72):

- Bowls (2 to 3 litres) and towels.
- Scale of 5 kg capacity ± 0.1 g.
- Notebook and pen for data recording (quantity of eggs, harvested time).

Milt harvest (Figure 72)

Procedures for milt harvest:

- Anaesthetize the male until the fish completely sleeps and place its back on the table.
- Incise the abdomen about 3 to 5 cm from the genital papilla.
- Introduce fingers into the abdomen to remove the testes.
- Puncture the testes with a syringe to collect the milt.
- Sew the wound and apply Betadine® solution.

Figure 72: Steps for harvesting eggs and milt

Photos: ©Abdoul Aziz Badiane

Materials needed for harvesting eggs and milt in catfish

Needle, surgical thread, scalpel for male surgery, syringe 5 ml, Betadine®, phenoxyethanol, notebook and pen for data recording (volume of milt, time harvested, body weight).

Photos: ©FAO/P. Murekezi

Fertilization

Egg fertilization
The sperm is added to the stripped eggs, and the fertilization of the eggs is triggered by adding an equal volume of clean water. The water and egg mass is then mixed by gently shaking the bowl for one minute.

Photos: ©Abdoul Aziz Badiane

Incubation of fertilized eggs

The fertilized eggs are spread out on a screen of floating wooden racks, or cacaban.

Materials needed:

- Infrastructure
  - – Concrete tank, aquarium, or 1 000-litre used plastic tank flow-through system or recirculation aquaculture system (RAS).
- Equipment
  - – Floating wooden tray (mesh size of 1 mm).
  - – Water parameters test kits (pH meter; alkalinity, hardness, nitrite and ammonia solution test; oxymeter).
  - – Chemical products to optimize water quality.

The development process from fertilized eggs to hatching is dependent upon water temperature; the higher the water temperature, the faster the eggs will hatch.

Materials needed:

- Basins of 40 to 60 litres for tray cleaning.
- Bucket of 10 litres to remove larvae trapped between the meshes.
- Disinfectant (12 percent bleach or other appropriate disinfectant).

Photos: ©Abdoul Aziz Badiane

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Steps for tilapia seed production

Production of monosex tilapia

Due to the ecology and ethology of some species, such as Nile tilapia, the culture of a monosex tilapia has been shown to be more profitable than a mixed-sex culture. Characteristics of females such as mouth-brooding of eggs (instead of feeding) and prolific breeding at a young age (instead of gaining body mass) have made the culture of males more preferred. The most common method for producing all-male tilapia involves the application of the hormone 17α-methyltestosterone.

The hormone is bound to feed by mixing with ethanol. It is recommended to use 300 ml of ethanol per 1 kg of feed (Badiane, 2015). The combination is then dried to allow the ethanol to evaporate.

The above-mentioned natural breeding method is employed to produce fry in hapas (10 m × 4 m × 1 m) and in ponds. The eggs can also be collected from the mouth of broodstock every 10 days and hatched in an incubation system. After hatching, there is a short window within which fry do not have phenotypic (obvious) sexes. The hormone-impregnated feed is then fed to the fry from the second to the 28th day in order to switch almost all genotypically female fingerlings into phenotypic (outward) males.

A number of factors influence the effectiveness of the sex-reversal procedure. Among others, temperature, feed quality and hormone quality can affect the consistency of sex reversal. The use of an egg incubation system also makes the process efficient. Feeding for less than 28 days will result in sex-reversed females switching back to their genotypic sex.

Broodstock and breeding

Broodstock selection

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The selection of broodstock is fundamentally based on three criteria:

- Body weight: male (200 to 300 g) and female (150 to 200 g).
- Presence of milt for male and eggs for female.
- Healthy broodstock (no wound, no deformity or disease).

Materials needed:

- Healthy broodstock.
- Basins (40 to 60 litres).
- Scoop net.
- Aerator with stone diffuser.
- Notebook for data recording (body weight, sex).

Steps after selection

Two days after selection, broodstock can be stocked in the facility (pond, hapa, concrete tank) at a sex ratio of three females to one male per square metre.

Three options exist:

- Harvesting eggs every 10 days, to be sent to the incubation unit for hatching.
- Harvesting fry every 21 days.
- Keeping fry in the facility used until they are reared for two months.

Harvesting eggs from a hapa is the best option to produce a homogeneous batch of same age and easy to sex reverse in all males.

Eggs are collected from the mouth of individual females every 10 days.

Materials needed:

- Basins to transfer broodstock to facility where they will be stocked.
- A larger mesh scoop inner net to retain female broodstock and prevent the fish from crushing the eggs.
- A thin mesh scoop outer net to harvest eggs.
- Box of 5 litres with cover to receive different stages of eggs.

Stocking different stages of eggs

Locally made incubator

Imported incubator

The different stages of eggs are stocked in separate incubation bottles for hatching.

The hatching duration depends on the egg stage and the water temperature.

The four stages of eggs

Stage	Colour	Hatching rate	Observations
1	Yellow	Varies between 65 and 85 percent	1-day fertilized eggs
2	Brown	Varies between 75 and 90 percent	Visible eyes
3	Brown	95 percent survival rate	Visible head and tail; presence of yolk sac, but the fry cannot swim
4	Dark-Brown	Not available	Swim-up fry and able to move

Different egg stage

Egg counting

Materials needed:

- Incubation unit (locally made or imported).
- Graduated cylinder (100 ml) to count eggs (1 ml = 100 eggs).
- Formalin to disinfect eggs (1 ml/L water and shake for one minute).
- Notebook for data recording (number of eggs in each bottle, egg stage).

Photos: ©Abdoul Aziz Badiane.

Sex reversal

What is sex reversal?

Mixed 17α-methyltestosterone with ethanol

Mixed feed and hormoned ethanol

Rearing all male tilapia is more profitable than rearing for a mixed-sex tilapia. Male growth is 1.57 times higher than female growth.

After hatching, fry should be sex reversed in a hapa or tank for 28 days to produce all males. The hormone used is 17α-methyltestosterone mixed with the feed at a rate of 60 mg per kilogram of feed.

Feed and hormone preparation procedure

Feed and hormone preparation

- A highly palatable feed is needed to obtain an active feed response and effective sex reversal.
- The feed is generally 40 percent protein and complete in vitamins and minerals.
- Effective diets can be prepared using rice bran and increasing the percentage of protein by adding fishmeal.

Specific information on hormone preparation:

- Steroids are not water soluble.
- An androgen such as 17α-methyltestosterone dissolves readily in ethanol.
- A stock solution using 95–100 percent pure ethanol can be prepared at a strength of 6 g/L.
- Ten ml of stock solution added to a carrier and mixed with 1 kg of diet would be adequate to prepare a diet to obtain 60 mg 17α-methyltestosterone/kg of diet.
- The solution is poured or sprayed over the feed and thoroughly mixed until all the feed is moist.
- The moist feed is air dried, out of direct sunlight, or stirred in the mixer until dry and then stored in a dark and dry place.

Materials needed for sex reversal

- 17α-methyltestosterone.
- Ethanol at 95 percent.
- Spray bottle ≥ 1 L.
- Feed: 0.2 mm, 0.3 mm, and 0.5 mm.
- Bowl of 5 L capacity.
- Graduated container.
- Gloves.
- Scale of 1 000 g ± 0.01 g.

Photos: ©Abdoul Aziz Badiane.

PRACTICAL EXERCISE

Please refer to Module 5 – Practical Hands-On Training for instruction on the exercises on the topics discussed above.

Larvae management

Daily monitoring of the larvae health status, survival rate, water and feed (calculation of ratio, feeding technique and frequency) is essential for good growth and survival rates during the first two weeks.

<table>
<tr><th colspan="2">Larvae management and feeding protocol</th></tr>
<tr><td>

Photos: ©Abdoul Aziz Badiane.</td><td>Materials needed:
➤ Water and larvae.
➤ Syphon to remove dead larvae and waste from water.
➤ Water test kit (see water quality monitoring).
➤ Buckets of 5 to 10 litres.
➤ Scoop net.
➤ Feed and feeding management.
➤ Plastic bucket, 5-10 litres, with cover for daily feed ratio for each tank.
➤ Different size of feed: Artemia or 0.1 mm (60 percent crude protein [CP]) only for catfish; 0.2 mm (50–55 percent CP); and 0.3 mm (50–55 percent CP).
➤ Desktop for daily feed ratio calculation.
➤ Digital scale of 5 kg capacity ± 0.1 g.</td></tr>
</table>


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Fingerling production

The daily management of fingerlings' water and feed is essential for good growth and survival rates. Fish should be graded before each transfer into new tanks. Figure 73 shows possible settings for fingerling production (aquarium, hapas and tanks).

From fry to fingerling production

Grading

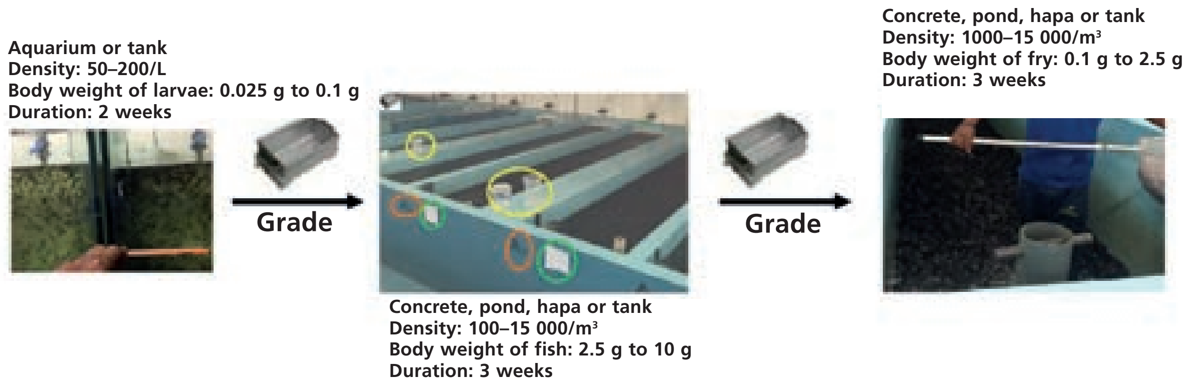
Sampling

Activities and materials needed:

- Sampling at interval of one to two weeks
  - Grader.
  - Scoop net.
  - Adjustable grader (4–17 mm).
  - Scale of 50 kg capacity.
  - Data recorder.
  - Buckets of 10–15 litres.
  - Recording data of fish survival, weight, growth rate.
- Feed and feeding management
  - Plastic bucket of 5–10 litres with cover for daily feed ratio for each tank.
  - Different sizes of feed: 0.5 mm (50 percent CP); 0.7 mm (50 percent CP); and 1 mm (48 percent CP).
  - Desktop for daily feed ratio calculation.
  - Digital scale of 5 kg capacity ± 0.1 g and 50 kg capacity ± 1g.

Photos: ©Abdoul Aziz Badiane.

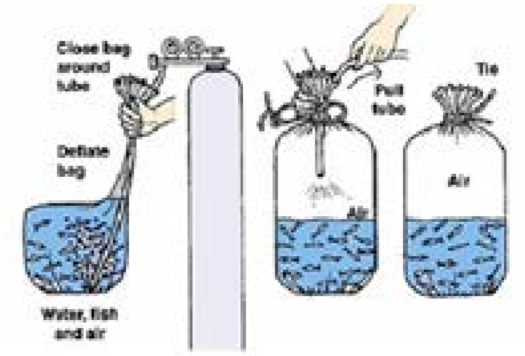
Figure 73: Fingerling production in aquariums, hapas and tanks



Photos: ©Abdoul Aziz Badiane.

Harvest, transport and acclimatization of fingerlings

How to prepare fingerlings for harvest and keep them in good condition (post-harvest)



Live fish transport (FAO, 1988)

Fingerlings should not be fed one day before harvest and must be conditioned before selling. Fish transport conditions are essential to limit stress and mortality.

Materials needed:

- Conditioning facility.
- Concrete tank/hapa.

Harvest

- Harvest net.
- Scoop net.
- Basins to transport fish to the conditioning facility.
- Grader (4–17 mm).
- Aerator (tilapia).
- Scale of 50 kg capacity.
- Record-keeping (number, body weight, biomass, seed source, and the facility name, date of harvest, name of traders, etc.).

Conditioning for market (sale)

- Scoop net.
- Transparent plastic bag of 50 litres filled with 19 litres of water that is oxygenated (density 1 kg/bag).
- Transport container of 500 to 1 000 litres (density: 50 kg/m^3).
- Oxygen bottle and plastic diffuser.
- Data register record (name of client, location, quantity sale, date, body weight).

Purchasing fingerlings

Make sure the fish are the requested size and are healthy. Fry/fingerlings should be guaranteed to be free of exposure to disease. Have the seller state in writing the terms of replacement if the fingerlings should become sick and die shortly after receiving them. You will be held responsible for any losses of fish if the seller can prove you have not followed recommended handling and stocking procedures.

Transporting

If the fish are to be shipped by bus or air freight, determine if the supplier or shipper will assume responsibility for safe delivery of the fish. Small fish may often be easily shipped in plastic bags containing water and oxygen. Large numbers of fingerlings are best transported in a hauling tank with aeration or oxygen supply. The water should remain clean and cool during transport. The fish should be loaded and unloaded with a minimum of handling and stress. In most cases, the supplier should arrange delivery of the fish or assure that the buyer has the equipment needed to successfully transport them.

Stocking back in ponds/tanks or cages

Fish should be "tempered" (slowly acclimated to any significant changes in water temperature or chemistry) when preparing to stock them into a new environment. Proper tempering requires at least 20 minutes of gradual adjustment for every 10-degree Fahrenheit difference in water temperature. If no thermometer is available, temperature differences between the two environments should be adjusted gradually until no difference can be felt using a hand as a guide. If fish are received packed in plastic bags with oxygen, float the bags in the receiving water without opening them until the fish are temperature acclimated. Opening the bags allows the oxygen to escape, and the fish must be quickly released after that point. If fish are being unloaded from a hauling tank, gradually mix the new water into the tank until temperatures are equalized.

Record-keeping

Water parameters

Tank/pond number

Number of fish:

Body weight (g):

Stocking date:

Date	pH	NO_2	

Feed and tank management

Hapa number:

Body weight (g):

Stocking date:

Number of fish stocked:

Source of fish:

Date	Daily amount of feed (g)	Amount of feed given	Amount of feed remained	Mortality

A farmer must know the number and the weight of fish in every production facility at any given time if he/she wants to be successful in fish farming. For instance, underestimated biomass will push to underfeeding resulting in poor growth, and overestimated biomass will result in overfeeding and subsequent waste of money (high cost of feed).

Data to record:

In case there are problems with water quality parameters, distribution and quantity of feeds must be adjusted to avoid further deterioration of water quality and avoid feed waste.

ALERT – ALWAYS have your Water Kit Test ready!

Mortality, which helps to readjust feed quantity.

Daily quantity of feed for each tank will help to calculate the feed conversion ratio at the end of batch production.

Diseases and actions taken.

Reproduction: volume of eggs, hatching rate, body weight of broodstock, which will help to calculate the egg production per kilogram of female and to establish a standard hatching rate in the farm.

Weekly or bi-weekly growth for a standard growth curve of the farm.

Sales data (client name, location, quantity, price).

Materials needed:

- Registry.
- Forms for data recording.
- Desktop/laptop.

Practical exercise foreseen for this section is for trainees to practice techniques, skills and basic hatchery good practices. Please refer to Module 5 – Practical Hands-On Training.

AQUACULTURE HYGIENE AND MONITORING FISH HEALTH

Initial considerations

- The aquatic environment faces serious problems, e.g. pollution by all sorts of waste, extreme fishing and poor resource management.
- Fish culture in ponds and tanks produces food for human consumption. However, some farms do not respect the environment; there may be competition for water among users, including wild animals; and fish diseases may occur among other problems. In Figure 74, good sanitary conditions are shown in some production settings (earthen ponds, cement tanks, floating cases).

Figure 74: Examples of aquaculture production settings

In earthen ponds …	… concrete tanks, covered or not …	… or in floating cages.

This section (Menezes *et al.*, 2016a) provides an introduction on good farming practices, which produce good and healthy fish that are proper for consumption and easily marketable.

The consumption of fish and fish products produced from aquaculture is only permissible when the fish are healthy and health hazards are avoided – for example, physical (metals, glass, etc.), biological (parasites, bacteria and viruses), and chemical (pesticides, heavy metals, biotoxins and medicines). All these hazards can be reduced or eliminated by introducing and implementing good hygiene and safe aquaculture practices. This will also determine the social acceptability of the product and of the aquaculture activities in specific places and times. For more detail, consult Module 2.

The health strategy for the sustainable development of aquaculture is based on farming (production) of healthy fish that grow well and are hygienic (safe), so the fish will not be a risk to consumer health. Therefore, it is necessary to promote good practices in aquaculture, such as improving hatchery, pond and cage management, observing ecosystems and carrying capacity, undertaking zoning, and taking biosecurity measures seriously to prevent pollution and diseases.

What are the hazards during production that can affect the final product?

Hazards exist during production that can affect the final product. The following are some hazards that can occur in the aquatic environment:

- Parasitic zoonosis transmitted by fish.
- Bacterial diseases, such as *Vibrio cholerae* or *Salmonella*.
- Contamination by agrochemical residues, veterinary drugs and heavy metals (mercury, cadmium and others), which can also cause illness to consumers.

During the production process, hygiene plays a vital role in fulfilling the following objectives:

- Reducing the number of potential pathogens.
- Minimizing environmental pollution.
- Preventing animal and plant diseases.
- Maintaining the health of animals, plants and humans.
- Establishing healthy and economical farming (aquaculture production).

As introduced in the general principles, each phase of preparation and production should be carefully evaluated for the produced fish to be of good sanitary quality.

Few potential health hazards

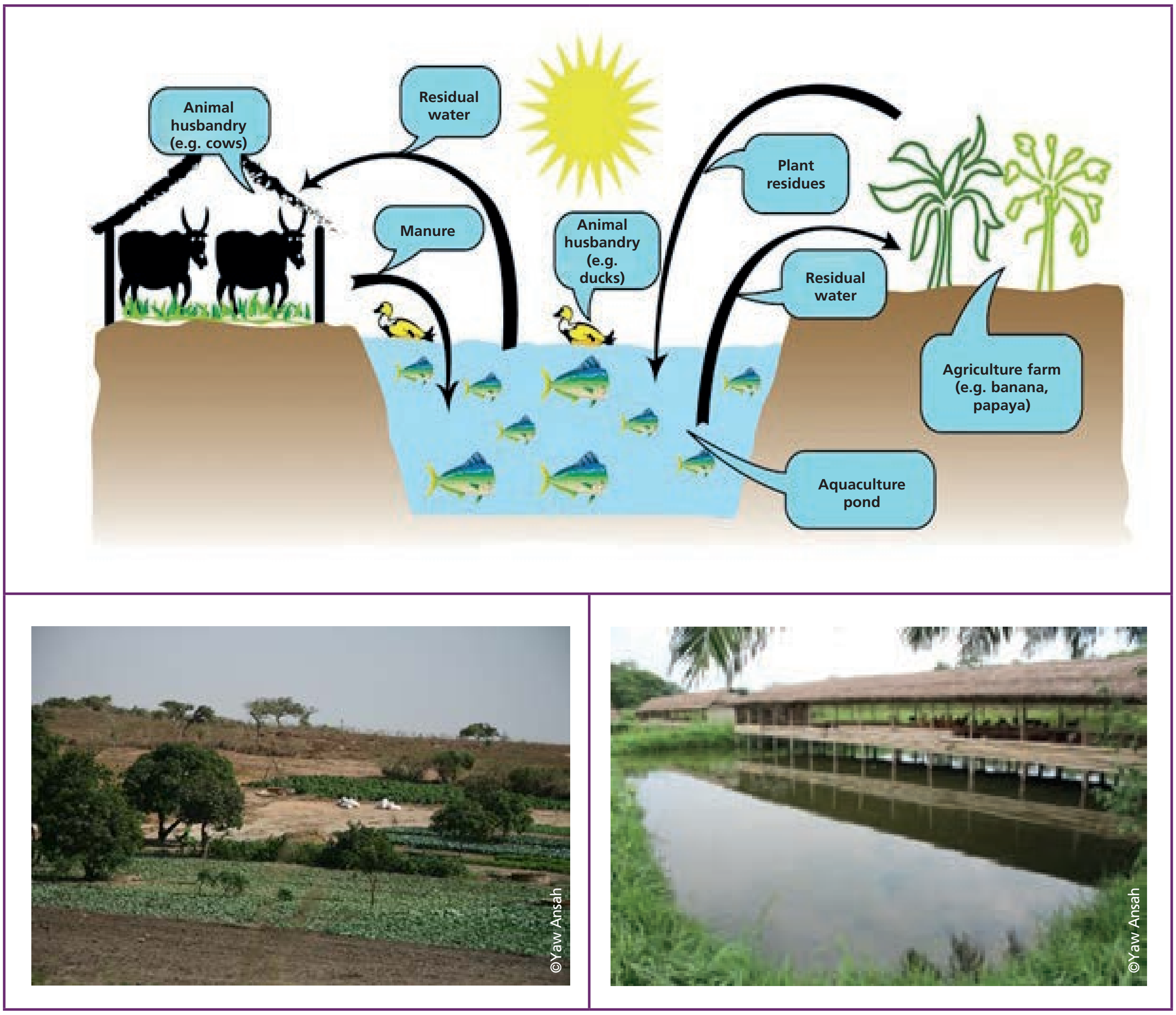
The precautions below are important to avoid health hazards that may originate from the location of the farm through water sources (which can cause water contamination) from direct contact with animals and from air contamination (chemical spraying). The following situations can be potential hazards or sources of contamination.

- Fish are reared in ponds, tanks or cages until reaching market size. For easy cleaning of the tanks, they must have a drain to enable their total drainage to avoid accumulation of organic matter, parasites and pathogens from one production system to another.
- Farms that use pesticides and fertilizers.
- Livestock farms (cattle, pigs, ducks, chickens and other animals) or their wastewaters (agricultural drains, and domestic and industrial wastewaters) can be a significant source of contamination from pathogens (e.g. bacteria such as *Salmonella*).
- Soil could be contaminated.
- Transmitters of parasites, such as snails and insects, should be eliminated.
- Special attention is required when implementing integrated aquaculture systems (Figure 75).

Integrated aquaculture has been practiced in many parts of the globe (Africa, Asia and Latin America) since the beginning of fish farming as one economic activity. One of the objectives of this ancient practice is the production of various food products (fish, vegetables, livestock, fruits) in the same available plot of land and water, and by treating effluents and residues from farming practices as resources rather than as pollutants. Through integrated farming, farmers are able to diversify their food and foodstuff, improve nutrition and raise livelihoods. Another positive aspect of the integrated system is the maintenance/creation of an ecological balance in the area.

However, integrated aquaculture, if not well managed, can also create problems, including the booming of pathogens and parasites from livestock excrements and contamination from pesticides used for crops. Care needs to be taken to avoid such risks.

Figure 75: Example of integrated farming



Care to be taken in nurseries

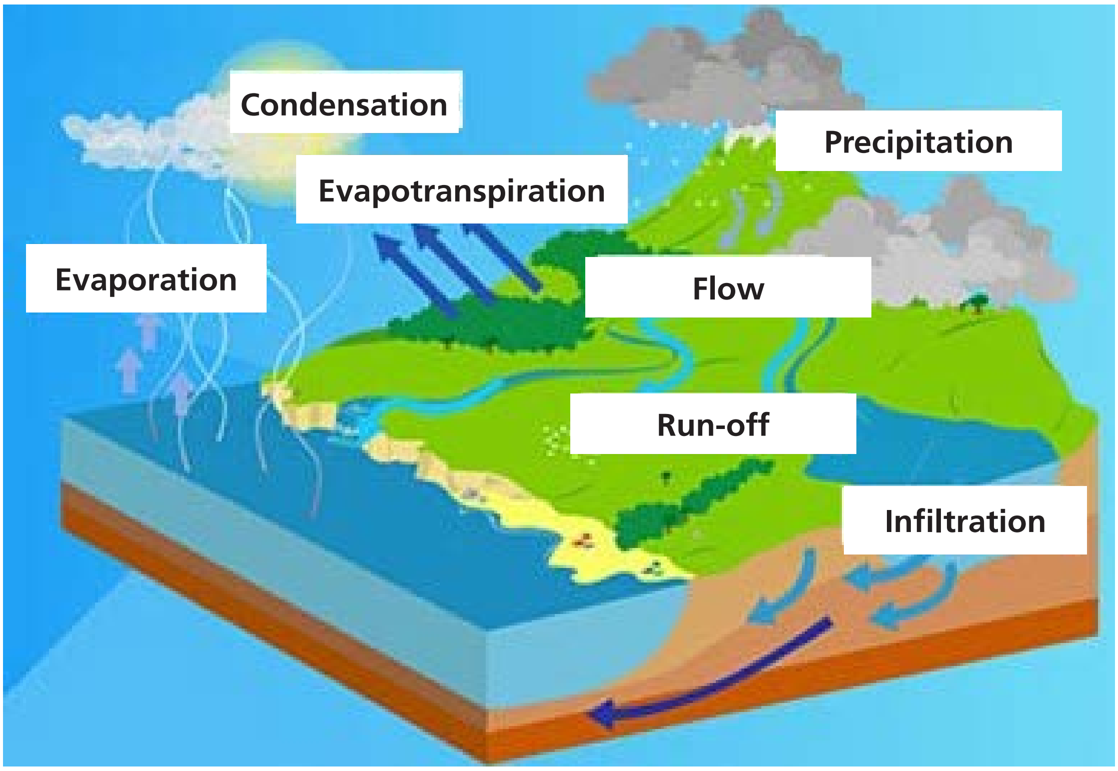
Nurseries need to observe good hygienic practices in the pond area to reduce the possibility of faecal contamination of water and fish. Nurseries also need to eliminate vegetation around the tanks or ponds; implement a programme of pest and animal control against such animals as rodents, turtles and birds; and keep farms closed to domestic animals such as dogs and cats.

Recalling the basic principles

Water quality

To facilitate planning for aquaculture production, the fish farmer must know how the water cycle works (Figure 76).

Figure 76: Water cycle



It is also important to have good water (e.g. free from pesticides and other pollutants), such as rain water. If possible, water quality analysis should be carried out to control dissolved oxygen, temperature, salinity, pH, transparency, nitrites and nitrates. For higher production, the water quality can be improved with nutrients by organic and inorganic fertilization.

The practice of fertilizing tanks with human or animal faeces can result in an end product (farm fish) contaminated by pests and/or pathogenic bacteria.

Animal faeces may also be contaminated with residues from drugs added to feed, which may pass into the seafood through the water.

Warning: Poor fertilization management results in the deterioration of water quality, affecting its sanitary quality and facilitating the emergence of diseases.

Selection of suitable species for farming

Selecting viable species for farming is one of the most important aspects in aquaculture. No matter which species a farmer has chosen for farming, it is important to avoid the contamination and spread of parasites and pests through their eggs, larvae, table-size fish, and so on.



Photos: ©FAO.

General production

In order to prevent health hazards to the consumer, the main precautions to take during production include:

- Checking the water quality.
- Controlling the origin and quality of post-larvae and/or fingerlings.
- Administering feed and medication carefully, and always according to the instructions on the label.
- Ensuring equipment and containers can be easily cleaned and disinfected.
- Implementing good hygiene practices (staff, facilities and equipment).
- Controlling pests.
- Removing any sick fish from the unit.
- Taking out dead fish immediately, always following appropriate health procedures.

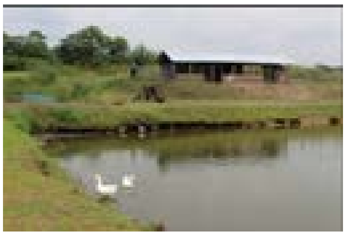
Sanitary and disease control in aquaculture

Knowledge of diseases, control of drug use, feed, water quality and the presence of pathogenic agents (e.g. bacteria) for all steps in the aquaculture process are critical to obtaining healthy products and for ensuring public health protection.

Diseases pose problems or can have negative impacts such as large economic losses; therefore, healthy aquaculture practices should never be neglected.

There have been some level of controls with specific international protocols over the use of chemical products to prevent and control disease in fish, causing contamination and reducing the quality of the water that makes its way back into the environment.

The following photos show some potential sequence of fish pond contamination.

		
A fish can be sick, e.g. through “black spot”, Saprolegnia fungi or Branchiomyces fungi, which attack the gills.	Fish receive medication through the feed.	Part of the medicine stays in the flesh and diffuses.
		
Another part goes into the environment (through faeces).	Water then flows from the tank into a lake or river; it feeds wells people use for drinking water. This water is contaminated with medicine residues.	In addition, there may be latrines and “open-air defecation” nearby, as well as washing (with soap, which is a chemical).
The water of the river is therefore contaminated with bacteria, parasites and chemicals and enters the tanks. Fish cultivated in these tanks are in turn contaminated and cause diseases to consumers.		

Photos: ©FAO.

Sick fish must be quarantined whenever necessary and appropriate (quarantine is the time during which an animal is observed in isolation from other animals).

Note: Due to primordial importance of this topic, it will be further developed in a separate manual that will address all components of fish health management and control measures from production to the consumer.

Harvesting

Appropriate harvesting techniques should be used in order to cause minimal physical damage and stress.

When necessary, "purge" (clean) fish by keeping them in running water for as long as necessary to reduce the content and any possible pollutants that might have accumulated in their digestive tract.

Storage and transport of live fish

After harvesting the fish, it is necessary to store and transport live fish according to the following:

- Only healthy and unharmed fish should be selected.
- The properties and composition of water in tanks and pumps used to preserve, handle and transport live fish should be similar to the water in the ponds and tanks where the fish were farmed in order to reduce stress to the fish.
- Water must not be contaminated, and storage and transportation tanks should be easy to clean and disinfect.
- Water in the tanks should be properly aerated (e.g. with air, with oxygen) before transferring the farmed fish into it.
- Fish should not be fed during preservation and transport after harvesting, as feeding the fish would quickly pollute the water in the tanks. Usually, the fish are not fed for approximately 24 hours before transport.

Packing, documentation and registration

When required, proper records are prepared for traceability purposes (and should be retained for a certain period), for example, recording the place of production, identification of the pond or tank, veterinary drugs given, feed, quarantine periods, destination of the consignment of farmed fish.

The packing label should always indicate the origin of the product – "AQUACULTURE" – and the code; these should be stamped on each box to allow tracking. This is a very crucial step to ensure social acceptability (Module 2).

Practical steps and tools for monitoring

Sampling and recording data

Sampling frequency and recording data

- It is important to establish a stringent fish health-monitoring programme incorporating a regular regime of sampling fish (Table 7).
- Sampling frequency: one to two times a week.
- Form for recording data: daily mortality, health checks, water parameters and treatments.

Table 7: Checklist for sampling fish and actions

Parameter	Frequency of sampling	Comments
Sample collection	1–2 weekly	
Behaviour	Each sampling	Feeding activity, swimming behaviour, etc.
Appearance	Each sampling	Skin, eyes, fins, gills, colour, markings, fin condition, shape of body
Number of fish affected	Each sampling	Number of moribund fish, number of dead fish
Number of fish sampled	Each sampling	
Weight of fish	Each sampling	
Parasite species observed	Each sampling	If species cannot be identified, photographed and/or drawn, describe size, appearance and behaviour
Location of parasites on/in fish	Each sampling	Body surface, gills, fins, internal organs
Number of parasites present	Each sampling	Number observed per sample
Action taken	Each sampling	What action was taken following inspection of fish (i.e. treatments applied)

Procedures for improving water quality and fish handling

Fish that are in poor health will not grow as rapidly as fish that are in excellent health. Poor health is usually caused by stress due to:

- handling during stocking and harvesting;
- poor water quality;
- unfavourable water temperatures; and
- nutritional deficiencies.

Most health-related stress is caused by poor water quality. Fish farmers usually stock fish at densities and with feed amounts that are too high for the culture level and for the water area used. The overfeeding per unit of water may result in poor water quality and chronic stress, which eventually leads to disease. Maintaining proper water quality conditions results in good fish health and fast growth. Often, fish farmers must lower fish standing crop to maintain good water quality. Some general actions to improve water quality and fish handling are described in the following box.

Actions to improve water quality and basic handling of sick fish

In case of abnormal values of water parameters, many actions can be undertaken to correct these values and to save fish.

- **Sample collection (of water):**
  - – Sample numbers that are high enough.
  - – Suspect fish are sampled (e.g. dormant, not active or with wounds).
  - – Sampling includes age groups and seasons.
- **When observing abnormal fish behaviour and health issues:**
  - – Flush the unit with freshwater.
  - – Infected fish should be isolated from other stock within the facility.
  - – All equipment exposed to infected/contaminated fish and water should be disinfected.
  - – Collect and send samples of infected fish to appropriate laboratories for diagnosis before administrating any drug.
- **Examination of fish:**
  - – Gill examination.
  - – Skin examination: remove skin/mucus with slides (scrape) and add two to three drops of water.
  - – Fin clip examination: scrape the fin with slide and add water. Then examine the slides with a microscope.

BASIC PROCEDURES TO IMPLEMENT AND KEEP PRODUCTION SAFE

Protocols

When bringing fingerlings or broodstock from other farms with the objective to initiate production or selling, quarantine protocols should be strictly adhered to and basic steps be followed, such as the ones noted below.

Quarantine protocol

- Testing a sample of fish prior to bringing the fish into the facility.
- Isolation or separation from other populations for a period of time.
- Reduction or elimination of infectious pathogens, disease prevention strategies.

Materials needed:

- Concrete tanks or earthen ponds that should have a separate water source or flow circuit and any water effluent on or off the farm.
- Scoop net and basins exclusively used for this area.
- Therapeutic medicine: copper sulphate or sodium permanganate and non-ionized salt.
- Disinfectant: 25 percent bleach, hand sanitizer.

Alert:
Proceed to treatment of infected fish with a therapeutic drug or management measures according to professional advice. Avoid guessing; always seek professional specialized advice.

Sanitation and disinfection protocol

Good sanitation and disinfection procedures reduce the number of disease causing organisms present within a given system and prevent or reduce the spread of these organisms from one system to another.

General farm recommendations:

- Install handwashing taps, hand sanitizer dispensers and footbaths in the main entrance of the farm.
- Clean and disinfect all farm equipment. Cleaning and disinfection of equipment requires the following: liquid soap, chlorine, 25 percent bleach, deep net, basins (40 to 60 L), and shelves for storing equipment.
- Farm disinfection:
  - The farm must always remain very clean.
  - The floor should always remain dry.

Materials needed for disinfecting floors: mops, 25 percent bleach, powder soap, buckets and brushes.

Disinfection of stations for people:

- Footbaths, handwashing taps and hand sanitizer dispensers should be installed in all the components of the farm.
- Uniforms and boots should be stocked in the dressing room.

Before any entrance or exit, workers or visitors should:

- Wear a uniform on the farm.
- Clean and disinfect hands.
- Materials needed: footbath, uniform, hand sanitizer, handwashing tap, soap, towel and rubber boots.

Net station:

- Nets should be placed in all the components of the farm (broodstock, hatchery and grow-out).
- Nets should be dipped in the basin before and after any utilization.

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Module 2

THE GOVERNANCE AND SOCIAL DIMENSION OF SUSTAINABLE AQUACULTURE

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GENERAL INTRODUCTION TO GOVERNANCE

The module comprises two parts, each of which is developed as a separate session designed to meet a specific number of learning objectives. It consists of lecture materials for presentation and a group exercise to assess learning outcomes.

The first session on the role and types of aquaculture governance presents drivers of sustainability as a principal goal and sets out its wider conceptual framework. The session introduces the concept of sustainable aquaculture development as reflected in the FAO Code of Conduct for Responsible Fisheries (the Code), guidelines commonly referred to as "governance tools" (FAO, 1995).

The second session examines the key guiding principles of good governance in aquaculture and trends in aquaculture governance, highlighting the growing importance of incorporating them in the design and implementation of aquaculture strategies and plans. The session looks at the challenges of governance in the framework of creating an enabling policy environment, improving effectiveness and efficiency in service delivery, enhancing accountability of institutions responsible for service delivery, and promoting a participatory approach in input delivery and access to capital through public-private partnerships and contract farming (Murekezi, Menezes and Ridler, 2018).

Group exercises have been designed in this module as a tool for the training facilitator to evaluate how well training participants understand the content and are able to apply the acquired knowledge in problem solving.

At the end of this module/session, participants will have developed:
A good understanding of the key principles that define the quality of governance and an enhanced knowledge about the organizational capacities of aquaculture governance at different hierarchical levels.
The ability to apply the principles of good governance.
The knowledge needed for innovative institutional arrangements, design and updating of laws and regulations in fair enforcement of the rights granted to farmers.
The skills to identify the key governance areas and the necessary measures to promote private investment in the sector.

What is governance?

Governance is a set of processes in which:

- A country's productive resources are allocated and managed.
- Government is accountable to its citizens.
- Society obliges its members to observe its rules and laws.
- State and non-state actors interact to design and implement policies within a given set of formal and informal rules that shape and are shaped by power.

What is aquaculture governance?

Aquaculture governance is a set of processes on how:

- A country manages its productive resources with respect to the sector.
- Stakeholders participate in making and implementing decisions affecting aquaculture's development.
- Government personnel are accountable to the aquaculture community and stakeholders.
- The respect for the rule of law is applied and enforced in aquaculture.

What is the role of aquaculture governance?

The role of aquaculture governance provides an enabling environment for more productive, responsible, and sustainable fisheries and aquaculture sectors.

Aquaculture contributes to the Sustainable Development Goals by:

- Providing protein and increasing the availability of food.
- Generating employment and income.
- Increasing economic growth, tax revenue and foreign exchange.
- Contributing to environmental protection by:
  - reducing the pressure on exploited fish stocks; and
  - empowering communities to act not only as resource users but also as resource stewards. Actions start at a young age.

Trends in aquaculture governance

Aquaculture governance remains an issue in many countries because of:

- Conflicts over marine sites and by disease outbreaks that could be prevented.
- Public mistrust of aquaculture, particularly marine cage culture, in certain countries.
- Lack of development of aquaculture in certain jurisdictions in spite of favourable demand and supply conditions.

Reasons for poor governance:

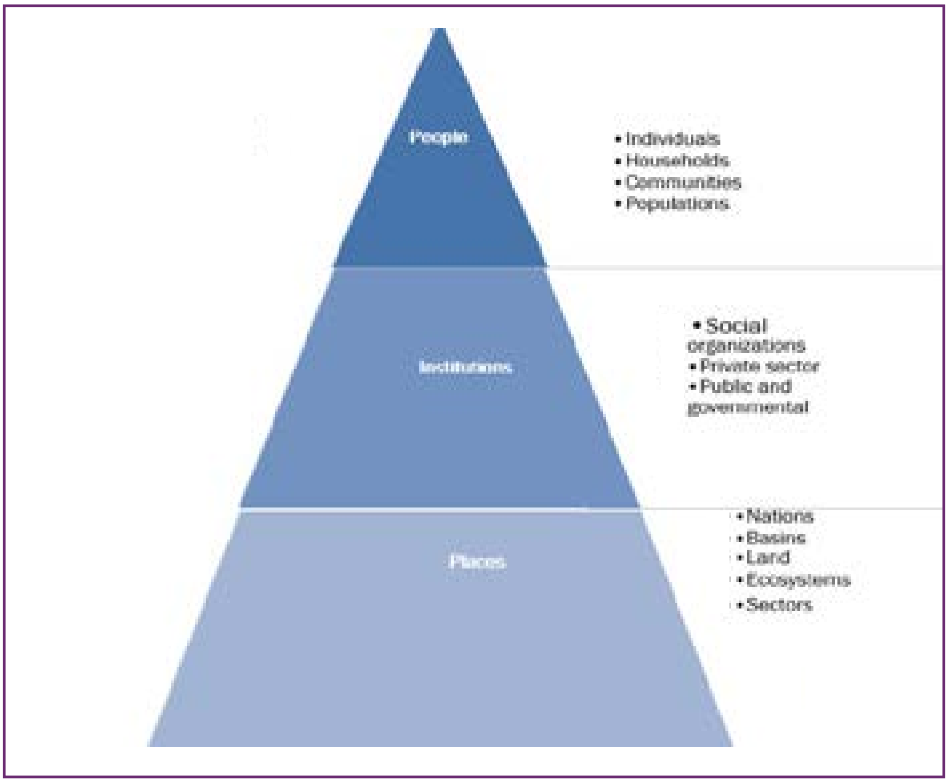
- The sector is low priority in some jurisdictions.
- Aquaculture is a fast growing industry, and institutional and legislative frameworks have not kept abreast with new challenges.
- Challenges with accountability by the government, private sector and stakeholders at large.
- Inadequate law enforcement.

Issues of governance

FAO identified the principal issues of aquaculture governance as:

- How to develop institutions and rules that recognize aquaculture as a distinct economic sector.
- Holistic resource planning.
- How to integrate aquaculture concerns into resource use and development planning.
- How to improve food safety and quality to safeguard consumers and meet the standards of importers.
- How to improve the management of aquaculture, particularly where it has the potential to be harmful.

The governance pyramid in aquaculture



Pillars and principles of governance

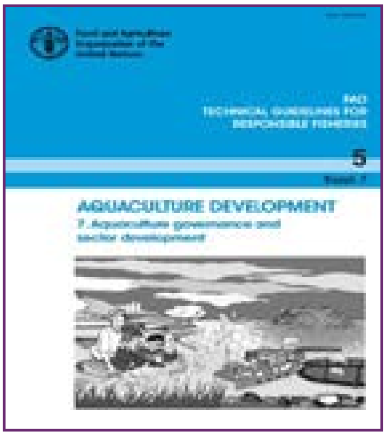
For the aquaculture sector, four general governance principles are suggested. They are a combination of Asian Development Bank and World Bank indicators that can be applied at the sectoral level to achieve the goal of sustainable aquaculture (Figure 77).

Figure 77: Comparing governance in different institutions

Asian Development Bank	World Bank
Accountability	Accountability/voice
Participation	Control of corruption
Predictability	Governance effectiveness
Transparency	Political stability
	Regulatory quality
	Rule of law

Pillars and principles of governance: aquaculture principles from the FAO Guidelines

- Accountability
- Effectiveness and efficiency
- Equity
- Predictability of rule of law



FAO Guidelines: accountability

- Openness in decision-making
- Decision-making based on:
  - pre-established, transparent and known criteria, such as licencing criteria, timely decisions, decisions open to appeal, and clear delineation of administration responsibilities;
  - reduced secrecy by the industry, and published and disseminated transparent information about processes, production and markets.

FAO Guidelines: effectiveness and efficiency

Effectiveness is results oriented and refers to “doing the right things”. It is indicated by policies and strategies that meet expected outcomes, i.e. the promotion of sustainable aquaculture. Examples of effective governance mechanisms include rules and regulations, market forces, economic incentives, voluntary codes of practice, and responsible self-management. A further aspect of this principle is cost-effectiveness. Policies and strategies, which ensure that aquaculture is sustainable, must also be cost-effective or efficient, reflected in the saving of time (and resources).

For aquaculture, this implies that:

- Governments provide and deliver essential services in the most cost-effective way.
- Sector-specific policies, strategies, plans and regulations are consistent with national policy objectives.
- Performance-based management systems are in place to increase effective and efficient delivery of services by the public sector.
- Integration, participation and subsidiarity are applied to enable performance-based management.

Indications of ineffective and inefficient governance

The indications could be:

- Over-regulation that deters investment and international competitiveness.
- Conflicting regulations.
- Multiple administrative layers to approve a licence.
- Criteria for obtaining a licence unclear and left to official discretion.
- Decisions made in ignorance of different contexts.
- Lack of capacity and resources to monitor and enforce regulations.
- Lack of support from communities and stakeholders.

How can the effectiveness of aquaculture be improved?

- Establishment of lead agency
- Cost–benefit analysis of regulations
- Establishment of one-stop shops
- Encouraging stakeholder participation
- Capacity building

FAO Guidelines: equity

Equity means that policies and decisions regarding sustainable aquaculture development must take into account the interests of different groups of the current generation such as gender or youth (intergenerational equity) and safeguarding those of future generations (intergenerational equity).

Equity therefore implies:

- Consensus orientation, which means that good governance mediates differing interests to reach a broad agreement on procedures.
- Institutional responsiveness, which means that institutions and processes serve all stakeholders, current and future.

FAO Guidelines: predictability of rule of law

Predictability of rule of law means that:

- Application of laws and regulations is fair and consistent.
- Decision-making process is transparent, open and clear.

Predictability of rule of law is indicated by, for example:

- Security of property and lease rights, security of tenure, the transparency of criteria and procedures for the expropriation of land, licence renewal and taxation, etc.
- Laws should also provide for and enforce the security of water access rights and property.

When is good governance achieved in aquaculture?

Good governance in aquaculture is achieved when the underlying key principles are adhered to, and appropriate instruments are in place and implemented.

Guidelines

1. The roles and responsibilities of the lead agency should be clearly specified and include:
   - Coordination of horizontal and vertical integration with other institutions.
   - Regular review of aquaculture legislation and regulations.
   - Responsibility for the negotiation and implementation of national, regional and international agreements.
   - Integration of administrative and regulatory initiatives of all activities related to, or impacting on, aquaculture.

The roles and responsibilities

The roles and responsibilities as the lead agency should be clearly specified and include:

- Development of national sectorial policies, strategies and plans.
- Continuous review of aquaculture legislation and regulations.
- Coordination of consultative and participatory processes with stakeholders.
- Setting of performance standards (accountability).

Good legal and regulatory frameworks

Major issues

- Lack of specific legislation in some countries.
- Face conflicting regulation over access to water and land, and environmental requirements.
- Ambiguous or insecure property rights.

Objectives of improvement

- Aquaculture producers are provided with a predictable regulatory environment.
- Arbitrariness is minimized. regulation ensures that business risk can be assessed rationally and governmentally.
- Security of property rights is enshrined in legislation.
- The legal framework provides security to an assured supply of good quality water.
- Guaranteed ownership of farmed fish (exclusive rights to the owner/producer).

Guidelines

1. Issues best served by hard law, soft law or economic incentives should be identified based on their nature and the resources available to implement regulations.
2. Issues requiring the enforcement of exclusivity are best served by hard law, such as licences or permit policies, access to water rights and zonation.
3. Issues requiring encouraging progressive involvement and the adoption of appropriate on-farm measures, such as the regulation of aquaculture practices, product quality and feeds, are more likely to be served by soft law.
4. Economic and fiscal incentives should be explored as an alternative to hard or soft law. Experience indicates that fiscal incentives have proved more effective than monetary incentives such as subsidies.
5. An appraisal process (such as a cost and benefit analysis) should be organized by the competent authority prior to the enactment of the regulations in order to determine the implications for monitoring and enforcement and guard against over-regulating the sector.

Good licensing policy and administration

Major issues

- Multiple layers of approval for a licence:
  - Long delays and heavy costs.
  - Unclear criteria for obtaining the licence.
  - Excessive discretionary powers by officials.

Objectives of improvement

- A clear, transparent and timely process for application evaluation and appeals.
- Licence fees cover the costs of administration and enforcement.
- Licensing considers aquaculture policy objectives such as intra-generational equity and environmental sustainability.

Guidelines

1. The requirement of a licence should be enshrined in law to confirm the right to the state to:
   - Directly regulate the operator of an aquaculture facility.
   - Enforce the basic rules of aquaculture.
   - Restrict the location and number of aquaculture facilities.
2. Legislation and regulations should enable the competent authority to grant and administer aquaculture licences.
3. All aquaculture operations should be licensed by the designated competent authority and a register of these licences be maintained.
4. Public announcements about licence applications should be scheduled, predictable, and provide an opportunity for the public to object.
5. Licence should be granted long enough to enable the amortization of investment and encourage long-term planning.
6. Licence should be transferable or assignable (leased) to enable it to be used as collateral and to allow capital gains and economic efficiencies to be achieved.
7. Where licences are transferable, the register should include third-party interests.
8. Administrative procedures for the application and granting of a licence should be transparent, publicly available and provided to all applicants.
9. The period of application and approvals should be kept to a minimum, with publicly available stated deadlines, so as not to impose a heavy burden on competitiveness.

Adequate non-state participation in decision-making and implementation for social licence

Major issues

- Lack of involvement of non-state participants in aquaculture governance may result in poor compliance, which can lead to less effectiveness and efficiency.

Objectives of improvement

- Cost-effective participation of non-state actors in the design and review of legal regulatory and policy instruments for aquaculture.

Guidelines

1. Consultation with local communities potentially impacted by an aquaculture operation should be mandatory prior to licence approval.
2. For coastal zoning and integrated coastal zone management, participation by local communities is essential.
3. If the local communities are given the power of veto, they should be informed of the loss of employment and income opportunities as a party of the discussion.
4. Producer associations should play a significant role in aquaculture governance. They should be included as active participants in discussions on legislation and perhaps in the co-management of the sector.
5. Geographically distant interests, which may conflict with local communities, should not be given precedence over community priorities.

Robust aquaculture statistics and adequate research in support of the policy of planning

Major issues

- Reliable and credible information.

Objectives of improvement

- Data collection, which is focused, targeted and cost-effective; demand oriented and applied research, which is relevant to the needs of the sector; wide dissemination of research activities and findings, which are important for acceptability.
- Improved communication with the public by government and industry.

Guidelines

1. Data analysis and reporting should be regular and timely, and enabling regular input, review and verification by local communities, producers and other stakeholders.
2. Requirement to provide regular data or sample surveys as a condition of licence approval/renewal should be implemented.
3. Industry should be obliged to contribute to demand-oriented and applied research. This contribution could be one of the conditions required to deliver/renew an aquaculture licence. Public-private research partnerships have proven effective and should be encouraged in this and other areas.

Group exercise for this module; please refer to Module 5.

INTRODUCTION TO SOCIAL ACCEPTABILITY

This module introduces social acceptability as an integral part of aquaculture sustainability. It consists of lecture materials for presentations.

The first session introduces the meaning of social acceptability in international instruments. It also introduces the concept of social acceptability that has been widely recognized in multiple stakeholder meetings and documents within and outside FAO.

The second session deals with the importance of studying social perception of aquaculture. It introduces the internal and external factors that influence perceptions.

The third session discusses the public perception and acceptance of aquaculture and the role of mass media.

At the end of this module/session, participants will have developed

- A good understanding of the key principles that define social acceptability.
- The ability to apply the measures necessary for social acceptability.
- Understanding of public perceptions and media involvement.
- The ability to apply social acceptability to new development of aquaculture farms in personal context.

Meaning and concept of social acceptability

Social soundness means that aquaculture should be socially acceptable (social sustainability).

"Social acceptability (SA) is an integral part of sustainability and refers to social licence and the degree to which aquaculture activities are accepted by the local community, by various interest groups and by the wider society" (Hishamunda, Ridler and Martone, 2014).

- The 1995 FAO Code of Conduct for Responsible Fisheries provisions include the need to consider the social aspects of fisheries and aquaculture.
- Interlinked social-ecological systems are also at the core of the FAO ecosystem approach to aquaculture for the integration of aquaculture within the wider ecosystem.
- Social acceptability has been widely recognized in multiple stakeholder meetings and documents within and outside FAO.

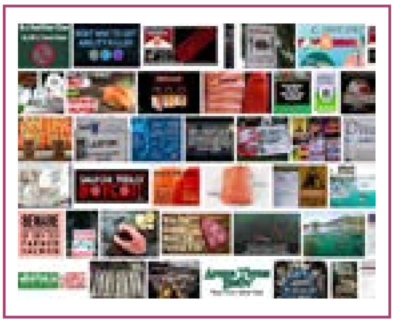
FAO Member States, in the 15th Session of the FAO Sub-Committee on Fish Trade (2016) and the 9th Session of the FAO Sub-Committee on Aquaculture (2017), recognized that the impact of aquaculture supply on trade and consumption is dependent on acceptance (perception) of aquaculture products in the marketplace. The Members led calls to facilitate market-oriented aquaculture and enhance public perception and requested:

- The improvement of consumer perceptions of aquaculture in general.
- Advocacy of aquaculture products along the value chain, emphasizing the benefits associated with the products.

- The development of communication products and further efforts to raise the image of fish in the media.
- Providing the public with correct information and relevant facts on aquatic products and develop and improve communication and media efforts.

Why is the study of social perception of aquaculture important?

- Global evidence indicates that social acceptability is a key driver for aquaculture development.
- Factors that influence perceptions of aquaculture are multiple (Bacher, 2015) and can be internal or external:
  - Individual knowledge and experience
  - Demographic characteristics
  - Local and regional context
  - Level of trust in industry and authorities
  - Perceived risks and benefits



Source: Google.

- Global social studies have addressed the public acceptance or rejection of aquaculture and farmed aquatic products (through surveys, interviews and public hearings, among others).

Perceptions, misconceptions, truths and myths

Influences

- Internal influences:
  - Governance systems: public good, private good, transparent information (production, market), sharing of benefits.
  - Unfair competition: misinformation by industry segments about other competitors to gain markets or simply to share the damages in reputation.
  - Trust: significant mistakes by the industry and regulators have significantly eroded trust. Governments are not always transparent and unbiased (tendency to protect big corporations).

Source: http://www.fis.com/fis/worldnews/worldnews.asp?l=ei&d=56640&ndb=1

- External influences:
  - Natural reaction, as traditionally people have been more exposed to wild fish products; moreover, there are many scandals about farmed products (exaggerated or not by the media).
  - Safety risks compounded and/or associated with incorrect or incomplete information regarding seafood, especially farmed species.
  - Scientific uncertainties on risks of seafood consumption.

Aquaculture as source of concerns and arguments

- Aquaculture can conflict with other users of waterbodies, such as the tourism industry, fishers and migrating fish (e.g. seaweed).
- Threatens the livelihood of fishers and specific fishery industry with aquaculture products.
- Pollutes water systems with nutrients (fish feed and wastes), chemicals and antibiotics.
- Provokes outbreak of fish diseases and uses antibiotics in aquaculture units.
- Transfers diseases and parasites to wild fish populations.
- Puts pressure on wild stocks in order to produce fish feeds.
- Compromises native gene pools if farmed fish and native species interbreed.
- Provokes global competition and inability to sustain market.
- Compromises the aesthetic beauty of coastlines.
- Profits only a small segment of society.

The role of mass media

Public opinion of aquaculture is interlinked with their understanding of aquaculture environmental interactions, and its environmental impact, and this understanding is often informed by the media.

While media effects theory is complex, and an ever-growing field of study, research has shown that mass media can heavily impact public awareness of certain topics and issues, their perceptions towards the issue, and in some cases, can even influence individual behaviours (Macnamara, 2005).

In the case of aquaculture, the media may not have the ability to tell people what to think, but rather may be quite successful in telling people what to think about.

Some examples of aquaculture perception in the media are the following:

- *Darwin's Nightmare*: www.darwinsnightmare.com
- *Chinese imports 'driving fishermen to despair'*: https://www.bbc.com/news/business-47611076
- *China-Kenya tensions rise over fish as traders cry foul – Cheap imports of tilapia are undercutting the local fishing sector*: https://chinadialogueocean.net/5572-china-kenya-tensions-over-fish-as-traders-cry-foul
- *Report critical of antibiotics in Indian shrimp*: https://www.seafoodsource.com/news/food-safety-health/report-critical-of-antibiotics-in-indian-shrimp

Perceptions, misconceptions and acceptance of aquaculture

How to tackle some of the issues and improve acceptability:

- Enabling good governance in aquaculture with a wider participation in decision-making guarantees accountability and increases social acceptability:
  - Site selection guarantees not only environmental but also social and economic optimization of the ecosystem where a venture is established.
  - Selection of species (check for public preference and explore new products and specific market niches).
  - Marketing. green labelling.
  - Social corporate responsibility.
  - Guidelines in support of social acceptability.
  - Working with journalists and other media outlets to inform them of aquaculture and aquaculture products.
  - Work towards embodying the One Health aquaculture approach.
- FAO is developing Guidelines for Sustainable Aquaculture (GSA), which has dedicated a chapter to trade and guidelines in support of social acceptability of aquaculture.

More information can be found on these guidelines and the Committee on Fisheries Sub-Committee on Fish Trade (FAO, 2019).

Module 3

THE ECONOMIC DIMENSION OF SUSTAINABLE AQUACULTURE

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THE ECONOMIC DIMENSION OF SUSTAINABLE AQUACULTURE: SOCIOECONOMIC REASONS

Commercial aquaculture can contribute to improved food security, poverty reduction, an improved trade balance and national economic growth. Commercial aquaculture is supported by governments and entities for its ability to contribute to food security, directly by producing fish and other organisms for human consumption, and indirectly by creating jobs and income to purchase food. It is also supported for its ability to generate income for governments through tax collection, for its financial viability independent of public funds, and also for its ability to aid small-scale aquaculture.

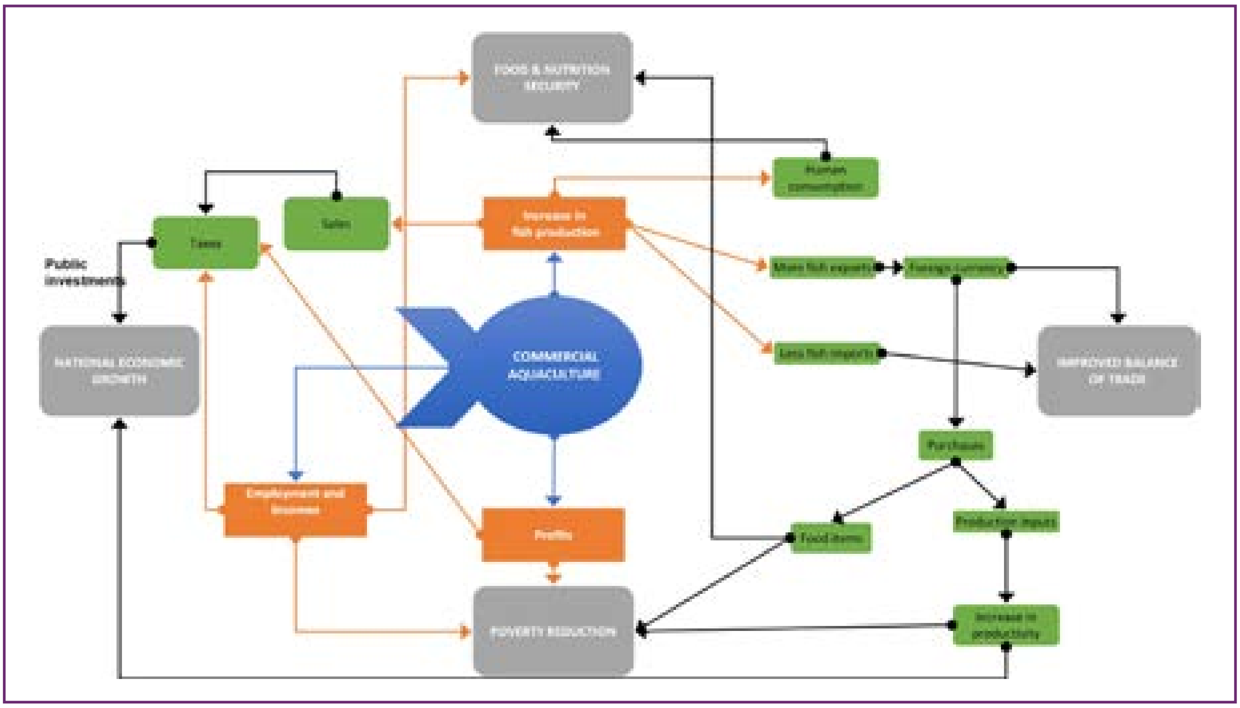
Commercial aquaculture also contributes to urban food security by creating jobs, and therefore income with which to buy food. The number of jobs is even higher when multiplier effects are considered. Indirectly, commercial aquaculture creates jobs in related sectors. A rough estimate of the job multiplier is that commercial aquaculture creates one indirect job for every two direct jobs in the case of salmon farming. In addition to the beneficial effects on job creation, commercial aquaculture contributes to the national fiscal balance. When successful, it pays taxes and thus contributes to income and government revenue. In turn, tax revenues finance social infrastructure such as health care and education, lowering poverty. On the expense side, commercial aquaculture has the advantage of being more commonly built with private funds than public funds. In a difficult fiscal context, this independence from public money gives the sector its autonomy and increases the chances of its sustainability. In addition, the private sector includes financial risks and is responsible in the event of default.

Commercial aquaculture can also be a source of foreign exchange. In countries where machinery (such as aerators) and inputs (food) are imported, the cost of imports should be deducted from gross foreign exchange receipts. Commercial aquaculture can also create other positive effects. When located in isolated rural areas, it results in improved infrastructure, the development of small communities, and an incentive for young people not to migrate to the city.

Finally, commercial aquaculture can stimulate research and technological development, with industry itself funding part of it.

All these linkages are illustrated in Figure 78.

Figure 78: A conceptual framework for commercial aquaculture's contribution to economic growth



Source: Hishamunda, Cai and Leung (2009).

The Economic Module includes both theory and practical sessions. The reference literature for the development of the Economic Module is listed in the reference section.

At the end of this module/session, participants will be able to:
Understand the major factors affecting the economics of aquaculture and of the key parts of a business plan for a commercial aquaculture venture.
Plan properly when conducting and assisting farmers in aquaculture operations.
Assess the profitability level and financial wealth of aquaculture farms.
Identify potential financial risks to aquaculture development in Zambia and develop skills for the critical evaluation of financial risks.

Economic key terminologies in aquaculture farm management

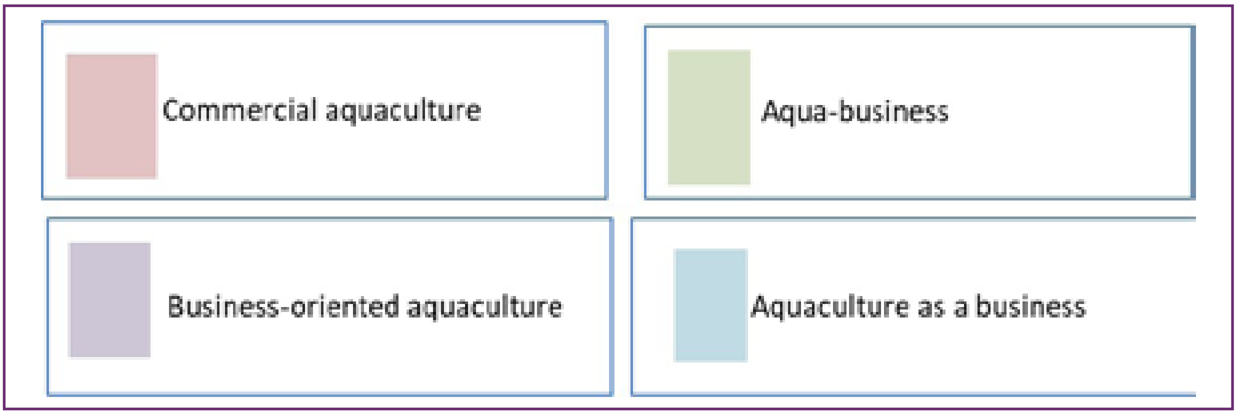
Definition

Commercial aquaculture refers to "fish farming operations with the goal to maximize profits, where profits are defined as revenues minus costs (perhaps discounted)" (Ridler and Hishamunda, 2001; Percy and Hishamunda, 2001). It supplies aquatic products for consumption, including fish, molluscs, crustaceans and aquatic plants, generates profits, creates jobs, pays wages and salaries, and provides tax revenues (Cai, Leung and Hishamunda, 2009).

The key principles to distinguish between commercial and non-commercial aquaculture are the presence in the former of a business orientation and the adoption of remunerated factors of production, such as labour. Non-commercial farms rely primarily on household members for labour, while commercial farms tend to hire labour (Ridler and Hishamunda, 2001).

Commercial fish farmers actively participate in markets by purchasing their inputs and ensuring the sale of their outputs.

Figure 79: Definition of commercial aquaculture



The different terms presented in Figure 79 are used interchangeably to indicate commercial aquaculture activities and to provide an indication of the profit-oriented focus and type of enterprise.

Commercial aquaculture indicates an enterprise with the goal to maximize profits, regardless of:

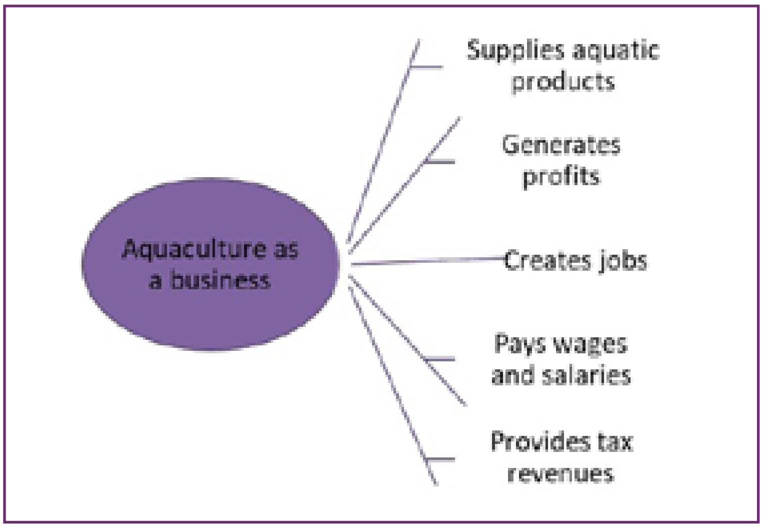
- The size of the farm.
- The farming system.

The defining features of commercial aquaculture are:

- The presence of a business orientation.
- The adopted method of remuneration of production factors such as labour, i.e. commercial farms tend to hire labour.

Referring to an operation as commercial aquaculture implies that the enterprise supplies aquatic products, generates profits, creates jobs, pays wages and salaries, provides tax revenues and brings in foreign currency (see Figure 80).

Figure 80: What commercial aquaculture generates



What do you need to start an aquaculture business?

Prerequisites for conducting aquaculture as a business include:

- A business sense.
- A business plan.
- Adequate resources and capital.

Based on the preferences and behaviour of consumers, farmers with a business sense will strive to identify:

- **What to produce:** the aquaculture products (e.g. fish, molluscs, crustaceans and/or aquatic plants) and their form (e.g. live, frozen, processed).
- **How much to produce:** the target quantity.
- **How to produce**: define the resources required and how to combine them for efficient production.
- **For whom to produce:** the target markets.

The farmer will need to elaborate proper financial statements, as well as the marketing and business plans.

What is a business plan?

- Identify objective (what?)
- Define target (how much?)
- Define basic means/resources required (how?)
- Identify and know/study the market (for whom?)

Basic principles in commercial aquaculture

Revenues, cost and profit in commercial aquaculture

Profit is a business performance indicator, calculated by subtracting total costs from total revenues, where the total revenues represent the gross income of the aquaculture farm, obtained by summing up all the receipts generated by the sales of aquaculture products (Figure 81). The total costs refer to the monetary value of all expenses associated with the aquaculture farm (e.g. fingerlings, feed, chemicals, ponds, machinery).

If the total revenues are higher than the total costs, the business generates a profit. If, on the other hand, total costs are higher than total revenues, the business generates a loss.

Figure 81: Formula profits

In short:
Commercial aquaculture farmers participate actively in the markets by purchasing their inputs and ensuring the sale of their outputs.

Non-commercial aquaculture farmers may also purchase inputs, mainly seeds and feed, and sell their outputs. However, they primarily use family labour and the potential sale of any products surplus is generally done on site.

An operation, which began for the purpose of subsistence, may possibly develop into a small-scale commercial venture under the right conditions.

Factors affecting economics and production

Major production factors include the seed, feed, land, water, fertilizers, fuel and veterinary products, among others. Factors affecting the economics of aquaculture are summarized in the box.

Major factors affecting the economics of aquaculture

- Increase in production;
- Stocking rate, survival rate, growth rate, etc.;
- Increase in farm prices;
- Quality of fish, seasonality and social customs, cooperative marketing, different markets and products, stage of distribution, etc.;
- Reduction of costs;
- Cost of construction, fertilizer, seed, feed, labour, water, interest, marketing cost, land lease, etc.

Factors of production (farm inputs)

Fixed factors:	Variable factors:
Capital or investment items that do not change in size from day to day and last several times longer than each production cycle. Examples: land, fish ponds and equipment.	Operation items required in varying quantities according to the fish production level. Examples: seeds, feed, fertilizers and fuel.

Fixed factors of production have a useful life:

- As time goes on, long-lasting factors of production such as ponds, buildings, equipment and vehicles wear out.
- After a certain number of years, they have to be replaced or renovated. This period is called the **useful life** or **economic life**.

Production costs

Fixed costs remain the same whatever the amount of fish produced in a given farm. They are related to fixed factors of production. Examples: depreciation cost, lease on land, interest on loans, and other fixed payments such as licences and insurance premiums.	Variable costs are those costs that are directly related to production and correspond to expenditure on the variable factors. Examples: seed cost, feed cost, energy cost, management costs and office expenses.

Record-keeping

Record-keeping refers to the systematic collection, recording and storage of the biological, technical, economic and/or financial data information, activities and transactions that take place during the life span of the fish farm. The collection, recording and storage need to happen in a standardized format.

This assembled information represents the starting point for the preparation of accurate financial statements and, subsequently, for assessing the economic and financial viability of fish farms.

Proper farm management: keeping records in commercial aquaculture

Commercial aquaculture requires systematic and detailed record-keeping, in order to:

- Provide a means of evaluating the performance and the biological or economic feasibility of the fish farm.
- Identify the factors accountable for the economic and financial viability and profitability of the fish farm.
- Provide fish farmers with reliable information on which to base decisions affecting their farm operations.
- Improve the efficiency of farm operations.

Record-keeping represents the starting point for the preparation of accurate financial statements and, subsequently, assessment of the economic and financial viability of fish farms.

Records can be kept on an annual, seasonal and daily basis.

Basic record-keeping in commercial aquaculture

- Monitoring fish ponds regularly.
- Keeping good records.
- Planning ahead for the operation of your farm.

Figure 82 through Figure 86 are examples of the different forms needed for good record-keeping in a commercial aquaculture farm.

Figure 82: Pond culture: example of a record-keeping form for variable inputs

Date	Pond No.	Item	Description	Quantity (A)	Unit cost (B)	Total cost (= A * B)
10 January 2016	1	Seed	Nile tilapia fingerlings	360 kg	USD 0.16	USD 58
…						

Source: Adapted from Shang (1981) in Hishamunda, Martone and Menezes (2017).

Figure 83: Pond culture: example of a record-keeping form for labour

Date	Pond No.	Economic activity	Type of labour	Number (A)	Wage (B)	Total labour cost (= A * B)
10 January 2016	1	Pond preparation	Full time	2 persons/ day	USD 50	USD 100
…						

Source: Adapted from Shang (1981) in Hishamunda, Martone and Menezes (2017).

Figure 84: Pond culture: example of a record-keeping form for fish harvesting

Name of farmer:	
Farm name:	
Pond No.:	
Pond area:	

Date	Species	No.	Average weight (g)	Total weight (kg)	Unit cost (USD/kg)	Total cost (USD)	Remarks

Source: Adapted from Okechi (2004).

Figure 85: Cage culture: example of a weekly record-keeping form for feed

Week from 20/06/2013 (Monday) to 26/06/2013 (Sunday)		Cage No. 1		
Date	Registration of distributed feed: observations and actions made	Feed timing and type		
		Ration 1	Ration 2	Ration 3
	Removed five dead fish, high turbidity, lack of appetite, etc.	10 kg	7 kg	4 kg
	Fingerlings sampling planned tomorrow			
	Sampling completed: 50 fish weighed with average weight = 112 g			
	No. of fishes ___ and estimated biomass ___			

Source: Adapted from Piccolotti (2014).

Figure 86: Cage culture: example of a monthly record-keeping form for fish management

Cage No. ___		Initial number of fish ___		Initial average weight ___		Initial biomass ___	
Month (from the month of rearing)	Fish No. (end of month)	Average weight g (end of month)	Biomass kg (end of month)	Distributed feed kg		FCR (end of month)	Notes and observations
				Type 1	Type 2		

Source: Piccolotti (2014).
Note: FCR = feed conversion ratio.

Capital in commercial aquaculture

Capital is more than liquid savings, such as cash and balances in checking and savings accounts. Capital also includes the monetary value of productive resources such as broodstock, feed stock, machinery, ponds, buildings, on-farm roads and land.

Commercial farming requires adequate capital to create, maintain and expand a business, increase efficiency, and to meet seasonal operating cash needs.

Source of capital: situation in sub-Saharan Africa	➤ The lack of personal equity suggests that most investors in sub-Saharan Africa will depend on external funding to start a commercial aquaculture business. ➤ The most common external funding source of capital for commercial ventures is borrowing, mainly from banks. ➤ In aquaculture, so far financial institutions play a minor role in loans provision for the procurement of investment capital. ➤ The lack of capital remains one of the biggest barriers to aquaculture.
Limiting factors to bank loans	➤ Banks' perception of high risk of failure of commercial aquaculture. ➤ Banks' demand for collaterals. ➤ High interest rates. ➤ Lack of knowledge of how to prepare a loan application to a bank.

Budgeting, accounting and a business plan in aquaculture

This section includes the following topics:

- Planning in commercial aquaculture
- Enterprise budget in aquaculture
- Income statement in aquaculture
- Balance sheet in aquaculture
- Cash flow in aquaculture
- Financial analysis

Why planning?

Planning contains a numbers of steps, including the identification and definition of the problem or decision-making, acquiring the initial information, identifying alternative solutions and analysing each alternative.

Planning is the most basic management function, as it means deciding on a course of action, procedure or policy. Action without a proper plan should be avoided by the farmer, as it usually leads to failure.

Analysis of potential plans makes use of the economic principles and budgeting techniques, which will be discussed below.

Enterprise budget

What is an enterprise budget?

It is an estimate of a fish farm's costs, revenues and profitability for a particular period, given a chosen set of assumptions and values.

Why do you prepare an enterprise budget?

An enterprise budget can help evaluate if the fish farm is likely to be profitable over a given period.

The entries show the typical products used in this business, clarifying which items are important and what costs will be necessary to properly run a farm. Figure 87 provides some additional information on how to fill in the sheets to make a budget.

Figure 87: Example of an enterprise budget

Item	Description	Unit	Quantity	Unit price	Total
Gross receipts					
Sales of marketable tilapia	Average revenue of whole table-sized tilapia	kg	Q	P	= Q * P
Sales of other fish species	Average revenue of other categories of fish	kg			
Total gross receipts		**$**			**(A) = Σ**
Variable costs					
Fingerlings	Average expenditure of fish used for stocking	No.			
Feed	Average expenditure of artificial feed	kg			
Fertilizer					
Urea	Average expenditure of nitrogen-based inorganic fertilizer	kg			
Diammonium phosphate	Average expenditure of phosphorus-based inorganic fertilizer	kg			
Lime	Average expenditure of material used to correct water acidity	kg			
Organic fertilizer	Average expenditure of compost, organic waste, etc.	kg			
Veterinary and pharmaceutical products					
Formalin	Average expenditure of this disinfectant/sanitizer	kg			
Potassium permanganate	Average expenditure of this disinfectant	kg			
Employees					
Field workers	Average level of remuneration paid to people employed in field activities on a full-time basis	No.			
Guards	Average level of remuneration paid to security staff	No.			
Managers	Average level of remuneration paid to directors	No.			
Secretaries	Average level of remuneration paid to people involved in secretarial activities of the farm	No.			
Accountants	Average level of remuneration paid to people involved in accounting activities of the farm	No.			
Drivers	Average level of remuneration paid to drivers of vehicles and other farm machinery	No.			
Annual cost of service providers	Average level of remuneration paid to temporary specialized staff	No.			

Figure 87 (*continued*)

Item	Description	Unit	Quantity	Unit price	Total
Other variable costs					
Maintenance and repairs	Average level of expenditures made on various maintenance and repairs on the farm during the year	$			
Fuel and lubricants	Average level of expenditures made on all kinds of fuel and lubricants needed on the farm during the year	Litre			
Electricity	Average level of expenditures on electricity consumed on the farm during the year	kWh			
Water	Average level of expenditures on water resources consumed on the farm during the year	Litre			
Interest on operating loan	Average level of interest paid to lenders (banks, etc.) of operating funds	%			
Total variable costs		**$**			**(B) = Σ**
Fixed costs					
Interest on investment loan	Average level of interest paid to lenders (banks, etc.) of investment funds	%			
Farm insurance	Average level of annual amount of money paid to insure the farm during the year	ha			
Property taxes	Average level of annual amount of money paid as property taxes during the year	$			
Depreciation					
Support infrastructure	Average level of the estimated annual reductions in the value of support infrastructure	$			
Equipment and machinery	Average level of the estimated annual reductions in the value of equipment and machinery	$			
Ponds	Average level of the estimated annual reductions in the value of ponds	$			
TOTAL FIXED COSTS		$			(C) = Σ
TOTAL COSTS		$	(D) = B + C		
GROSS MARGIN (GM) *(Total gross receipts minus total variable costs)*		$	(E) = A – B		
NET RETURNS (NR) *(Total gross receipts minus total costs)*		$	(F) = A – D		

Income statement

An income statement is a financial statement that summarizes the financial transactions of the fish farm occurring over a selected period, usually a year. It contains the revenues, costs and the net income (or net returns) and is necessary to assess if the fish farm is profitable over the given period.

Figure 88 is an example of how to generate an income statement using the items used in a commercial aquaculture farm.

Figure 88: Example of an income statement

Item	Year 1
Revenues	
Sales of marketable tilapia	
Sales of other fish	
(A) TOTAL REVENUES	**(A) = S**
Cash farm expenses	
Variable cash expenses	
Fingerlings	
Feed	
Fertilizer	
Urea	
Diammonium phosphate	
Lime	
Organic fertilizer	
Other fertilizers	
Veterinary and pharmaceutical products	
Formalin	
Potassium permanganate	
Other veterinary products	
Employees	
Permanent employees	
Field workers	
Daytime guards	
Night-time guards	
Farm managers	
Production managers	
Sales managers	
Other managers	
Secretaries	
Accountants	
Drivers	
Unpaid permanent employees	
Occasional employees	
Annual cost of occasional field workers	
Annual cost of service providers	
Annual cost of other occasional employees	
Hypothetical annual cost of all unpaid occasional employees	
Other variable costs	
Maintenance and repairs	
Fuel and lubricants	
Electricity	
Water	
Other	
Interest on operating loan	

Figure 88 (*continued*)

Item	Year 1
(B) TOTAL VARIABLE CASH EXPENSES	(B) = Σ
Fixed cash expenses	
Interest on investment loan	
Farm insurance	
Other fixed cash costs	
(C) TOTAL FIXED CASH EXPENSES	(C) = Σ
(D) TOTAL CASH EXPENSES (Variable plus fixed cash expenses)	(D) = B + C
(E) NET CASH FARM INCOME (NCFI) ABOVE CASH EXPENSES (Revenues minus cash expenses)	(E) = A – D
Non-cash adjustments to income	
Fish inventory adjustment	
Depreciation	
Support infrastructure	
Equipment and machinery	
Ponds	
(F) TOTAL NON-CASH ADJUSTMENTS TO INCOME	(F) = Σ
(G) NET FARM INCOME FROM OPERATIONS (NFIO) ABOVE CASH AND NON-CASH EXPENSES (NCFI minus non-cash adjustments)	(G) = E– F
Gains and losses on sale of capital assets	
Land	
Equipment and machinery	
Other	
(H) TOTAL GAINS AND LOSSES ON SALE OF CAPITAL ASSETS	(H) = Σ
(I) NET FARM INCOME (NFI) (NFIO plus/minus total gains and losses on sale of capital assets)	(I) = G ± H

Balance sheet

Balance sheet
What? Statement of the value of all assets and liabilities of the fish farm over a given time period. **Why?** Measure the financial position and strength of the fish farm through the net worth and the solvency and liquidity ratios.

Figure 89 is an example of a balance sheet.

Figure 89: Example of a balance sheet

Item	Year 1
ASSETS	
Current assets	
Cash balance	
Fish inventory	
Prepaid expenses	
Accounts receivable	
(A) TOTAL CURRENT ASSETS	(A) = Σ
Non-current assets	
Land	
Support infrastructure	
Equipment and machinery	
Ponds	
(B) TOTAL NON-CURRENT ASSETS	(B) = Σ
(C) TOTAL ASSETS	(C) = A + B
LIABILITIES	
Current liabilities	
Operating loan	
Accounts payable	
(D) TOTAL CURRENT LIABILITIES	(D) = Σ
Non-current liabilities	
Investment loan	
Capital lease	
(E) TOTAL NON-CURRENT LIABILITIES	(E) = Σ
(F) TOTAL LIABILITIES	F = (D + E)
(G) OWNER'S EQUITY (NET WORTH) (Total assets minus total liabilities)	G = (C – F)

Cash flow

Cash flow
What? Statement containing the total cash inflows and outflows of the fish farm over a given time period. **Why?** Identify the borrowing needs and when they are likely to arise, the loan repayment capacity and when it might be possible for a loan to be repaid.

Figure 90 is an example of a cash balance form.

Figure 90: Example of a cash balance form

Item	Year 1
(A) BEGINNING CASH BALANCE	(A)
CASH INFLOW	
Revenues from sales of tilapia	
Revenues from sales of other fish	
Revenues from sales of capital assets	
(B) TOTAL CASH INFLOW OF THE FARM	(B) = S
(C) TOTAL CASH INFLOW	(C) = A + B
CASH OUTFLOW	
OPERATING CASH EXPENSES	
Fingerlings	
Feed	
Fertilizers (including lime)	
Veterinary and pharmaceutical products	
Permanent employees	
Occasional employees	
Maintenance and repairs	
Fuel and lubricants	
Electricity	
Water	
Prepaid expenses	
Other operating cash expenses	
(D) TOTAL OPERATING CASH EXPENSES	(D) = S
NON-OPERATING CASH EXPENSES	
Farm insurance	
Property taxes	
Other non-operating cash expenses	
(E) TOTAL NON-OPERATING CASH EXPENSES	(E) = S
(F) NON-FARM EXPENSES	(F)
LOANS REPAYMENT	
Investment Loan – Principal	
Investment Loan – Interest	
Operating Loan – Principal	
Operating Loan – Interest	
(G) TOTAL LOANS REPAYMENT	(G) = S
(H) TOTAL CASH OUTFLOW (Operating cash expenses plus non-operating cash expenses plus non-farm expenses plus loans repayment)	(H) = D + E + F + G
(I) CASH (BALANCE) AVAILABLE BEFORE ANY NEW OPERATING LOAN (Cash inflow minus cash outflow)	(I) = C – H
(L) New operating loan	L
(M) CASH (BALANCE) AFTER NEW OPERATING LOAN	(N) = I + L

Financial analysis

After having used all these tools, filled them in properly with the information on your business that you gather on a daily, weekly, monthly and annual basis, these tools will help you obtain a clear picture of the financial situation your business is in – as well as help you support and justify your request for a loan, for instance (Table 8).

Table 8: Overview of financial tools in aquaculture

Cash flow analysis	**What?** The analysis of the fish farm's cash inflows and outflows. **Why?** Evaluate borrowing needs and to determine the cash needed to repay any new loan, the loan repayment capacity and when it might be possible for a loan to be repaid.
Sensitivity analysis	**What?** It shows how varying the costs or quantities of factors of production affect fish farm profitability. **Why?** Useful in order to assess the risks associated with a business.
Cost structure analysis	**What?** It defines the weight (the relative proportion) of a single cost item on variable, fixed and total costs. **Why?** By showing the distribution of financial resources among factors of production, it is useful to fish farmers seeking to improve the profitability of their farm.
Financial analysis	**What?** Assessment of the solvency, liquidity, profitability and financial efficiency of the fish farm. **Why?** It is useful to evaluate the sustainability of the fish farm.

Business plan

Definition
A business plan is a detailed written document that addresses all the major aspects of the enterprise (Table 9). The business plan should describe in a structured format, with a logical flow of information, the business, its operating environment, its short- and long-term goals, and how it proposes to achieve these goals.

Objectives
The business plan should provide a guide for entrepreneurs, with a set of goals against which to monitor the financial performance of the business. • As a tool for raising capital, the business plan should anticipate questions anyone considering risking money in a business may ask. • It should demonstrate that the entrepreneur has thought through the development of the business in terms of products, management, finances, markets and competition. • It can help the entrepreneur to avoid mistakes or recognize hidden opportunities.

Structure: key parts
The proposed business plan for a commercial aquaculture venture includes two main parts: • The first part contains the title page, table of contents and an executive summary. • The second part consists of the main body.

Main body
The main body of an aquaculture business plan may be broadly divided into three sections: 1. Anatomy of the proposed aquaculture business: – Proposed aquaculture venture – Site – Production system – Legal structure of the business – Management capacity of the business – Financial history of the borrower 2. Marketing plan 3. Financial documents: – Estimate of required financing: summary of financial needs, loan funds dispersal statement – Pro forma financial statements: pro forma income statement, pro forma balance sheet, pro forma cash flow statement

Table 9: Checklist for the elements of a business plan

	Essential elements	What to include	Further remarks
First part of plan	Title page, Table of contents, Executive summary		Do not forget them
Second part: Description of the proposed aquaculture business	Description of the business	Organizational structure; brief description of new aquaculture venture	
	Site	Suitability	Soil characteristics (suitable for ponds); water supply (water type, quantity and temperature)
		Proximity	Processing facilities; feed mills; disease and diagnostic laboratories; extension office
	Production system	Stocking rates; seed source; aeration strategy; anticipated feed rates; harvesting methods	Ensure consistency, e.g. feed rate should be consistent with stocking rate
	Management competence	Qualifications/ experience of key management and technical personnel	Explanation should be given of how any shortfall will be remedied
	Financial statement of the borrower	Three years of statements, if possible	
Marketing plan		Marketing plan	Existing demand; market potential; alternative markets; volume and size requirements Local and/or export; consider cost of safety and quality measures for export market
Financial documents Pro forma financial statements		Estimate of required financing Cost and returns; pro forma balance sheet; pro forma income statement; pro forma cash flow budget	Summary of financial needs; loan funds dispersal statement
Supporting documents			Any document that will back up your claims Solid evidence to support claims makes a business more credible

THE FAO "USER-FRIENDLY TOOL FOR INVESTMENT DECISION MAKING IN AQUACULTURE": INTRODUCTION

The beta version of the User-Friendly Tool for Investment Decision Making in Aquaculture (UTIDA) is based on an interactive and user-friendly model designed within Microsoft Excel, which allows rapid data entry by the users. UTIDA requires no advanced knowledge of economic concepts or advanced skills in the use of spreadsheets. The tool is targeted to assist small- and medium-scale fish farmers in their decision to invest or not in aquaculture under specific assumptions. When used properly, UTIDA may provide valuable assistance to small- and medium-scale fish farmers for improving the financial management of their operations.

Introducing the UTIDA tool

The tool analyses two fish species: Nile tilapia (*Oreochromis niloticus*) and North African catfish (*Clarias gariepinus*). For each species, it provides two main groups of farming systems: grow-out and nursery.

This section addresses the following aspects of UTIDA:

- Background
- Definition and scope
- Structure and utilization

Background
The beta version of the User-Friendly Tool for Investment Decision Making in Aquaculture (UTIDA): • Is based on an interactive, user-friendly and Excel-based model, which allows rapid data entry by the users. • Requires basic technical, economic and financial knowledge to perform the data entry.

Definition and scope: Why use UTIDA?
UTIDA is designed to assist small- and medium-scale fish farmers in investment decision-making for aquaculture under specific assumptions. UTIDA is set to: ➤ Cover a number of farming systems: – Grow-out – Nursery ➤ Analyse two fish species: – Tilapia – African catfish

Structure and utilization: download and first access

The tool is available as a zip archive called "UTIDA_EN.zip" in the FAO web page www.fao.org/fishery/statistics/software/utida/en.

First, the users must download the archive UTIDA_EN.zip and save it in any local drive.

After that, users must unzip it and maintain the same folder structure.

Finally, to start using the tool, users must open the file "INDEX-EN.xls", which contains the "Home pages" (Table 10).

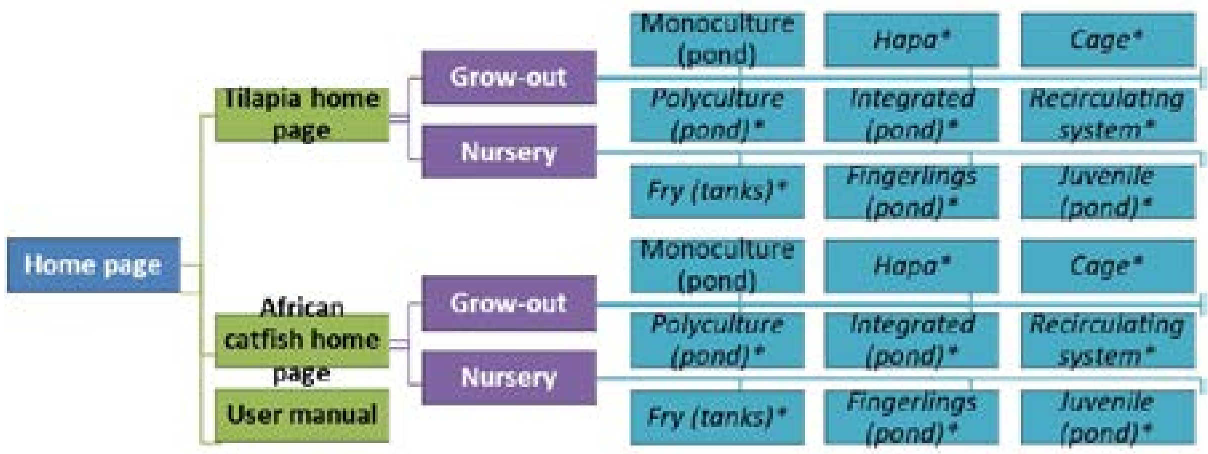
UTIDA web page (English): www.fao.org/fishery/statistics/software/utida/en

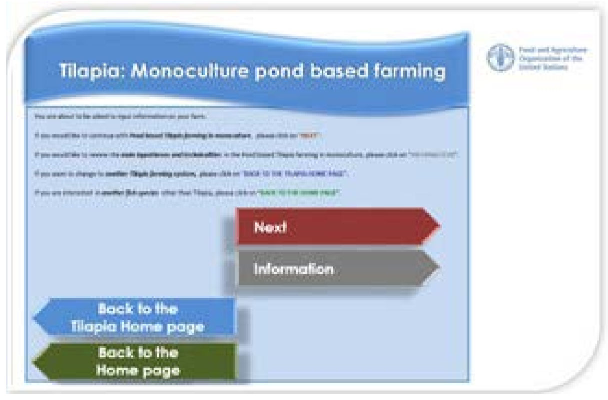
UTIDA web page (French): www.fao.org/fishery/statistics/software/utida/fr

Attention!

Since the tool consists of a series of linked Excel workbook files within a folder, it is very important to maintain the zipped file structure when extracting.

Table 10: Image of some of the pages on UTIDA





Attention!

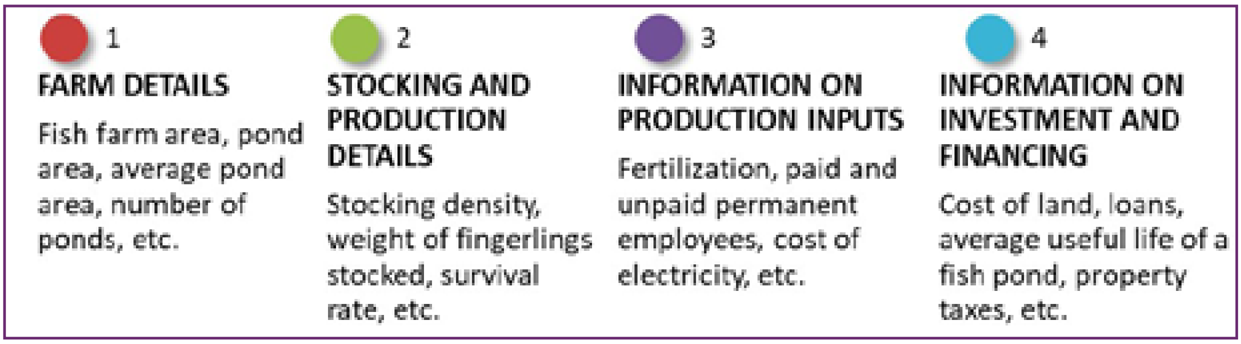
Please note that each file is protected. The user is allowed to perform the following actions: save; save as; print; print preview; modify column width; insert data in the green cells; and click on the arrows.

Data entry

There are four data entry sheets (the tables in Excel): each is meant to enter data related to a specific part of the commercial aquaculture farm, and each needs to be filled in completely for the program to provide advice on your investment decisions. The four sheets cover (1) farm details; (2) stocking and production details; (3) information on production inputs other than seed and feed; and (4) information on investment and financing.

Figure 91 shows the type of data required in each of the sheets. All the requested information needs to be entered, as the accuracy of the results depends on it. Further down, Figure 92 shows an example of data entry and how the green cell turns white after entering the requested data.

Figure 91: Structure of UTIDA tool on website



Item: Please click here to see the instructions

In each spreadsheet, it is possible to click on the cell "item" to obtain a brief explanation about the contents and commands. By clicking on the related cells, the tool displays the meaning of the acronyms or additional information on how to perform the data entry process.

Figure 92: An example of data entry

Item

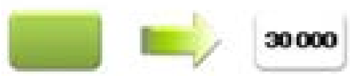
Stocking density

Definition

Number of fingerlings stocked per square metre of pond

Unit

Fingerlings/m^2



It is also possible to click on the "green cells"; the tool then displays input messages, for example, "pay attention to measurement units while entering values in the green cells".

After the user has entered all the requested information in the green cells, the tool automatically calculates the values in the "**orange cells**" in the four data entry sheets. Because the calculations are already programmed in the sheets, there are several points of attention that the user must focus upon in order to avoid making an error. While some are listed in the pages above, Table 11 lists all the "do nots" that can hinder the accuracy of the UTIDA tool.

Attention!

- All the information needs to be filled in only into the related "**green cells**" under the column named "**value**".
- Do not leave any green cells empty because the accuracy of the results analysis depends on it. Any green cell requires a value.
- When the user enters the requested information, the colour of the cell turns from green to white.

Table 11: List of "do nots" when using the UTIDA tool

DO NOT	
⚠	Do not copy and paste values from one cell to another.
⚠	Do not drag and drop when inserting data.
⚠	The user cannot change the values calculated in the orange boxes. 150 000
⚠	Do not leave any green cells empty because the accuracy of the results analysis depends on it. Any green cell requires a value.
⚠	Please note that each file is protected. The user is allowed to perform the following actions: save, save as, print, print preview, modify column width, insert data in the green cells and click on the arrows.

Results sheets

Summary of the information provided	Average annual income statement	Annual income statement	Cash flow	Balance sheet	Summary of the result

There are six result sheets once the data are entered correctly and completely (Table 12).

Table 12: Overview of result sheets in UTIDA

1	**Summary of the information provided:** data entry snapshot
2	**Average annual income statement:** total revenues, cash expenses, net income, etc.
3	**Annual income statement:** depreciation, fish inventory adjustment, net income, etc.
4	**Cash flow:** cash inflow and outflow, loans repayment, cash available after new operating loan, etc.
5	**Balance sheet:** current and non-current assets and liabilities, net worth, etc.
6	**Summary of the results:** summary of the main outcomes of the analysis

Attention!

In the "**Summary of the information provided**", the "**yellow cells**" indicate that values are automatically summarized by the tool after the user has filled the four data entry sheets.

If the user wants to modify the summarized values in the yellow cells, he or she has to return to the corresponding data entry sheet by clicking on the arrow "**back**" until he or she gets to the page of interest.

150 000

Analysis structure

The financial analysis allows fish farmers to gain a clear picture concerning their farm, through the assessment of the following:

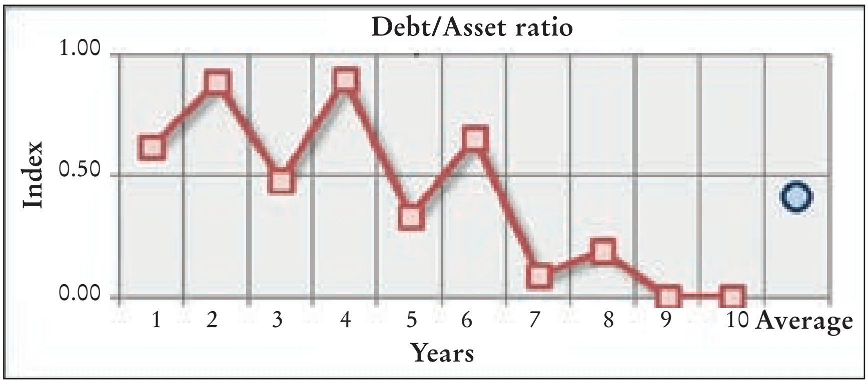
- Solvency indicators refer to the value of assets as compared to the amount of liabilities on the fish farm.
- Liquidity indicators refer to the ability of the fish farm to meet its cash flow obligations.
- Profitability indicators are generally calculated by subtracting total costs from total revenues.
- Financial efficiency indicators refer to how effectively a fish farm can generate income.

In Figure 93, the solvency indicator is shown in a graph. The data needed for this ratio come from the balance sheet.

Figure 93: Solvency indicator

Solvency indicator

Debt / Asset ratio = Total liabilities / Total assets



The cost structure analysis provides fish farmers with a clear picture on how financial resources are allocated among factors of production:

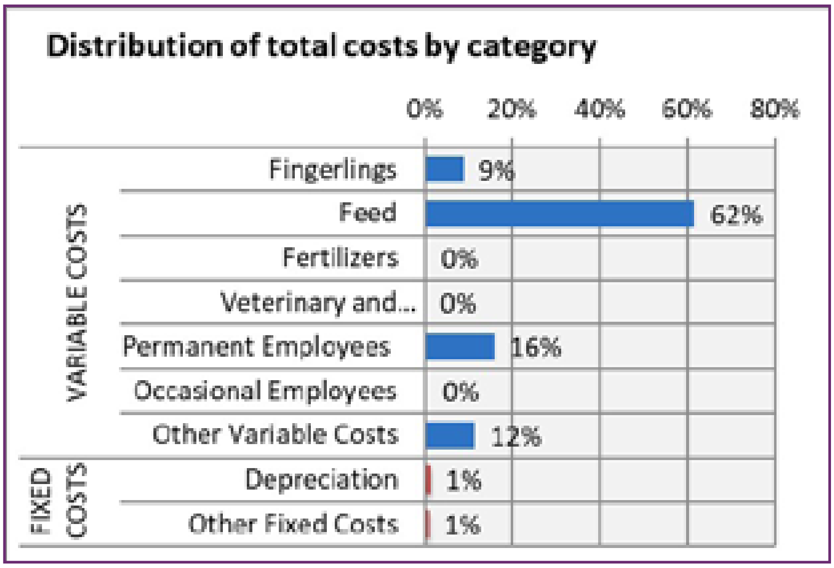
- Share of each variable cost on total costs
- Share of each fixed cost on total costs

Figure 94 shows the formula used to make the cost structure analysis and an example of the distribution of a few variables; in this way, you can see the costs for the "weight" of the fingerlings as compared to the weight of the costs of permanent employees and other costs (Figure 95). In this example, the biggest cost is clearly feeding. The data needed for this analysis are derived from the income statement.

Figure 94: Formula for cost structure analysis

Feed Costs (vc_a)
As percentage of Total Variable Costs (TVC) = vc_a/TVC
As percentage of Total Costs (TVC) = vc_a/TC

Figure 95: Weight of total costs by category



The Sensitivity analysis (Figure 96) shows fish farmers the combined effects on average net farm income of:

- Feed price
- Feed conversion ratio
- Survival rate
- Price of fish harvested
- Length of growing cycle

Figure 96: Sensitivity analysis

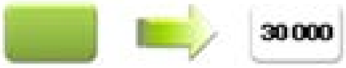
Scenario	Average feed price (LC/kg)	Average FCR (%)	Average survival rate (%)	Average fish harvested price (LC/kg)	Average length of one growing cycle (months)	Average net farm income (LC)
1						
2						Please fill in all green cells
3						Please fill in all green cells
4						Please fill in all green cells
5						Please fill in all green cells

Note: FCR = feed conversion ratio; LC = local currency.

REMEMBER:

Please note that the sensitivity analysis can be performed only after having completed all the data entries and explored all the results.

- All the information needs to be filled in only into the related "**green cells**".
- Do not leave any green cells empty because the accuracy of the analysis depends on it. Any green cell requires a value.
- When the user enters the requested information, the colour of the cell turns from green to white.



In Figure 97, the graph made for the sensitivity analysis, based on the data from the income statement and the cash flow, shows the possible net income for different scenarios. The basic data for scenario 1 is used as an example in this graph (Figure 98).

Figure 97: Example of graph on sensitivity analysis; income by scenario

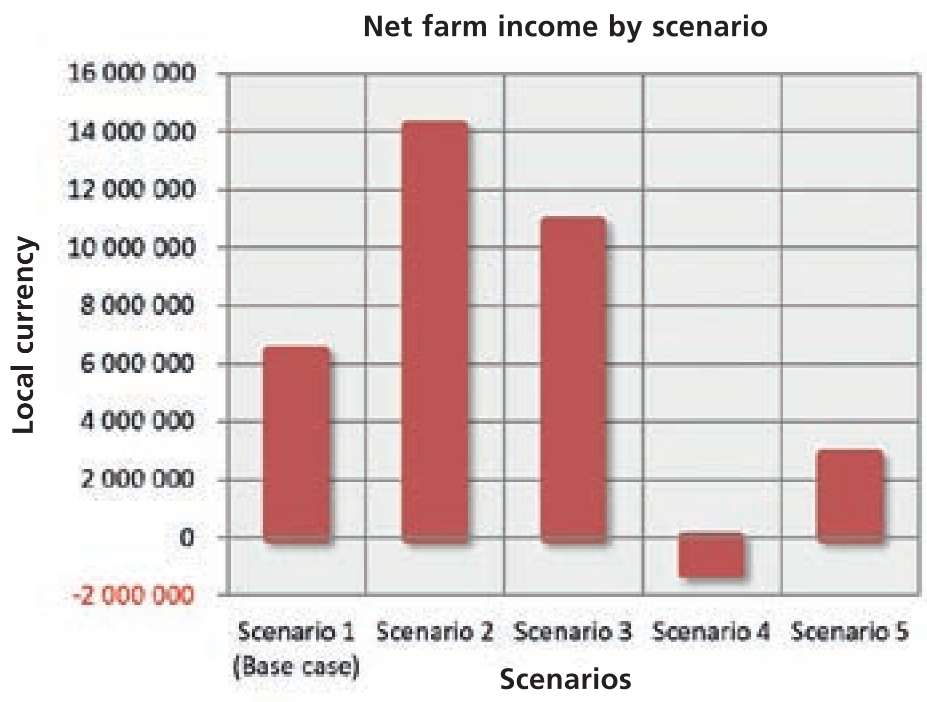


Figure 98: Data used for scenario

Scenario 1
Feed costs = 800 (local currency/kg)
Net farm income= total revenue – [(800 * qa + vcb + … + vcn) + total fixed costs]

Let’s try it out

EXERCISE

Make sure you program working groups at the end of this segment and plan enough time for the extensive exercises.

Or

Go to the exercises in Module 5.

Divide participants in groups of four to six people; make sure the participants are mixed in terms of experience and proactive behaviour. If that is not possible, make sure that the selection is completely random, for instance, by having people counting up to the number of the working group you are organizing (e.g. if there are three working groups, you have people count up to three).

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FINANCIAL RISKS AND HAZARDS IN DEVELOPING AQUACULTURE AS A BUSINESS

Aquaculture, like any other agricultural activity, faces threats and risks and has the potential to create vulnerabilities. Some threats are internal, directly related to farmer and farm management, and others are external such as the status of weather, climate, global markets and social order. It is important to have an objective, systematic, standardized and strong method of assessing the likelihood of negative consequences occurring due to a proposed action or activity and the likely magnitude of those consequences.

Risk and hazard definition

- Risk is defined as uncertain consequences, usually unfavourable outcomes, due to imperfect knowledge (Arthur *et al*., 2009).
- Risk can be lowered by reducing or removing hazards, i.e. sources of risk.
- Hazards are tangible threats that can contribute to risk but do not necessarily produce risk.

What kind of risks can be identified in aquaculture?

There are many risks that can be identified in the aquaculture business, some affecting only the culture itself and its owner, while others have a bigger impact extending beyond the farmer and his or her farm (Arthur *et al*., 2009). These are the different categories of financial risk:

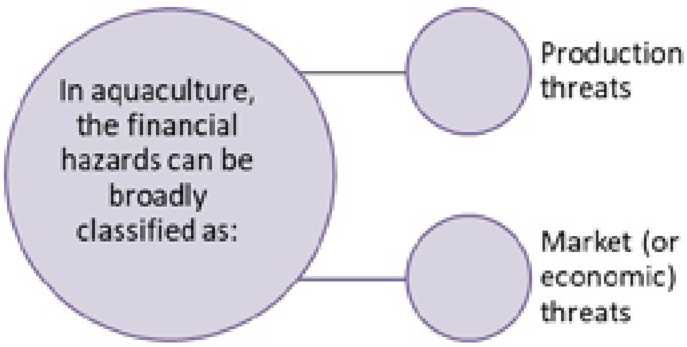
- Pathogen risks
- Food safety and public health risks
- Ecological (pest and invasive) risks
- Genetic risks
- Environmental risks
- Social risks
- Financial risks

In this module, we specifically look at the elements that contribute to the financial risks.

Financial risks

Financial risk in aquaculture	Financial risk represents the likelihood of a hazardous event occurring and the potential financial loss that could result. In aquaculture, financial risk refers to the potential loss associated with an aquaculture investment. Aquaculture investments may be public or private and made on behalf of stakeholders, including individual farmers, shareholders, farm enterprises, financial institutions and/or government institutions. Financial risk in aquaculture refers primarily to investment risk associated with individual farms or facilities.

Financial hazards in aquaculture



Source: Kam and Leung, 2008.

Market risks and production risks

Market and production threats are commonly viewed as sources of financial risks that lead to losses, as represented in Figure 99.

Figure 99: Diagram of hazards, risks and consequences

Source: Kam and Leung, 2008.

Production threats result in financial loss due to reduced yield

- These impacts can be realized based on adverse environmental conditions, equipment or other asset failure, poor quality stock, disease or pest infestation, and others.
- Many of these external factors can be improved by knowledgeable staff:
  - Broodstock low quality or limited availability
  - Seed stock low quality or limited availability
  - Equipment/asset failure
  - Decreasing growth rates
  - Disease spread
  - Lack/loss of skilled labour
  - Natural disasters
  - Limited availability of feed
  - Social acceptability

Market threats include price fluctuations and the impacts of the regulatory environment

- Competition, either domestically or internationally, will add to the volatility of market prices and hence to profit margins.
- The regulatory environment may become increasingly demanding, costly to satisfy over time, and may be subject to change.

Some examples of market threats in aquaculture are:

- Decreasing sale prices (prices of outputs)
- Increasing production costs (prices of inputs)
- Availability (scarcity) of inputs
- Escalating interest rates
- Decreasing market demand
- Limited market access
- Creditor instability
- Political instability

Risk analysis

A risk analysis (Arthur and Bondad-Reantaso, 2012) is an objective, systematic, standardized and defensible method of assessing the likelihood of negative consequences occurring due to a proposed action or activity and the likely magnitude of those consequences (Figure 100).

Figure 100: Recapitulation of the elements of a financial risk analysis

Source: Kam and Leung (2008).

Features of financial risk analysis and its implementation and challenges

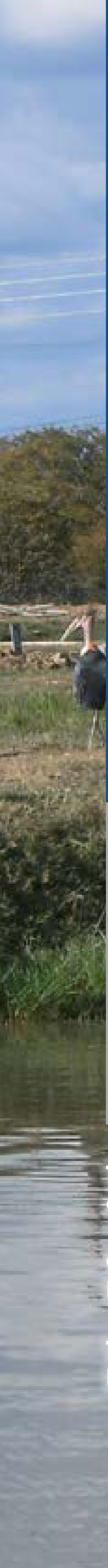
- Analyses of financial risk are typically quantitative because financial risk generally implies monetary loss.
- Analyses can be applied at the level of a farm or across a sector at the national or regional level.
- No specific international or regional agreements exist that provide guidance on financial risk analysis.
- Actions required at the farm operational level may include:
  - Initial business planning
  - Ongoing management planning
  - Insurance

Challenges for the aquaculture business regarding risk analysis

- Farmers and policymakers may require the assistance of risk analysts/modellers to decompose their financial risk concerns.
- Sufficient data may not be available to estimate uncertainty and characterize the financial risk (Kam and Leung, 2008).

EXERCISE

Brainstorming session on the potential risks of an aquaculture enterprise



Module 4

EXTRA READING AND PRACTICES: POST-HARVEST, PROCESSING AND VALUE ADDITION

This module was prepared under the Blue Growth Initiative (FMM/GLO/112/MUL) and the Africa Solidarity Trust Fund (GCP/SFE/001/MUL).

Contributors to this chapter: Ana Menezes, Bernard Adrien, Yaw Ansah and Henock Asmelash (Menezes *et al.*, 2016b).

The original version was prepared by Luisa Arthur, Carlos Lima dos Santos and Esperanza Silva (INFOSA, 2009a, b, c, d, e).

©A. Menezes

The information provided in this module intends to enrich readers' ability to go beyond the sole practice of fish production. The objective is to provide a general overview of good practices on fish handling and conservation methods post-harvest. This Extra Reading Module was prepared based on previous manuals prepared under a few projects in sub-Saharan Africa, notably the Blue Growth Initiative Project (FMM/GLO/112/MUL) and the Africa Solidarity Trust Fund (GCP/SFE/001/MUL).

Mostly, those manuals benefited from a previous series of guides and brochures prepared under one INFOSA project "Aumento da eficiencia nos mercados do sector de pesca de pequena escala em Angola e Mocambique". For easy reference and deeper knowledge on the topics, check the reference section (INFOSA, 2009a, b, c, d, e).

POST-HARVEST, PROCESSING AND VALUE ADDITION

Markets are a major driver for aquaculture upscaling. Improving the linkage to them requires applying better management practices to produce high-quality aquatic food from the farms and developing post-harvest technologies to improve meat quality, shelf-life and product value. It also indicates facilitating access to markets, *inter alia*, through better roads, transportation means and equipment in addition to better information about market opportunities. However, aquaculture value chains are frequently underdeveloped and do not take full advantage of value addition, product development and diversification, certification, and intra- and inter-regional fish trade. As a result, aquaculture value chains tend to be short and restricted to the immediate vicinity of farms.

While there are many factors hampering the full development of aquaculture value chains, this curriculum and training manual offers a good understanding of the basic techniques, methods and procedures to be followed during the production, post-harvest handling and processing that are essential to overcome some of the identified deficiencies, allowing the producer to market higher quality fish and aquatic products and maintain a sustainable enterprise.

This section briefly introduces some key principles, information and techniques to correctly apply the necessary sanitary measures during the post-harvest process and the various fish processing techniques. The section aims at creating basic skills and competencies for all stakeholders along the aquaculture value chain, especially for those engaging with fish processing and market development.

This section touches upon methodologies and practices for fish processing and markets, such as smoking, chilling and freezing, and sanitary conditions of fish markets. Throughout the section, good and bad practices are illustrated.

At the end of this module/session, participants will have developed:
A good understanding of the techniques, methods and procedures to be followed while preparing aquatic products for the market after harvesting.
The ability to apply good practices for post-harvest handling and value addition.
The knowledge needed to correctly apply the necessary sanitary measures in the post-harvest process.

Salting and drying fish

Raw materials for salting

The raw materials for salting are fish and salt; both must be of good sensory, sanitary and nutritional quality.

Fish

Only good quality (fresh) fish can be salted and dried because neither drying nor salting will improve the quality of spoiled fish.

			
Fish with *rigor mortis.*	Red and shiny gills.	Pleasant smell of sea or fish.	Firm and elastic texture.

Photos: ©Bernard Adrien.

Salt

Salt is the main ingredient used in salting fish, and its quality is very important.

- The grain size for dry piles of salt should be 2–3 mm.
- Insoluble residues, such as sand and other foreign particles, must be less than 0.5 percent in weight.
- The salt must be free from contamination by halophilic bacteria (putrefactive bacteria that live on salt and are red).
- In summary, the principle of preservation by salting is based on:
  1. The dehydrating power of salt through chemical or osmotic equilibrium, which causes water inside the fish tissue to evaporate, thus the flesh dries.
  2. The bactericidal or bacteriostatic power of salt, which kills and/or inhibits the development of microorganisms, thus slowing down enzymatic reactions.
  3. Appearance – salt improves texture and the general appearance of salted and dried fish.

Methods of salting

Salting is done using both industrial and non-industrial methods.

There are two methods of salting fish: (i) dry salting (or dry pile salting); and (ii) drying in brine (wet salting). For either type of salting, the amount of salt should be about 30 percent of the weight of fish in order to obtain stable salted fish.

Steps to prepare fish for salting

STEP 1 RECEPTION OF THE FISH		
		
Before handling fish, staff must wash their hands with clean water and disinfect them.	Only accept good quality fish and never use spoiled fish.	Always work in the shade and mix the fish with ice.

Photos: ©Bernard Adrien.

		
Always process the fish in clean places, where there is no rubbish...	...and not directly on the ground or on the beach...	...but always on a table or a tarp.

Photos: ©Bernard Adrien.

The fish must be handled carefully:

- Avoiding physical damage;
- Separating different types and species of fish;
- Removing trash or non-target organisms.

STEP 2
WASHING AND SELECTION IN A BOWL OR CONTAINER (WITH HOLES)

Sort the fish by size, wash with clean water on a tarp ...

… and preferably use running water.

Photos: ©Bernard Adrien.

STEP 3
REMOVING THE FISH SCALES
ON A TABLE, RACK OR TARP, AVOIDING CONTACT WITH THE FLOOR OR GROUND

If the fish has large scales that might slow the entry of salt, remove the scales...

…with a brush or with a scale remover made from bottle caps.

Photos: ©Bernard Adrien.

STEP 4
PREPARATION OF FISH
ALWAYS USE CLEAN WATER

Open the fish and remove the viscera and gills…

…but NOT on the sand of the beach or in dirty surroundings.

Do not wash the fish in dirty water, especially water that contains fish parts and residue.

Photos: ©Bernard Adrien.

NOTE: The viscera can be used to make animal feed, e.g. for chickens (fishmeal or fish silage); otherwise, it must be buried or burned to avoid polluting the area.	 

Photos: ©Bernard Adrien.

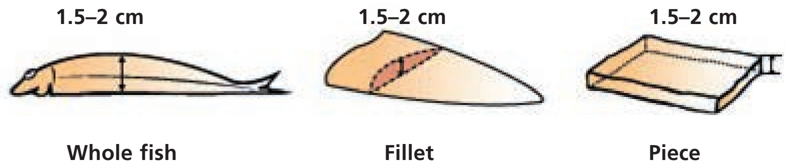
STEP 5 PREPARATION OF LARGE FISH ON A TABLE, RACK OR TARP, AVOIDING CONTACT WITH THE FLOOR OR GROUND		
 		
Large fish (more than 100 g) should be gutted and the thickness reduced (to no more than 2–3 cm).	Afterwards, splay them, butterfly style (open from the back), keeping the head intact.	

Photos: ©Bernard Adrien.

		
Fish can also be flattened fillets, butterfly style (open from the back), head removed...	...or fillets...	or pieces.

Photos: ©Bernard Adrien.

Salting fish with a thickness of over 2–3 cm is not recommended because the fish can spoil before becoming properly salted. Examples of proper thickness are presented in the illustration.



STEP 6 PREPARATION OF SMALL FISH ON A TABLE, RACK OR TARP, AVOIDING CONTACT WITH THE FLOOR OR GROUND	
	
Small fish (more than 20 g) may simply be gutted.	Hygienically: (1) Do **not** put sand on small fish to make it easier to gut. (2) Do **not** have sand in a bucket near you to make it easier to gut the small fish.

STEP 7 ANOTHER WASHING IN A CONTAINER OR BOWL, SUBMERGING A BOX OR A BASKET WITH HOLES		
		
Wash the fish in clean water (potable or, as an alternative, seawater, collected far from dirty areas such as beaches and harbours).		Do not use boxes that have been mended, as they could physically damage the fish.

Photos: ©Bernard Adrien.

Throughout the process of preparing fish for salting, always keep the fish well mixed with ice. Also register their place of origin so that the fish can be traced.

Dry pile salting

Summary of steps for dry pile salting

STEP 1 SALTING THE FISH
DESCRIPTION
Alternate layers of fish and salt, starting and ending with a layer of salt.
In general, the salting time is one to five days.

THE PLACE

- For salting small quantities of fish: pallet or wooden box, containers, buckets or bowls with drainage.
- For salting large quantities of fish: wooden pallets or less shallow tanks, usually with a sloping bottom to facilitate the flow of water.

The pile of salted fish is ready.

Photos: ©Bernard Adrien.

STEP 2 WASHING FISH AFTER SALTING IN A CONTAINER OR BOWL
DESCRIPTION
Preferably, after removing the fish from the dry pile, quickly dip them into a light 10 percent brine to remove the excess salt.

Salting in brine

The advantage of brine is that it produces reliable products and, moreover, it is easier to control than dry pile salting.

Wet pile salting (no pre-prepared brine)

In this method, the mixture of fish and salt is placed in a container that has no drainage, a plastic bucket for example. Normally, a salt layer is placed at the bottom, then a layer of whole fish, then another of salt, ending with a salt layer on top. Water is never added to the mixture.

Photos: ©Bernard Adrien.

ATTENTION:
The salt must be of good quality.

Because there is no water drainage in the container, brine is formed by the water from the actual fish mixing with the salt. This type of salting in a wet pile is recommended for semi-oily and oily species, such as sardinella, tuna, mackerel, horse mackerel and eel.

Fish should be kept in the wet pile for at least three days but are usually kept there for two to four weeks.

Wet salting (pre-prepared brine)

One can also make brine and immerse the fish into it: a ratio of one part salt to three parts water; or about 3.5 kg of salt in 10 L of water.

Brine is a mixture of salt and water. It is prepared in a bucket or a bowl and placing the fish into the mixture at the ratio of one part salt to three parts water; or about 3.5 kg of salt in 10 L of water. The fish absorb the salt; water goes out of the flesh and dissolves the brine.

Photos: ©Bernard Adrien.

This method follows the same steps as the salting in a dry pile, by immersing the fish in the brine, which has been prepared earlier. The salting time in this brine must be at least two to three days.

In summary

Brine can be used twice if it is not very dirty and does not contain fish blood after the first use; more salt must then be added to the brine.

Photos: ©Bernard Adrien.

Fish drying

The principle of fish drying is based on an increase of heat that causes a reduction in the amount of moisture in the fish through evaporation of the water contained within its muscle into the surrounding air (Figure 101).

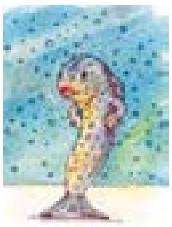
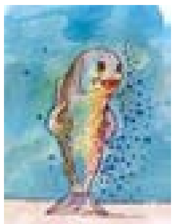
Drying occurs primarily through evaporation and osmosis of water. Therefore, for fish drying, it is important for the moisture in the air to be much lower than that of the fish.

From where it is most concentrated (the fish) → To where it is less concentrated (the air)

If you try to dry clothes on a very hot, but rainy day (too humid), the clothes do not dry very well because there is already moisture in the air and so the moisture in the clothes cannot easily escape into the air. The same thing happens with fish: a rainy and humid day is not favourable for drying fish.

However, on a day when there is low air humidity and wind, clothes dry much faster because the wind removes moisture that forms around clothes as they begin to dry. Since the air surrounding the clothes already contains only a little moisture, it can receive more moisture from the clothing.

Figure 101: Air humidity and fish drying

			
1. A fish contains a lot of water. If the air around the fish is also full of moisture (water), the fish will not dry. 2. If there is little moisture in the air around the fish, the water inside it evaporates (it leaves the fish's body) and the fish dries.		3. If there is too much moisture around the fish, which originates from the actual fish...	4. ...and a little wind appears, it removes the moisture and the fish continues to dry.

The stages of fish drying

Drying occurs in two distinct phases: initial drying and actual drying.

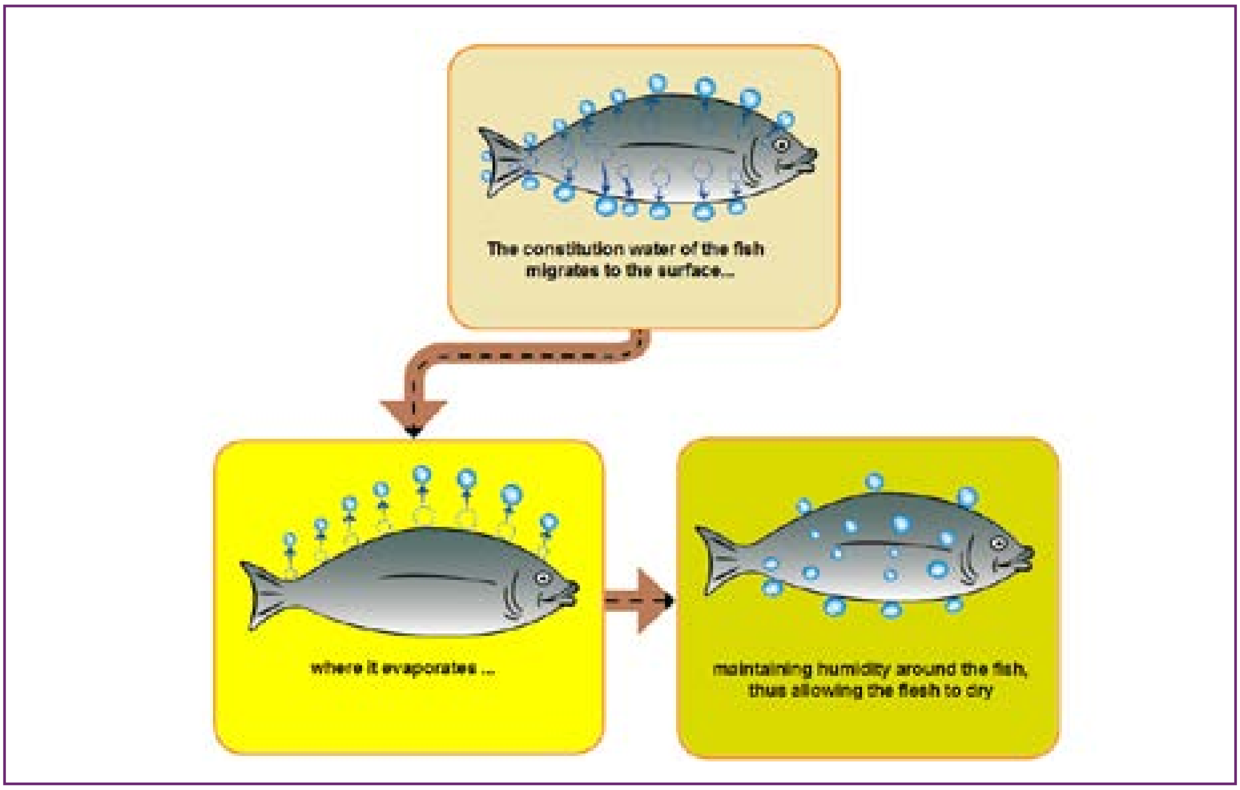
Initial drying (first step of drying) is the period of continuous drying, with water evaporating from the surface of the fish (the fish looks like a sponge and always has water evaporating from its surface). The air surrounding the fish absorbs moisture as vapour.

This phase should be as short as possible because the conditions are optimal for insects to deposit their eggs on the moist surfaces of the still-drying fish, spoiling the fish.

Actual drying (second step of drying) is the period of reduced drying when water inside the fish diffuses to the surface and then evaporates.

During this step, the drying speed is limited by the diffusion of water in the inner layers of the flesh. The water inside the fish muscle migrates to the surface and evaporates, drying the fish (Figure 102).

Figure 102: How a fish dries



Furthermore, if the superficial drying is too fast, a hard external coat is formed, which blocks the water inside the fish (internal moisture) and prevents its evaporation. Thus, the fish does not dry. For this reason, starting the drying process at noon on very sunny days is not recommended.

Types of drying

Natural drying is the easiest method, where fish are placed on trays or on racks and exposed directly to sunlight. Some examples appear in the following two photos.

	
Natural drying is carried out at ambient temperatures, generally under the sun.	Racks are used to lay the fish out to dry, in a single layer and without overlapping.

Photos: ©Bernard Adrien.

To build a rack

		
1. Put four sticks into the ground to form a rectangle and make a frame with four other sticks across the top of these sticks.	2. Place a net over this frame, tie and stretch it well.	3. The rack is ready!

		
The trays and the fish should never be placed directly on the ground, but must be raised above it (e.g. on racks) ...	...as the fish must be protected from contamination by animals; the air must circulate easily to facilitate drying.	Solar dryers may be used during rainy days or in a humid climate.

Photos: ©Bernard Adrien.

Warehouses and packaging

		
Warehouses should be well ventilated; the fish should be packed in bales (do not use feet to force the fish into the bag).	Preferably, the bags are made of jute.	They should be closed to prevent flies from laying their eggs on the fish!

Photos: ©Bernard Adrien.

Smoking fish

What to do when it rains for days, making it difficult to dry fish?

Or when the access road to the community is of poor quality, preventing the selling of fresh fish?

The solution is **SMOKING FISH**.

Check your market, as some customers prefer smoked fish, in which case invest your resources in that technology.

Construction of a disposable smokehouse

Box A – Prepare the base of the smokehouse

1. Use a cardboard box, one that has been used for computers or printers, etc., for the base of the smokehouse **(Box A)**.
2. Make an opening for inserting the tray holding the sawdust (which will be the furnace).
3. On top of Box A (which connects to the smoking chamber – Box B), make a series of holes to allow the smoke to exit evenly into the second box (Box B), which is basically the smoking chamber.

Photos: ©Bernard Adrien.

Box B – Prepare the smoking chamber

- You can also use a cardboard box, preferably taller and wider, to better accommodate the fish to be smoked (**Box B**) (Step 1).
- On the base of **Box B**, which directly connects to the top of **Box A** that has been pierced, an opening is made so the cardboard on the bottom does not prevent smoke from entering from the furnace in **Box A**. Leave some cardboard on the sides of the opening so **Box B** can be properly fitted to the smokehouse (**Box A**) (Step 2).

- **Box B**, make an opening for inserting the prepared fish (Step 3).
- On top of **Box B,** make another opening, which will act as a chimney for the smoke to exit (Step 4).

On the sides of **Box B**, open holes for the rods on which the fish will be hung, or for inserting the trays (Step 5).

Photos: ©Bernard Adrien.

BEFORE

People used to cut trees from the mangroves and plant new ones; with the wood, they made a fire to smoke fish.

This fish maintained good quality thanks to the heat and the smoke particles, which give smoked fish several unique characteristics, i.e. taste and colour.

NOWADAYS

Smokehouses are used; a flame produces smoke, which enters the smoking chamber and passes onto the surface of the fish.

Do not cut a mangrove; ask your extension officers for advice about correct smoking techniques and necessary equipment and materials.

Types of smokehouses

Preservation of fish by smoking is a combination of the following factors:

- **Salting –** a procedure done before smoking fish.
- **Smoking** – a process ensuring appropriate separation of fish and correct temperatures.
- **Drying** – an activity performed during and at the end of the smoking process.

There are various types of smokehouses

Using simple mud ovens

Drums prepared for that effect

Smokehouses made of blocks

And even more sophisticated equipment

Photos: ©Bernard Adrien.

Types of smoking processes

Smoking processes can be grouped into three main types: hot smoking, cold smoking and liquid smoking (Table 13).

Table 13: Types of smoking processes and their characteristics

Type of smoking process	Smoking temperature	Duration of smoking	Storage time	Preparation of smoked fish for consumption
Hot smoking	70–80 °C, even reaching 110–140 °C in order to cook the meat	It depends on the type of fish (species, thickness, type of cut), use and desired storage time, which in traditional smoking can last from one hour to two days	Fish that is smoked and then dried has a long shelf-life	No need to cook before consumption
Cold smoking	Never rises above 35 °C, with the meat remaining raw	It may take from a few hours to several days depending on the characteristics of the raw material and the desired end product	Must be refrigerated, between 0 °C and 5 °C, for a maximum of 30 days	With the exception of salmon, it is cooked before consumption
Liquid smoking	The fish is put into a liquid obtained from smoke condensation, which improves the sensory characteristics of food, mainly of the meat, and accelerates the smoking process. It is applied by injection and spraying.			

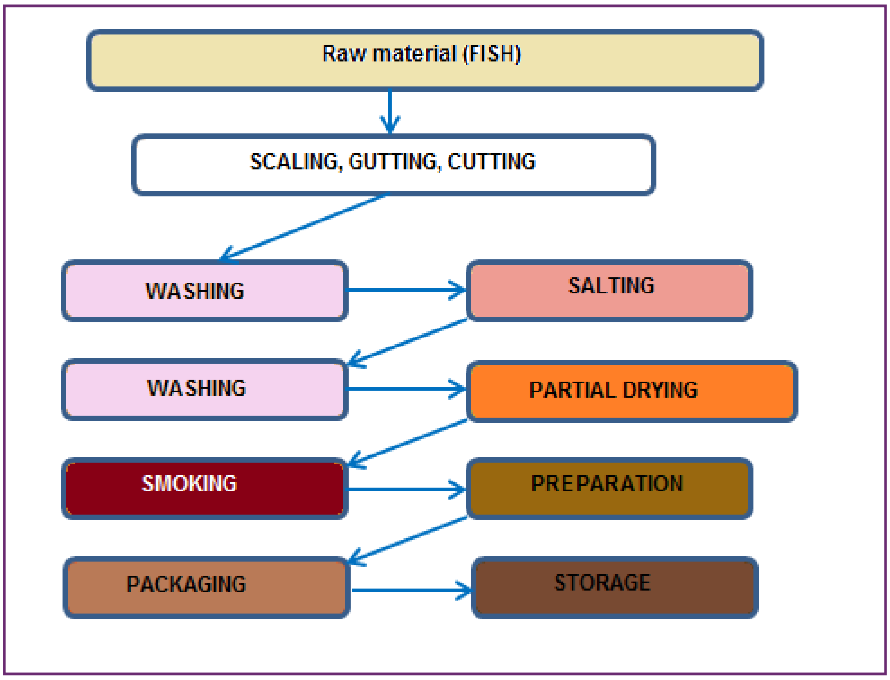
Hot or cold smoking can both be used on the same species of fish, depending on local traditions and characteristics of the consumer market. The quality of smoked products depends primarily on the level of freshness of the fish and also on the type of smoking.

How to carry out the hot smoking process

Various activities, described below, are involved in preparing smoked fish; in order to obtain good quality smoked fish, it is necessary to comply with a number of rules.

A summary of the hot smoking process is provided in the diagram (Table 14). Additionally, the following sections detail some of the steps for hot smoking.

Table 14: Hot smoking process



Primary production (raw material)

In the hot smoking process, it is better to use fat pelagic fish such as sardine, mackerel and horse mackerel, among others. Only use good-quality fresh fish and never smoke spoiled fish. Always keep fish stored in ice (before smoking).

Preparation of fish – gutting

The size of the whole fish or pieces of fish entering the smokehouse is extremely important because if the fish is very thick it will prevent the fish from drying or prevent smoke from penetrating deep into the flesh.

The thickness of the whole fish or the fillets should not be more than 1.5–2 cm.

		
Whole fish…	…or fish fillets…	…or pieces of fish.

Photos: ©Bernard Adrien.

Table 15 summarizes the different types of processing according to the size of fish.

Table 15: Processing of fish intended for smoking, by size

Weight of the fish	Processing
Less than 20 g	None (normally the head, fins and scales are not removed; however, it is good practice to remove the gills or slash the fish)
Between 20 and 100 g	Gutting
More than 100 g	Gutting and scaling
More than 1 000 g (1 kg)	Gutting and filleting

According to the size of the fish fillets, you may be able to prepare a butterfly fillet.

Without removing the head, the fish is opened along its back. The viscera are removed ...

... and a butterfly-type fillet is obtained.

Photos: ©Bernard Adrien.

Preparing the fish – washing

The fish should be well washed in clean, salty or freshwater, or even in brine made with salt and water, so that all the blood and viscera are removed.

©B. Adrien

Salting fish before smoking

Salting of fish before smoking improves the preservation of smoked fish. However, when salt is not available, smoking can still take place; in this case, the smoking process should be longer in order to obtain drier products.

©B. Adrien

There are two techniques for salting fish before smoking:

- Dry salting: The fish is packed with salt for some time, usually two to six hours:
  - In a pile or on a pallet; or
  - In a bowl, with holes in the base, for smaller quantities.
- Salting in brine: The fish is put in saturated brine (with a ratio of one part salt to three parts water; or about 3.5 kg of salt in 10 L of water).

The ratio of fish to brine is 2:1 (2 brine: 1 fish). Submerge small to medium-sized fish in this brine for about 30 to 60 minutes.

Rinsing, draining and partial drying of fish

After any salting, fish should very rapidly be placed in freshwater to remove excess salt from the surface. This will remove part of the salt, preventing formation of salt crystals on the surface of the smoked fish.

The fish are then placed in trays or hung on rods, hooks or nails to drain and are ready for smoking, as shown in the photographs below and in Figure 103 and Figure 104.

Drying the surface of fish eliminates a considerable amount of water, one of the elements that facilitates growth of the bacteria responsible for altering fish, thus retaining the quality of fish for a longer period of time.

Whole fish hanging by the head on wooden sticks

Photos: ©Bernard Adrien.

Figure 103: Butterfly type of fillet on one stick

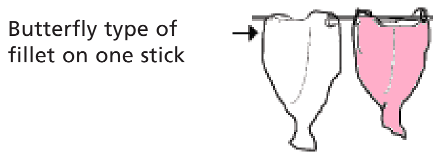
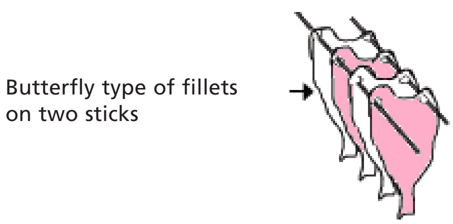


Figure 104: Butterfly type of fillets on two sticks




Fillets on trays before smoking.

Photos: ©Bernard Adrien.

Smoking

When the preparation and partial drying period are complete, the fish are taken to the smoking chamber.

Smoking time depends on environmental conditions and the type of fish; it can take half an hour for small or medium-sized whole fish or up to a few days for larger fish. Less time is needed for large fish cut into fillets, slices or chunks because the smoke penetration and drying are faster.

During smoking, the smoke carries various chemical products that settle on the surface of the fish and gives them a specific colour and flavour. These particles of smoke also act against bacteria, helping to preserve the fish.

The most important element to obtaining the characteristics of smoked fish is not only the adhesion of smoke particles to the surface of the fish but also the absorption of the steam generated by the surface water on the fish.


To produce smoke, use cashew nut tree wood, palm fruit, sawdust, coconut shells, wood chips from sawmills and other similar products.

Do not use painted, wet or mouldy wood or cardboard.

Photos: ©Bernard Adrien.

Hot smoking is carried out in three phases

FIRST PHASE

- **Heat:** The smokehouse should already be prepared (heat source should be lit); the temperature inside the chamber reaches about 100 °C.
- **Preparing the fish:** Fish must be distributed evenly inside the smoking chamber.
- **Temperature:** Reduce the temperature to approximately 70 °C.
- **Duration of smoking:** The time depends on the size of the fish (30 minutes to 4 hours).

SECOND PHASE

Smoke production

To produce smoke, you may use any available timber, provided it is not hard and resinous.

At the end of the first phase, the heat is reduced by pouring sawdust on the embers; the doors are closed and the smokehouse begins to produce smoke.

In the second phase, the wood should smoulder.

To speed up burning, a 2 cm layer of sawdust can be soaked with alcohol.

Uniform and compressed sawdust should be used and not very large pieces of wood.

After 6 hours of smoking, the product already has a good smoked flavour and there has been sufficient smoke impregnation for its conservation.

Arranging the fish

Positioning the fish should also be controlled to avoid burning them; and the position of the fish should be periodically changed, i.e. the fish lower down, closer to the fire, should be moved up and those on top should be lowered. Using mobile shelves in smokehouses, for example, facilitates this rotation

Duration of smoking – second phase

The duration of this smoking phase is about 8 hours and the temperature is between 80° and 100 °C.

THIRD PHASE

The third phase begins when the fish meat is red and well dried.

The smokehouse must then be cleaned and be given a new layer of fine sawdust.

The fish should be exposed to the smoke for long enough to give the product the desired colour, i.e. the smoke sediment burns progressively and at a high temperature thereby attaching to the fish surface.

This stage can take from 2 to 16 hours.

After smoking, in warm humid climates, it is necessary to dry the smoked fish.

At the end of the process, cool the fish until completely cold (about 1 hour is sufficient). After this, the fish should be packed.

Packing and storage

Packaging for smoked fish should be aerated, preferably in bags made of rope. Raffia bags can also be used. Plastic bags should never be used.

Photos: ©Bernard Adrien.

Commercialization of smoked fish

In markets, many forms of smoked fish are available, including whole and slashed and butterfly fish fillets, as shown in the following photographs.

The above-mentioned ways of processing/selling fish parts or of displaying them in the market provide the best value (added value) and lead to more sales.

Whole and slashed

Fish heads

Butterfly fish fillets

Pieces of fish

Photos: ©Bernard Adrien.

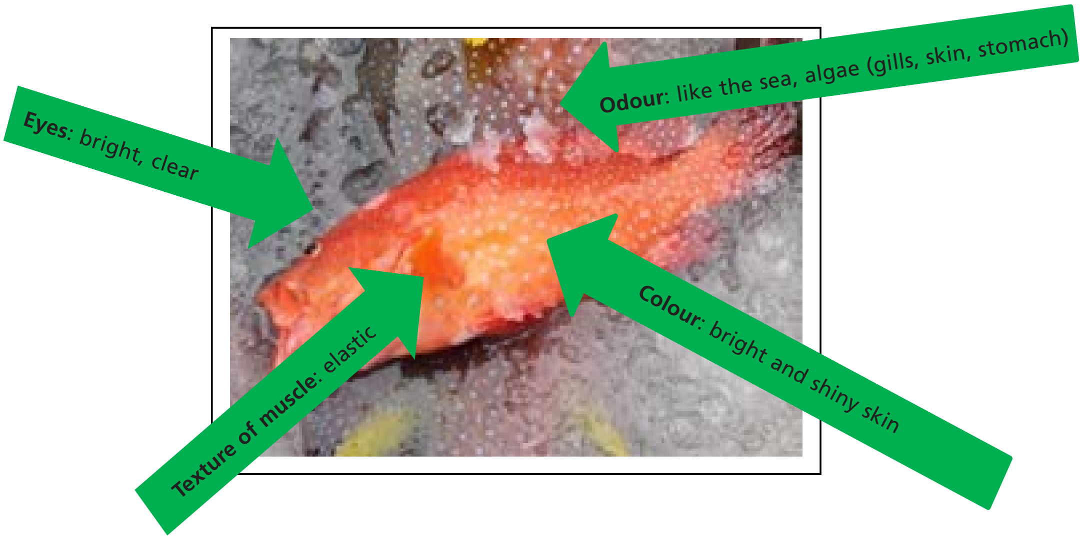
Chilling fish

The fish quality starts to alter soon after capture.

The only way to limit the rapid deterioration of fish is to immediately lower their temperature using ice.

Fish quality: freshness and deterioration

Characteristics of a fresh fish



	
During *rigor mortis*	After *rigor mortis*

Photos: ©Bernard Adrien.

The alteration process

The quality of fish changes immediately after being caught (the fish deteriorates/rots). When fish die, the process of biochemical, physical, chemical, microbial and sensory change begins.

Initially, fish undergo the process of "autolysis" or self-digestion (action of the enzymes present in the intestines; Figure 105); next is the phase where the enzymes of microorganisms are active, as are any actual microorganisms that may have contaminated the fish (activity of bacteria; Figure 106).

Figure 105: The fish gut

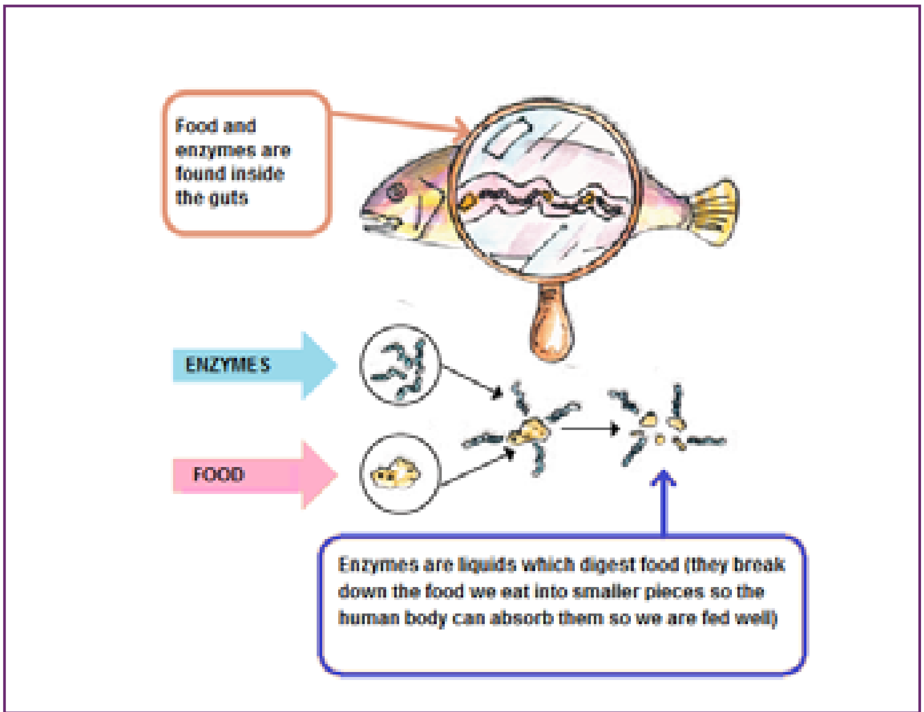
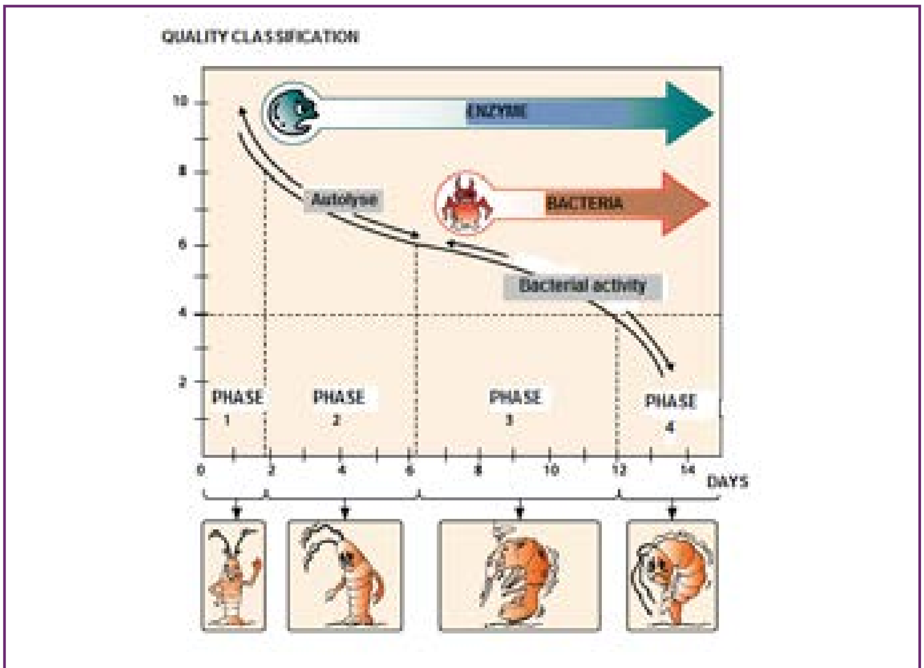
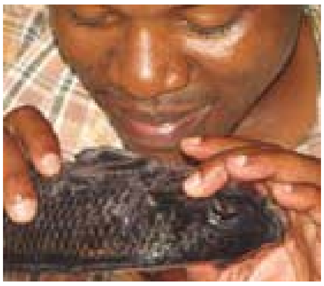


Figure 106: Quality of fish over time



Signs of healthy fish

	
Good smell …	firm texture …
	
red gills …	and good taste

Photos: ©Bernard Adrien.

Factors that cause changes to fish

Under certain circumstances, bacteria multiply very quickly and make fish to become rotten.

Fish kept under the sun will stay fresh during one day maximum.

Fish chilled with ice will keep its good quality for 15 days (Figure 107).

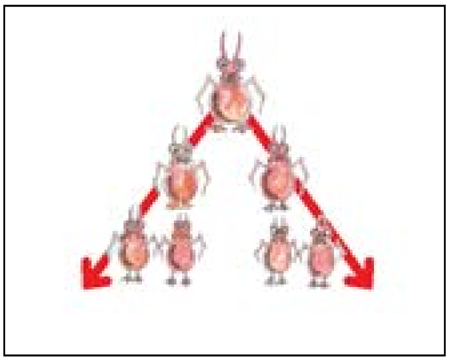
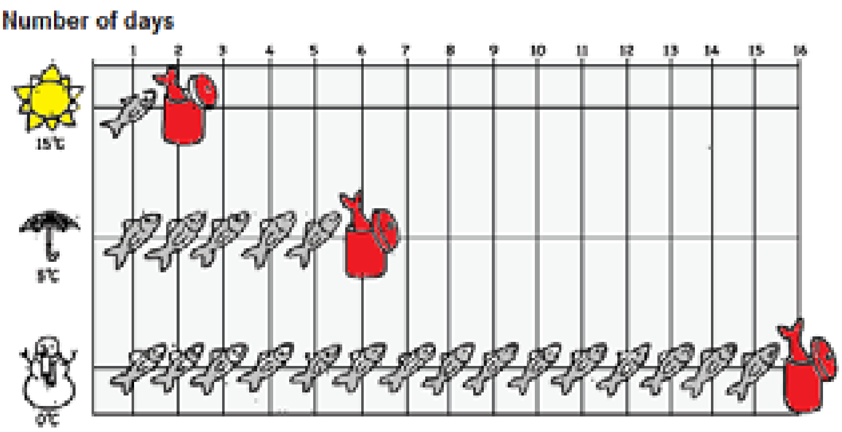
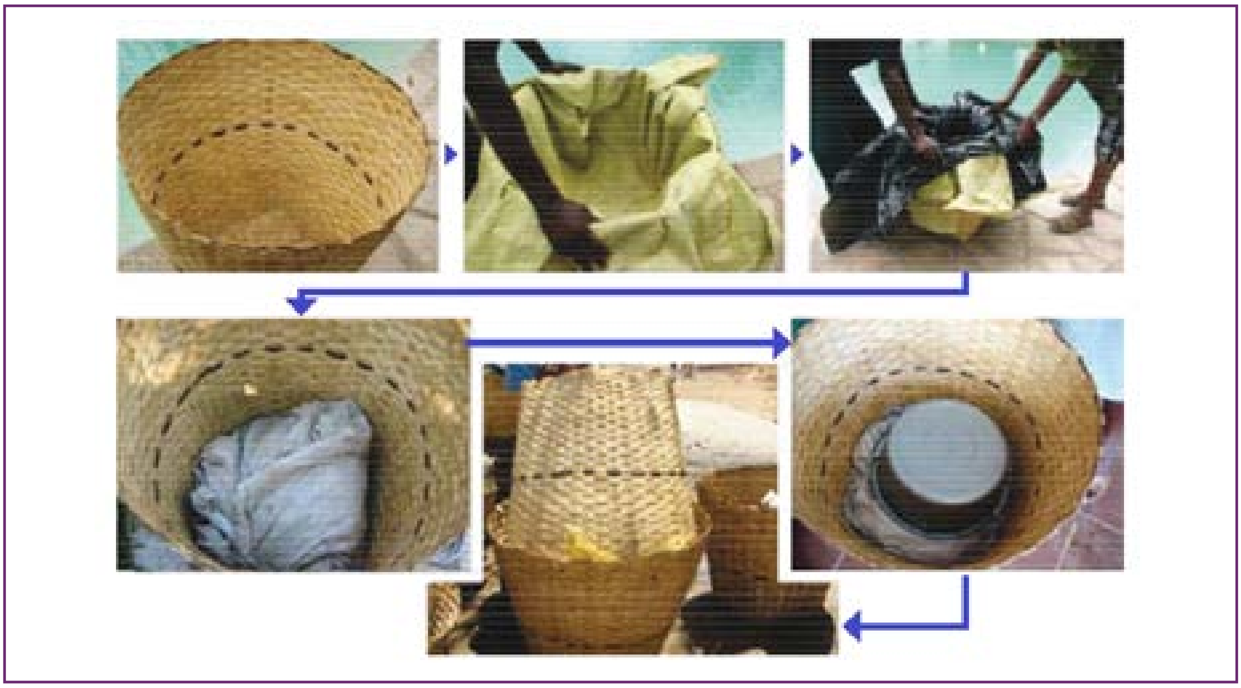


Figure 107: Temperature and fish quality



How to keep fish in a basket made locally

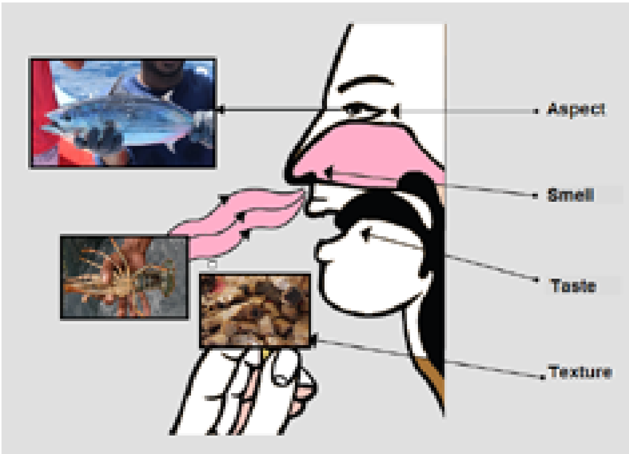


Photos: ©Bernard Adrien.

PRACTICAL EXERCISE:

Let us preserve our fish species in a straw basket with plastic and ice. Every day, in the morning and in the afternoon, we control the quality of fish by smelling and feeling them. We do not need a laboratory; we use our senses to evaluate the sensory quality of the fish (Figure 108). Then we observe and note how many days the fish remain of good quality (fresh) until they rot.

Figure 108: Sensory evaluation of fish quality

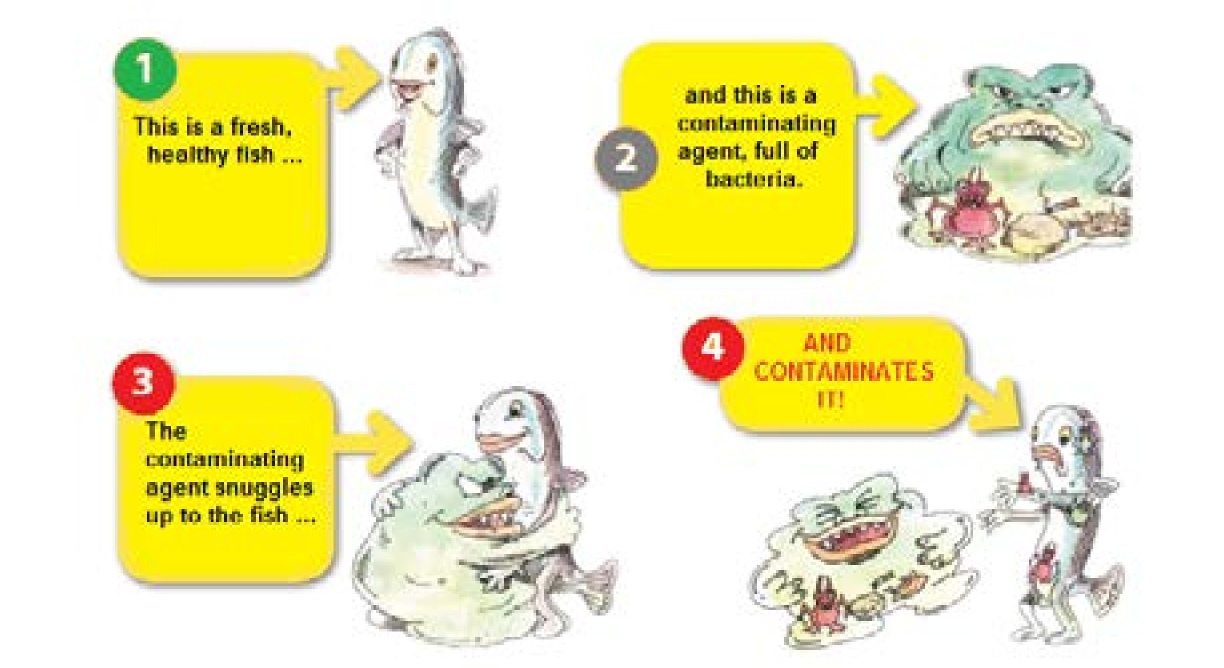


Some bacteria live in filth and easily contaminate fish (Figure 109).

Therefore, Good Hygiene Practices must be implemented.

HYGIENE – ALWAYS WASH THE BOAT, BOXES, HANDS AND FISH!

Figure 109: Note how bacteria can contaminate fish directly



Fish can be contaminated by chance.

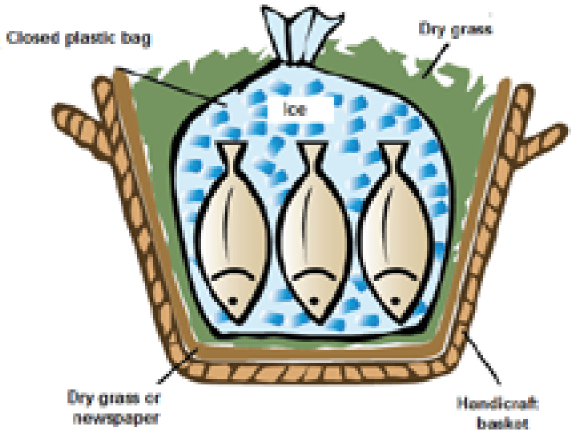
This is called **cross-contamination**.

		
At a market stall, this fishmonger is processing fish with a dirty knife loaded with bacteria.	Her neighbour's fish is clean and free from bacteria; she borrows the dirty knife ...	...and processes her fish with the dirty and contaminated knife; her fish ends up dirty and contaminated too. This is called "cross-contamination".

What can be done to avoid fish deteriorating quickly?

Consider the following

Cover the fish with a jute sack (burlap) dampened with seawater, or even old and clean clothes ...



…or even in a plastic bag filled with water and with the fish placed inside a straw basket…

…or in old refrigerators that are not rusty.

Boats come in all shapes and sizes, but on all of them fish must be protected from the sun's rays by covering the fish or mixing the fish with ice.

Photos: ©Bernard Adrien.

Some helpful practical tips to keep fish fresh

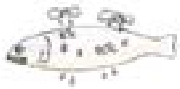
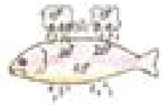
	
Do not leave fish directly exposed to the sun's rays.	Fish must always be kept in the shade.
	
Local materials can be used. Eventually, a tarpaulin can cover the place where fish are handled; protect the fish by hanging them under a thatched roof.	Or even just shade the fish with an umbrella.

Do not clean and gut unloaded fish on the beach or under direct sunlight. You should not prepare and pack the fish with ice on the beach.

Photos: ©Bernard Adrien.

How ice keeps fish fresh at the right temperature?

Ice can absorb heat from fish. By absorbing heat, the ice melts and so the fish become cooler; simultaneously, the surface of the fish is washed by the water from the melted ice.

			
1. Fish temperature of 25 °C.	2. The ice (at 0 °C) surrounds the fish and absorbs the fish's temperature; the surface (skin) drops from 25 °C to 20 °C and the inside temperature drops from 25 °C to 23 °C.	3. The ice continues to melt as it absorbs heat from the inside of the fish. The surface of the fish is at 5 °C and the inside at 10 °C.	4. Ice stops melting when the fish surface reaches the temperature of 0 °C, i.e. the temperature of the ice.

What are the types (shapes) of ice?

Ice is water that passes from a liquid to a solid state. Ice comes in different forms, such as flakes, blocks and bars.

	
Flake ice (small pieces of ice)	Ice bars

Photos: ©Bernard Adrien.

Which is the best ice?

	
All types of ice are proper to use; however, flake ice cools fish down more rapidly as it surrounds the product.	Ice in block form, not crushed, cools only part of the fish in this bowl.

Photos: ©Bernard Adrien.

How to break an ice block into smaller pieces?

		
Ice should be placed into a clean bag, which is then tied. The ice is crushed with a stick (do not hit the ice directly, but instead hit it through the bag); never put the ice directly on the ground.		The ice is ready when it is in small pieces.

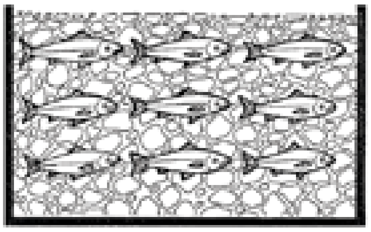
Photos: ©Bernard Adrien.

How to store fish with ice?

		
First, put one layer of ice on the bottom of the cool box. Alternate one layer of fish with one layer of ice.		The first and the last layers should be ice, in order to maintain good fish quality.

Photos: ©Bernard Adrien.

Good distribution of ice around the fish is important to improve the contact between ice and fish, so the heat is absorbed more quickly from the fish, which then cools down.

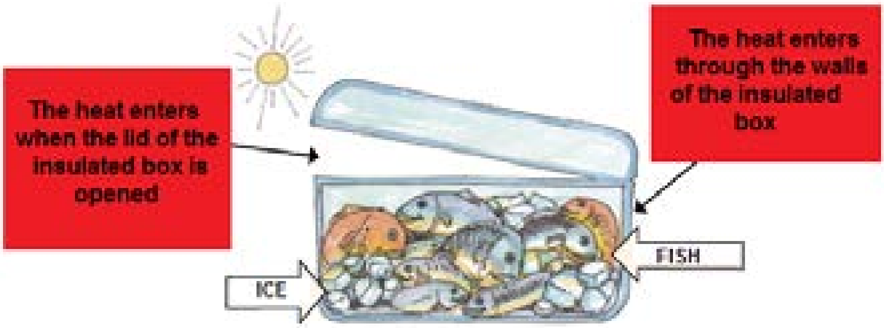


Where to store fish with ice?

	
In a plastic or insulated box … (Figure 110)	…in an open box or on a tray.

Photos: ©Bernard Adrien.

Figure 110: Use of an insulated box to keep fish fresh



To avoid fish coming into direct contact with ice (to better preserve the mucous surface of fish skin), ice can be kept off the fish using a clean plastic sheet, as shown in the following photographs.

	
Place ice on a clean tray and …	…set a sheet of plastic on top of the ice.

	
Place the gutted fish on top of the plastic sheet, then place a new plastic sheet on top, then ice, plastic, fish, etc.	Alternate the fish, head to tail, with the ventral side down.

Photos: ©Bernard Adrien.

To sell fish at a higher price, process it in order to better please consumers (increase the value of the fish). An example is removing the operculum to reveal the fresh gills (see the photographs).

	
Instead of selling small pelagic fish (e.g. mullet, sardine, horse mackerel) stacked on top of each other …	…remove the operculum to show how fresh the gills are and make a better sale!

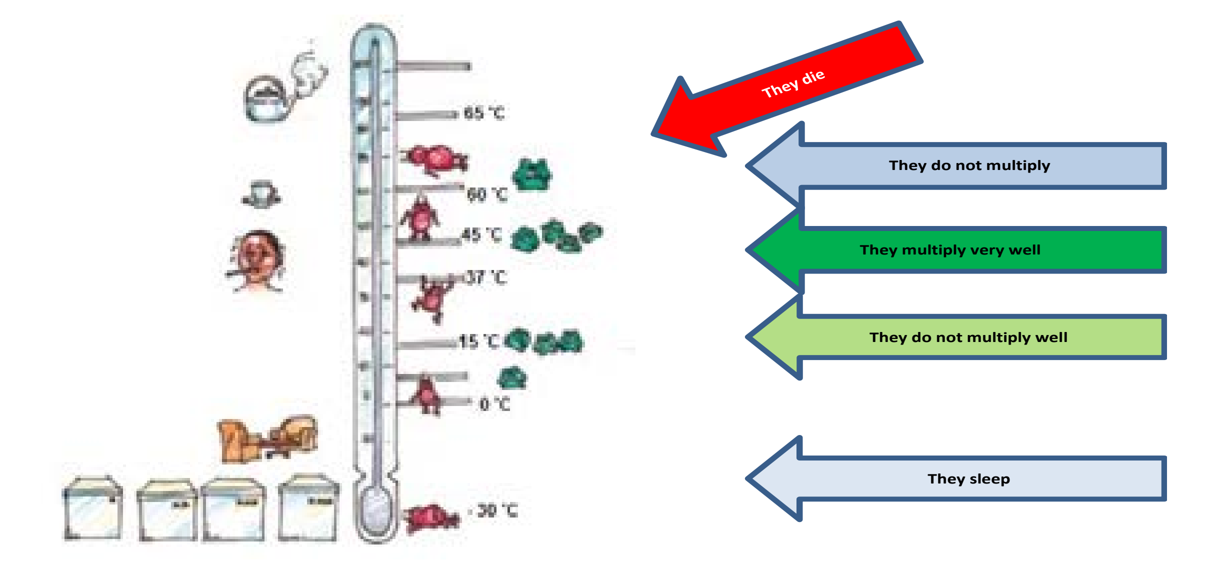
Photos: ©Bernard Adrien.

FREEZING FISH

- Fish left in the **sun** will spoil in **one day**.
- Fish kept **under ice** will remain fresh up to **15 days**.
- **Frozen** fish can be stored for **up to one year**.
- The cold "puts to sleep" the bacteria which cause fish to decay.

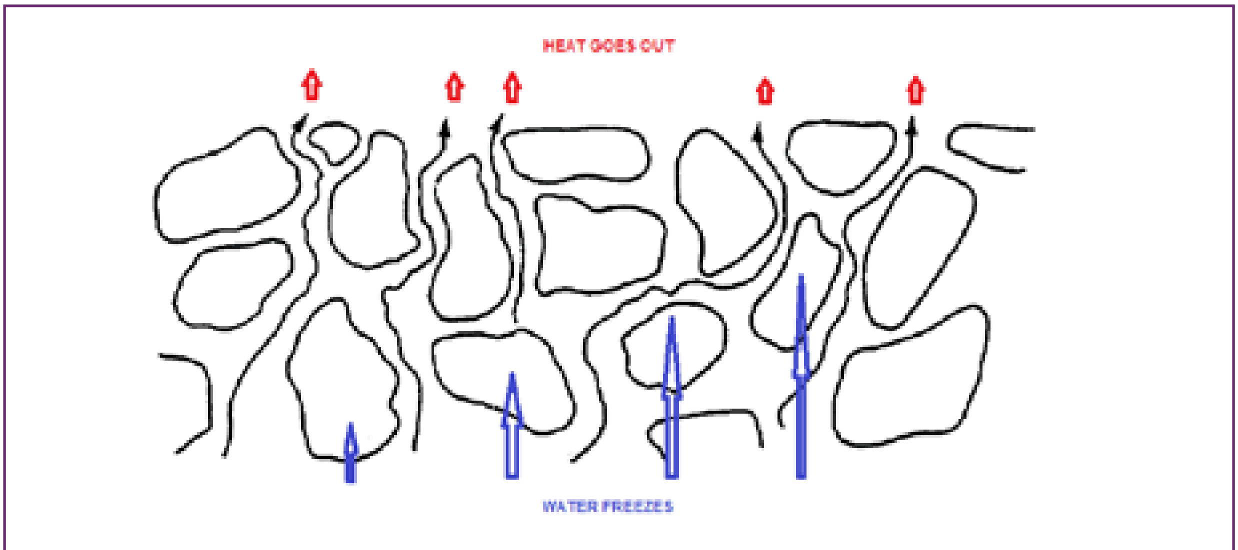
In Figure 111, observe the temperatures marked on the thermometer to see what happens to the bacteria.

Figure 111: Bacteria and temperature



Freezing is the process of lowering the temperature (cooling) of all parts of a fish to a temperature below the freezing point of its water content, i.e. between 0 °C and -1 °C (Figure 112). This water content changes from a liquid to a solid state in the form of microscopic ice crystals.

Figure 112: How ice removes heat



Module 4 EXTRA READING AND PRACTICES: POST-HARVEST, PROCESSING AND VALUE ADDITION

The freezing process is considered complete only when the internal temperature of fish in its thermal centre is equal to or below -18 °C.

		
Only freeze good quality (fresh) fish with red gills …	…and not brown gills, as this shows they are rotten…	…and with bright and bulging eyes.

VERY IMPORTANT:

	
1. Always freeze fish that is fresh.	2. Freeze live crab …
	
3. … or live prawns.	4. Never freeze spoiled prawns.

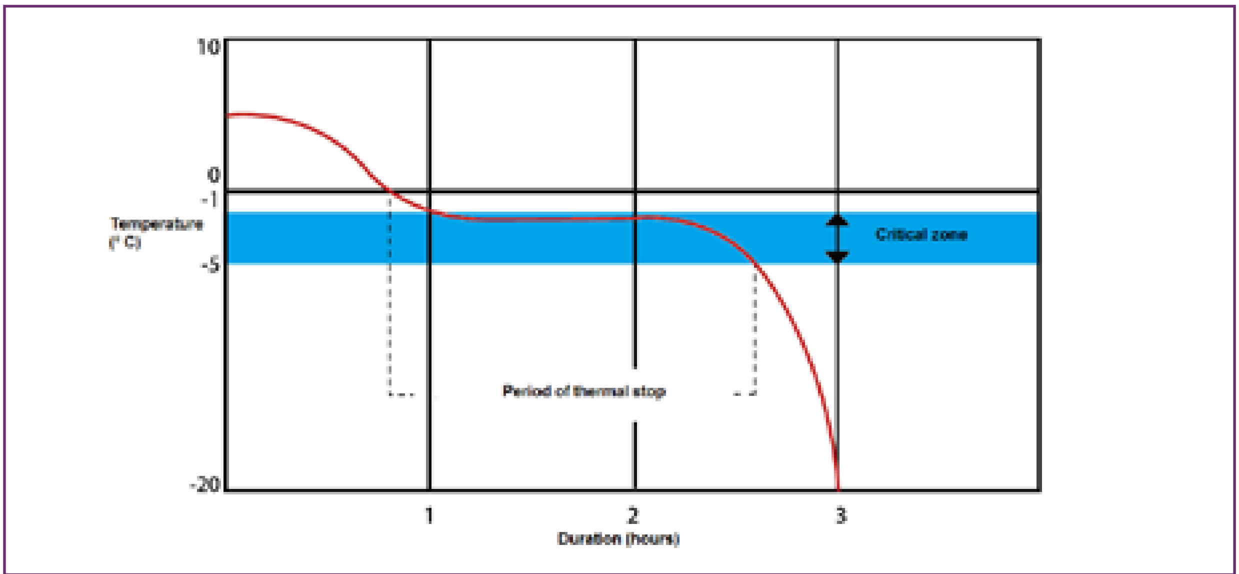
Photos: ©Bernard Adrien.

In conclusion, fish should be frozen as soon as possible after capture. Fish that has been previously kept in ice can be frozen.

There are three phases in freezing, depending on the time and temperature at which it takes place:

- **First phase:** Starts when the fish temperature decreases rapidly from the initial room temperature of, for example, 25 °C to about 1°C.
- **Second phase:** This is the most important phase where the temperature ranges from 0 °C to -5 °C because ice crystals are formed (water solidifies); it is called the critical phase (Figure 113).
- **Third phase:** At this stage, the cooling of the fish is very fast until it reaches the temperature at which the freezing process is considered complete, i.e. around -18 °C.

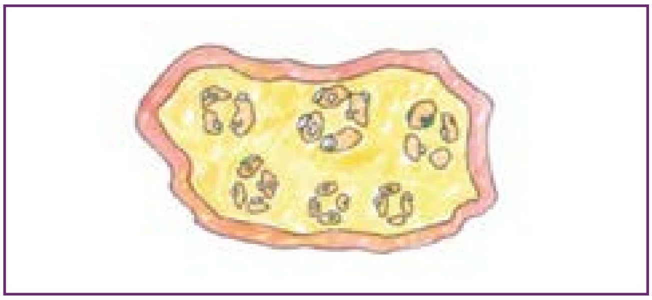
Figure 113: Thermal drop and critical zone



Fast freezing

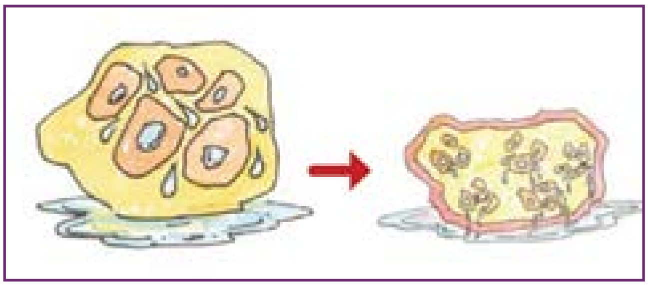
If freezing happens quickly, crystals are plentiful, very small and rounded, so they do not damage the cells (they do not tear the cell walls – meaning water does not exit but remains inside the cells) (Figure 114). Therefore, the substances that give fish nutritional value and taste are not removed from the cells.

Figure 114: Crystals in the fast freezing process

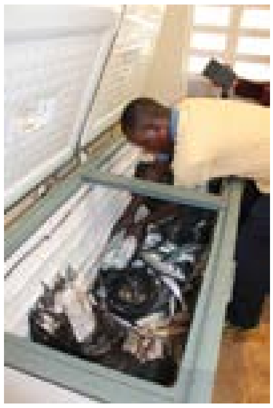


When fish thaw, little fluid is lost because the intact cell walls retain the water resulting from the melting ice crystals (Figure 115).

Figure 115: Crystals in the slow freezing process



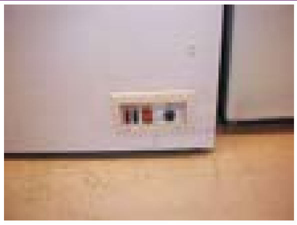
Slow freezing can happen when freezing seafood in unsuitable freezers and household refrigerators, which lack the capacity for this activity.



Photos: ©Bernard Adrien.

The cooling capacity of home refrigerators is indicated with one to three stars. Refrigerators with capacity for correct freezing have four stars: three small stars and one big star. Moreover, the correct place to place each type of product is indicated on each refrigerator. Fish should be frozen in the places indicated in the home appliances.

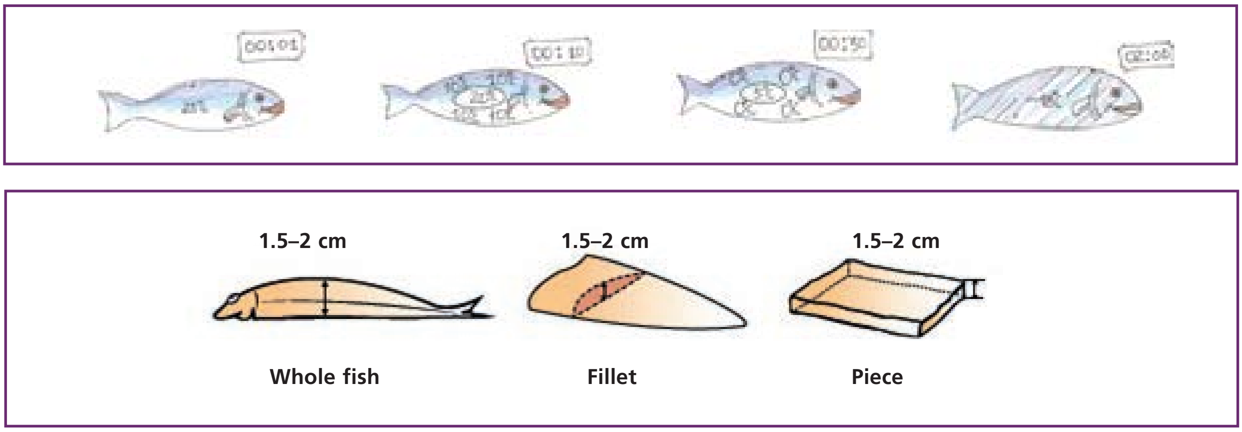
In the case of this home freezer in the photograph, the yellow light must be turned on in order to increase power and better freeze fish.



Photos: ©Bernard Adrien.

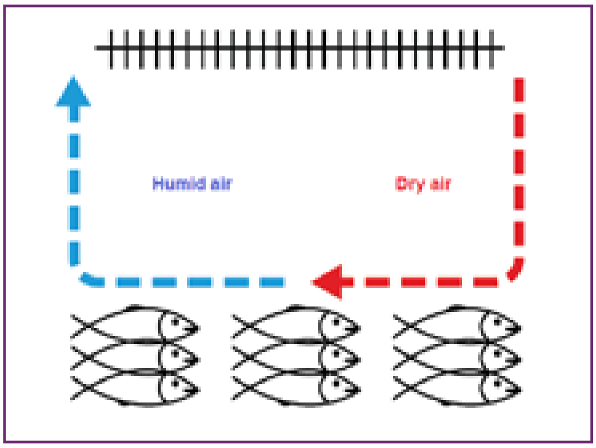
The freezing time depends on many factors, such as the shape and thickness of the seafood (Figure 116). A very thick fish takes longer to freeze than a small thick fish because the heat of the interior takes longer to reach the surface of the fish.

Figure 116: Freezing time



Just after freezing, fish must be removed from the freezer and stored in a cold room.

Figure 117: Air circulation in freezer room



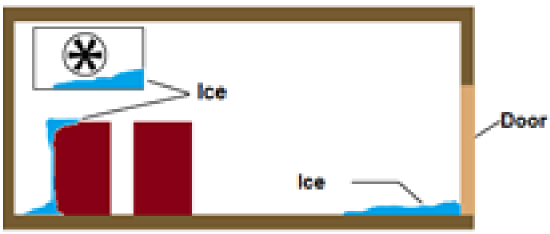
Freezer rooms have good ventilation (Figure 117). If fish remain in the freezer room after they have been frozen, the fish will become severely dehydrated, leading to significant weight loss. Dehydration, however, can be avoided if fish are protected by packaging and/or if fish undergo a process called glazing, which is applying a layer of ice on the surface of frozen fish (Figure 118).

Figure 118: Danger of dehydration

The temperature of these rooms (cold and freezer) must be between at least -20 °C and -35 °C to ensure the temperature of the fish is always below -18 °C.

Rules for storing seafood products in preservation rooms:

1. Do not impede adequate air circulation along the walls of the room and do not impede air reaching the evaporator.

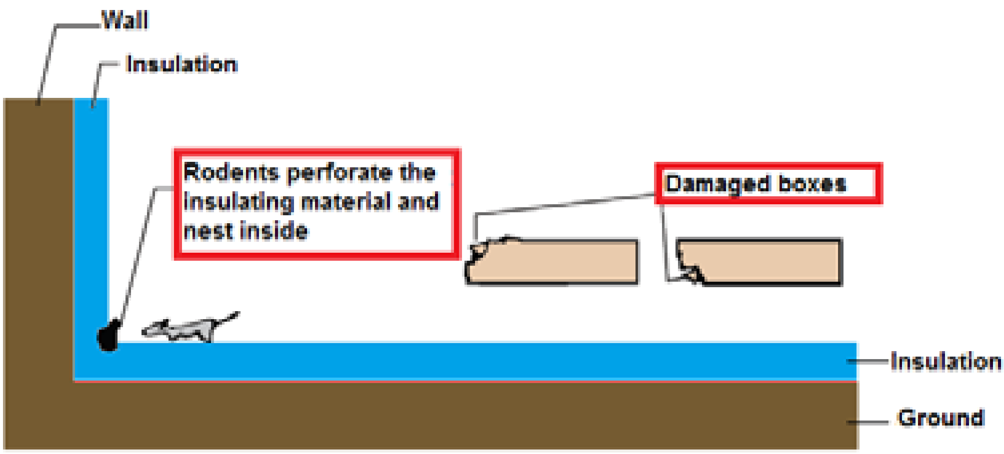


2. Avoid opening the doors frequently, as this will cause temperature oscillations and partial thawing of frozen fish.

3. Products should be stored on pallets, if possible.


©Bernard Adrien

4. In case of containerized cold rooms, fish must be placed in clean areas.
5. Another important control is the application of good hygienic practices: even rats can survive inside the wall insulation in a preservation room.




©Bernard Adrien

All chambers are closed rooms prepared to absorb heat from fish that are to be cooled and interconnected by pipes, filled with a coolant, also called a refrigerant.

There are various types of freezers

	
The freezing tunnel is best suited for fish of different sizes and irregular shapes and whole fish.	The plate freezer is only suitable for freezing products in block form (e.g. prawn boxes).

Photos: ©Bernard Adrien.

		
All rooms have a thermometer to control the temperature.	Products must be packed in wax cardboard or corrugated cardboard boxes with plastic.	

Photos: ©Bernard Adrien.

Commercialization of frozen fish

One way to increase the sale value of frozen fish is, for example, to cut it into slices and pack it instead of selling it whole.

Sanitary conditions in fish markets

SOME BASIC RULES

- Implement good hygiene and handling practices to maintain the quality of the products all along the value chain, from the catch to the consumer.
- Always transport fish mixed with ice, and if possible, kept in a cool box.
- A fish market should have a reliable water supply (tap water, if possible).
- One of the most important aspects in a fish market or shop is the processing and display area (sale) to customers.
- Separate fish upon purchase, i.e. fish to be sold fresh and fish to be salted or dried.
- Hygiene (of fish, persons, facilities and equipment) in markets is crucial.

What is a fish market?

A fish market is a place where sellers and buyers (or consumers) meet to exchange products or goods. For example, sellers sell fish in exchange for money they receive from buyers or consumers; sellers, if they wish, can exchange their fish for a spare part or petrol for a fishing boat, or for flour and clothing, among other things.

- The seller had to catch or buy fish, wash the fish and keep the fish in an insulated box with ice.
- The seller has to calculate the selling price of the fish, including all expenses ("y"), plus the amount he/she wants to gain (profit).
- If the seller wants to obtain a 20 percent profit, his/her selling price will be: y + (y × 20 percent).

In summary, commercialization of fish may encounter several problems, such as the two noted here:

- On the supply side: Irregular supply – the seller is not able to find fish to sell every day.
- On the demand side: Consumers have allergies or an aversion to fish – certain substances in fish, such as in horse mackerel and tuna, can cause allergies.

Quality and marketing of fish

A product with good sanitary quality does not sicken consumers, unless they are allergic to the item.

However, the commercial quality of fish can be associated with the species, size, packaging, added value, and so on. The commercial quality can also be associated with cases of fraud (e.g. altered names of species so as to obtain higher prices).

Quality is not a matter of luck or lack of luck. The quality is a result; it is uniform and must be consistent with a pre-established standard or norm.

With regard to "quality is meeting requirements", a fish fillet without bones and scales does not have more quality than a whole fish. If the consumer wants to prepare a breaded fish fillet, then a fish fillet, deboned and descaled, of the right weight and in plastic packaging will meet the required quality. If the consumer wants to cook a whole fish in the oven, then a whole fish, with bones and descaled, of the right weight and in plastic packaging will meet the required quality.

Summarizing, fish is made up of protein – to build the body Fish muscle is succulent because it does not have much collagen, unlike beef. Consequently, eating fish enables good, speedy digestion.	**Fat – gives energy to the body** The darker fillets of horse mackerel and tuna have a higher fat content.	**Minerals and vitamins – defend the body against disease**
		

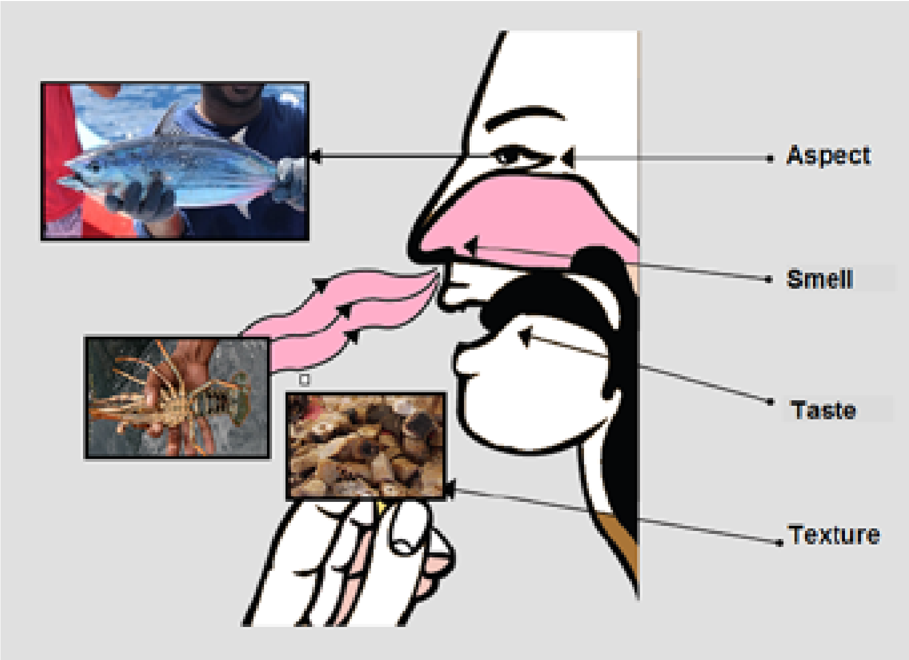
Photos: ©Bernard Adrien.

It is important to take care of the quality of the fish...

	
... from capture ...	...until it reaches the consumer.

Photos: ©Bernard Adrien.

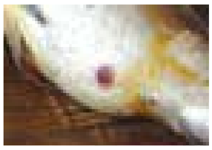
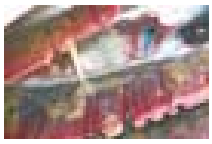
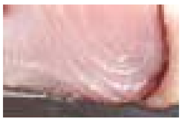
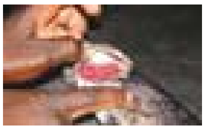
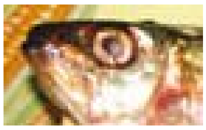
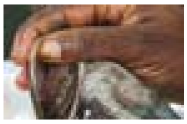
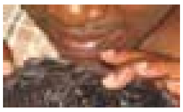
When choosing fresh fish, the consumer uses his/her own senses to observe characteristics revealing the sensory quality of fresh fish and to check on its freshness (good quality).



This method is called "sensory evaluation."

Table 16 shows how to carry out a sensory evaluation.

Table 16: Details on fish sensory evaluation

Fresh fish		Spoiled fish	
Skin is shiny, moist, brightly coloured, uncut.		Pale and dull skin.	
No mucus is present. When mucus is a characteristic of the species, it should be aqueous.		Mucus is present, or it is thick.	
Scales joined together, firmly stuck to the skin; they are translucent and shiny.		Scales loosen up easily, are opaque and dull.	
Flesh is firm, elastic and attached to the bones.		Milky flesh, yellowish or dark, with poor adhesion to the bones.	
Operculum (gill membrane lining) is rigid; it should resist its opening.		Operculum does not resist its opening and the zone is streaked with blood.	
Pink or red gills, with moisture and shiny. Absence or discrete presence of translucent mucus.		Pale gills and/or with presence of a thick and strong mucus.	
Prominent eyes, transparent and shiny.		Sunken eyes, opaque and dull.	
Mild or no smell.		Intense and unpleasant smell, which is a sign of alteration.	
Well-defined internal organs, with mild smell.		Stained and liquefied internal organs, with acid smell.	

Source: National Institute for Fish Inspection (INIP), Mozambique.

One of the most widely used tests to evaluate if fish is fresh is applying finger pressure on the flesh. The fish flesh should be firm and elastic; if the flesh takes long or does not return to its original position, the fish is already in some state of spoilage.

In regard to other seafood, Table 17 gives an overview of the quality requirements to be checked at the time of purchase.

Table 17: Summary of sensory evaluation of some seafood

Lobster and prawn	Crab	Bivalve molluscs (oysters, mussels)	Cephalopod molluscs (squid and octopus)
General appearance is shiny, with moisture.	When exposed for sale: alive and vigorous.	When exposed for sale: alive, with their valves closed, offering resistance to opening; if open, quick reaction to the slightest stimuli by closing the valves (shells).	Important: octopus and squid must not show red or purple colour, especially in the inner part of the tentacles.
Body naturally curved, rigid; resistant and firm joints.	Presents normal and mild smell.	Liquid present within the shells, clear and colourless.	Lively and prominent eyes.
Carapace and head firmly fitting to the body.	Overall shiny look, with moisture.	Pleasant and strong smell.	Consistent and elastic flesh.
Colouring as per the species, no black spot (melanosis) or orange spot on the shell, which is a characteristic of lobster and prawn spoiling.	Full and firm appendages and legs.	Flesh with moisture, adherent to the shell, spongy, light grey colour (oyster) and yellowish (mussels).	Absence of any pigmentation, unusual to the species.
Eyes are alive and prominent.	Shell adhering closely to the body.		Normal and pleasant smell.
Normal and mild smell.	Colouration as per the species, without any strange pigmentation.		Octopus is greyish and slightly pink.
	Eyes are alive and prominent.		Smooth and moist skin.

Source: Pescado fresco – Cartilha_do_Pescado_meg.pmd. Brazil. Abras, 2007.

Table 18 presents a summary of the quality requirements to be checked when purchasing frozen and salted dried fish.

Table 18: Summary of sensory evaluation of frozen and salted dried fish

Frozen fish	Salted dried fish
The product must be stored at the temperature recommended by the manufacturer on the packaging.	The product should be stored in a clean place, protected from dust and insects.
Products should not be soft or with liquid inside, which would be a sign that they underwent a process of defrosting.	There should not be any mould, fly eggs or larvae, dark or red spots, superficial loaminess, softening or unpleasant odour, which would indicate that the product is not good for consumption.
The presence of ice or a lot of water indicates that the refrigerator or freezer was turned off or that their temperature decreased temporarily.	When the fish is sold with packaging, the label must state the name, expiration date, origin and bear the inspection seal.

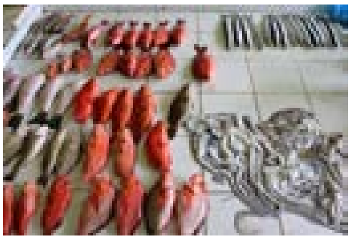
Source: Pescado fresco – Cartilha_do_Pescado_meg.pmd. Brazil. Abras, 2007.

The facilities in a simple market are important

An ideal stall is made of a cement structure ...

…where stainless steel trays can be removed to be washed and all the coating is made of stainless steel…

…with shelf stands for the scales.



The facilities must be easy to clean and disinfect.

Fish should not get contaminated through spoiled wood utensils…

Proper maintenance of the stalls is required to prevent their deterioration.

As a minimum, a plastic or a jute bag should be placed on top of the stall ...

… to prevent direct contact of the seafood with wood. Note: Wood is not easy to wash.

Improved facilities, with cement stalls and running water system.

Photos: ©Bernard Adrien.

Imagery of best practice measures regarding transport of fish to the market

1. The hygiene conditions of the vehicle that transports the fish and the fish itself: Fish is protected from the sun, dust, etc., during transportation, and the smell does not offend the passengers.

2. Frozen fish, when transported on a bicycle or a motorcycle, must reach the destination quickly so the fish do not thaw, or they must be transported in an insulated box.

3. Salted dried seafood may sometimes reach its destination by individual means of transport; however, it must be protected from rain, dust, etc., during the trip.

4. The tools used in the transport and packaging of the product, such as cool boxes where fish is mixed with ice and protected from sunlight, should be clean and well maintained.

Photos: ©Bernard Adrien.

		 
5. The market should implement a sampling system for sensory analysis and evaluation of the temperature of fish received. This procedure must be performed by properly trained staff.	6. Market vendors should also know that they must put fish offal into closed trash bins which are in a clean environment and not in overfilled boxes with rubbish falling on the ground.	

Note:
Availability of clean water – if possible, tap water – is an absolute must in a fish market. Availability of ice, freezers and even cold rooms are crucial for storage of fresh fish; warehouses for salted and dried fish should be well aerated and have proper pest control.

One of the most important steps for selling seafood in fish markets and shops is setting up the processing and display area (point of sale) for customers.

Processing, salting for example, is carried out in order to present a more attractive product to consumers. Normally, markets do not have suitable hygiene conditions for preparing salted fish.

The photos below show various ways to store fish products, as well as some attractive ways to display them.

		
The correct action would be to store this fish mixed with ice in a refrigerated room.	Some markets use freezers, which need to be cleaned and comply with the rules of use.	Other markets have suitable cooler and refrigerated rooms.

Photos: ©Bernard Adrien.

	
Fish pieces in a handcrafted basket and a plastic bowl...	… or presented in an attractive way on a tray of clean wood.
	
Octopus and squid presented in different ways.	

Note:
The fish should be well mixed with ice.

		
Prawns, lobsters and shellfish in various containers.		

Photos: ©Bernard Adrien.

Note:
Always comply with hygiene rules and always use ice.

In more sophisticated markets, fish is sold packed in ice and presented in display cases. In some fish retail shops, these display cases are very attractive and efficient for the sale of fish.

Photos: ©Bernard Adrien.

> **Note:**
> Always use ice.

There are various ways to display salted dried fish for selling

In stalls, using improvised measurement tools. Glass is not as good, as it may break on top of the fish.

A can should not be rusty, as rust will infect the fish.

Fish can also be sold on tarpaulins on the ground ...

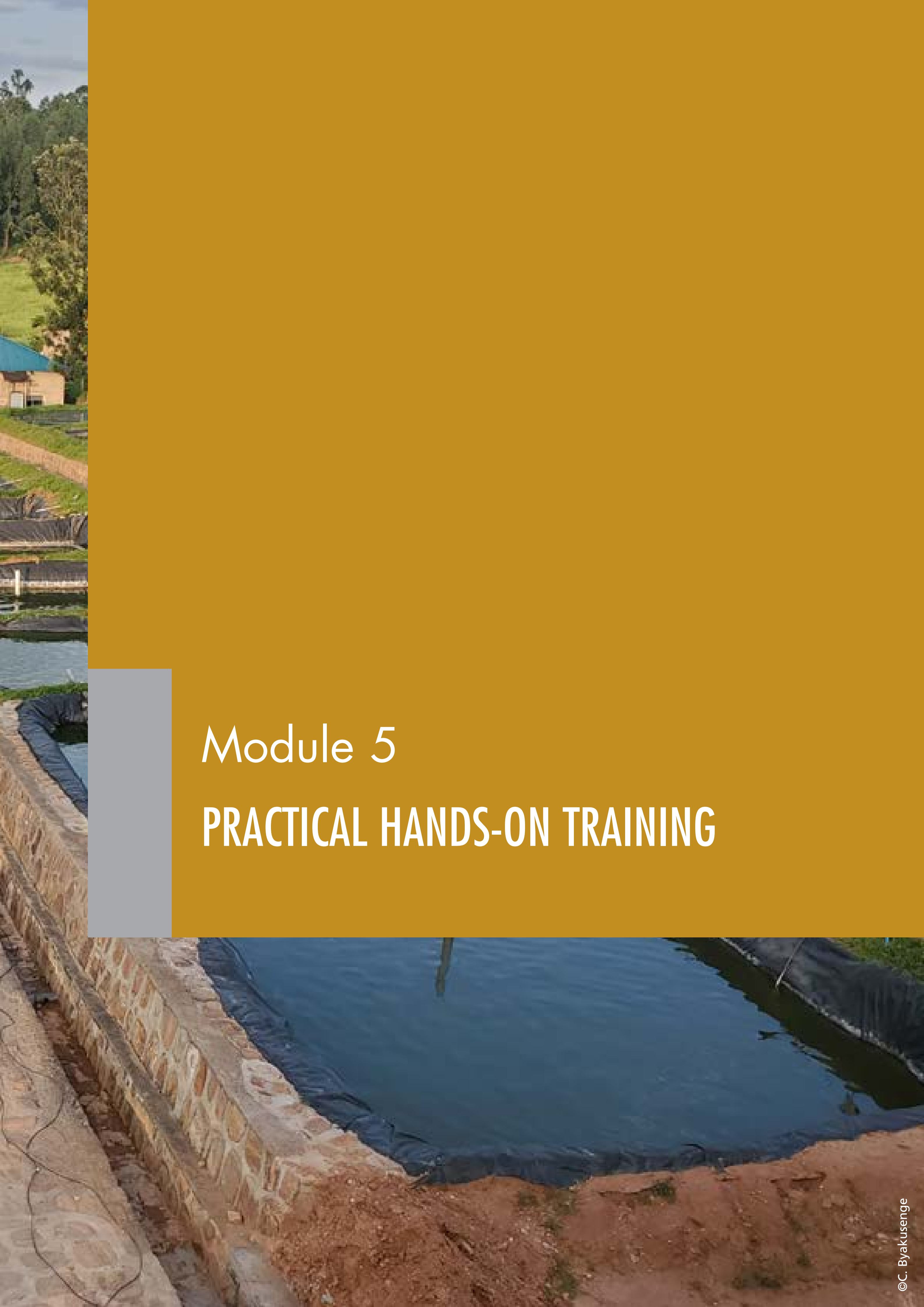
…or in markets with high hygiene and shelter conditions.

Photos: ©Bernard Adrien.

Hygiene is very important in markets. Customers will always choose a clean display rather than a dirty one. The seller himself or herself should be clean, wearing clean clothes, and comply with hygiene rules and process the products with care.

Module 5

PRACTICAL HANDS-ON TRAINING



©C. Byakusenge

EXERCISES RELATED TO THE TECHNICAL MODULE

Whenever possible during organized field visits to aquaculture farms, trainees will acquire hands-on experience and will apply theoretical principles. Such visits will expose trainees to real scenarios involving simulations of aquaculture situations. Trainees are expected to provide advice to the farmers of the farms based on the technical, governance and economic principles they have learned during theoretical sessions. The programme for the field visits will be developed together with national entities and farmer associations. Table 19 presents some of the hands-on practical exercises. For participants wishing to obtain a training certificate (8–12 weeks' training), in-farm practical training and daily performance at the farm will be part of the curriculum.

Table 19: Exercises for the Technical Module (Module 1)

Fieldwork exercises on site selection, surveying, design and pond construction
Seed production: hatchery and nursery management practices
Seed production for catfish
Fish health monitoring
Production monitoring and record-keeping

After these exercises, participants will know how to
perform all technical manipulation related to the topics mentioned above.

The following exercise will be conducted in the field and should be complemented by appropriate materials and equipment.

- **Site selection parameters:** water quality and quantity testing and evaluation, land profile/topography evaluation, soil quality and structure testing and evaluation, and other general considerations.
- **Surveying:** pace factor calculation, measuring distance, contour line/canal and determining slope.
- **Using dams and reservoirs for aquaculture:** evaluation of dams and reservoirs, pond and dam staking, and construction and spillways.
- **Pond construction:** theoretical and practical demonstration of various steps – dyke, pond bottom, inlet, outlet staking and finishing tasks stabilization including grass planting.
- **Pond renovation:** staking a pond to be renovated; learning the major steps of pond renovation of major steps for pond renovation.

Site selection and pond construction exercise

Example of field practice for site selection and pond construction

Tools to be used: rope, line level/GPS/dumpy level, measuring tape, pegs, machetes, shovels, string/rope, notebook, and water, among other things.

Participants will be split into groups. Facilitators will allocate an area to each group where the participants will undertake the following activities:

- Evaluate the condition of the site and determine if it is suitable for commercial aquaculture. Explain why it is or not suitable for commercial aquaculture.
- Survey longitudinal and cross-section of the site and indicate the slope.
- Survey the contour line of the future canal and indicate the catching point of water.
- With the results of the survey, identify where the ponds should be constructed, determining how many can be constructed on that surface, and mark a pond with accurate dimensions.
- Demarcate/stake the ponds and indicate the evacuation point, inlet canal/pipe, drainage point, deep end point, shallow end and pond bottom.
- Draw the diagram on a piece of paper.
- Process your findings in the classroom the following day or on the site.

Pond renovation theoretical exercise

1. Mr YY has a 500 m^2 pond, which was constructed a while ago. The dykes are uneven because of erosion, and it is very likely that specifications were not followed when building them. What procedures could help renovate the dykes?
2. The slopes of Mr XY's pond are 1:1. What will he do to shape them to commercial aquaculture specification?
3. Three rosary ponds belong to Mr XZ. He wants to renovate them and comes to you for advice. What do you advise him to do?
4. Mr YY's pond is 50 cm deep and he wants to renovate it. What do you think would be appropriate advice?

Steps for pond renovation

Define the objective an individual or entity should pursue when renovating a pond. What standards should the pond meet? Is it for nursing or for grow-out? Is the renovation of the pond small or large?

Identify degraded parts of the pond(s) and other problems with the site

In order to obtain good visualization of the pond, the farmer should drain the water completely, if water supply allows, and stake out the pond according to objectives (dykes, pond bottom, outlet and inlet systems, and finishing touches). Apply appropriate techniques to renovate the pond, such as (i) repairing (reconstructing) the dykes with good soil if they are eroded in order to obtain the previous shape; (ii) compacting and shaving the dykes; (iii) removing silt and roots at the pond bottom and on the dykes; and (iv) fixing the inlet and outlet systems.

Poor pond staking and construction, Congo, ©FAO/Mulonda Boniface.

Degraded slope of the dyke, Uganda, ©FAO/Mulonda Boniface.

Poor dyke construction, Guinea-Bissau, ©FAO/Mulonda Boniface.

Degraded dyke, Kenya, ©FAO/Mulonda Boniface.

Dyke demarcation/staking out for renovation, Uganda, ©FAO/Mulonda Boniface.

Staking out the height of a dyke for renovation, Uganda, ©FAO/Mulonda Boniface.

Preparing a pond renovation by cleaning the site, Guinea-Bissau, ©FAO/Mulonda Boniface.

Making a core trench for reinforcing the dyke of a pond, Guinea-Bissau, ©FAO/Issa Barry.

Repairing a drainage canal during pond renovation, Uganda, ©FAO/Mulonda Boniface.

Shaving a dyke during renovation, Uganda, ©FAO/Mulonda Boniface.

Compacting the dyke

Mechanical soil compacting and drainage of excessive water, Guinea-Bissau, ©FAO/Issa Barry.

During renovation, leave open the drainage point to dry the pond bottom, Uganda, ©FAO/Owan Simon.

Shape pond dyke after renovation. Final shape of a dyke after renovation, Uganda, ©FAO/Mulonda Boniface.

Vulnerable dyke to erosion owing to lack of cover vegetation after renovation, Guinea- Bissau, ©FAO/Mulonda Boniface.

Pond preparation steps before stocking and after harvesting

Pond bottom after harvesting. Very degraded dyke and silted pond bottom, Egypt, ©Randy Brummett.

Bad preparation of the pond after harvesting. Pond bottom full of mud, Congo, ©Edouard Kikashi.

Assess the ponds above after fish have been harvested (and note any problems).

How to prepare a pond before restocking

- Dry the pond completely to kill off any remaining fish and to eliminate diseases;
- Remove excess silt from the pond bottom, if necessary;
- Cover old fish nests on the slopes and pond bottom;
- Repair the dykes and rebuild slopes, if necessary;
- Lime the pond, if necessary;
- Cut any grass in or around the pond;
- Verify inlet and outlet systems (inlet pipe, outlet pipe, etc.);
- Repair or replace screens and/or chip filters;
- Plug up the pond (close the drainage pipes);
- Fill the pond.

Seed production – Hatchery and nursery management practices

Facilities preparation

This exercise can be done individually or as a group, but it is expected that at the end of the exercise each trainee/participant has acquired some knowledge of and experience with the following:

- Verification of available equipment.
- Improvement of inlet and outlet water systems.
- Construction and installation of a hapa in a pond or tank for tilapia.
- Construction of tray (floating wooden tray and 2 m of hapa net, 1 mm mesh).
- Cleaning and disinfection of equipment and floors.
- Water quality monitoring (how to measure water parameters, how to adjust parameters);

- Installation of biosecurity protocols in the hatchery (handwashing taps, hand sanitizer dispensers, foot dips).
- Identification of each production unit and facilities in general.
- Attaching an information fact sheet to each tank (recording incubation date, number of eggs stocked, body weight of the female, number of harvested larvae and water quality).

Catfish seed production

Just like for other species, the production of catfish seed follows protocols. Some of the important steps a farmer should observe are the following:

Step 1: Facilities preparation: clean and disinfect all equipment and fill the tank or aquarium with water. Make sure to change the volume of water in each tank at least three times a day.

Step 2: Select females and males.

Step 3: Weigh each female and isolate each fish in a basin capable of holding 50–70 L of water, large enough to hold the fish without stress.

Step 4: Inject pituitary hormone or a synthetic one into the dorsal muscle over the lateral line. The dose should be 0.5 ml/kg of female.

Step 5: After 10 to 30 hours have passed, strip the fish (i.e. press the eggs out of the fish). Make sure the bowls used to collect eggs are dry.

Step 6: Weigh the stripped eggs and place them in separate bowls of 1 to 2 L at a rate of 30 g.

Step 7: Remove the male, turn to belly up and cut the fish open. Use a syringe to remove the volume of milt needed and sew the belly closed.

Step 8: Add some drops of milt to the stripped eggs in the bowls, then add water (the same volume of the eggs) and mix by gently shaking the bowl for 1 minute.

Step 9: Spread the fertilized eggs on a tray.

Step 10: Wait 20 to 30 hours for hatching; once eggs hatch, they will slowly move in the receptacle.

Step 11: Remove the tray, and clean and disinfect it.

Step 12: Siphon the dead cells/waste accumulated at the bottom of the receptacle.

Step 13: 48 hours after hatching, start feeding the larvae with *Artemia* or 0.1 mm artificial feed (50–55 percent crude protein).

How to harvest the milt of catfish

The following steps describe practical ways of harvesting milt from the male fish.

Step 1: Remove the male from the water and cover its head and tail with a wet towel. Anaesthetize the fish until it is completely asleep.

Step 2: Place the fish on a table with the back facing up.

Step 3: Incise the abdomen, about 3–5 cm from the genital papilla.

Step 4: Introduce fingers into the abdomen to bring out the testes.

Step 5: Clean the testes and a syringe with sanitary paper to avoid any contact with water.

Step 6: Puncture the testes with the needle to withdraw the milt with the syringe until reaching the right quantity (0.25 ml for 100 g of eggs).

Step 7: Place the syringe containing the milt in a dry place.

Step 8: Sew the wound closed.

Step 9: Apply Betadine® solution on the wound.

Step 10: Isolate the male in a tank until it wakes up.

Step 11: Follow the male's health for two days, and do not hesitate to apply a treatment by adding 40 g of oxytetracycline per 1 cubic metre of water.

Step 12: Return the male to the rearing tank.

Taking care of fish larvae

- Construct a siphon with an 8–10 mm transparent pipe attached to a stainless steel rod.
- Siphon any residues every day before the first feeding, or at 18 hours for larvae.
- Calculate the amount of fish daily.
- Feeding strategy and frequency (see Seed production, nutrition and feeds).
- Feed the larvae at least four times every three hours, or six times every four hours in a recirculation aquaculture system (RAS).
- Remove dead fish daily.
- Remove shooters (fast-growing fingerlings) regularly in the case of catfish.
- Monitor the water quality daily and act promptly to correct any water quality problem observed during daily inspections or feeding times.

Feed and feeding practices at the hatchery

Feeding larvae at the hatchery is a very delicate process and includes some of these tasks:

- Formulation of local/farm feed: ingredients, proportion of each ingredient, sifting of ingredients, mixing and adding binder, and drying.
- Feed storage to avoid deterioration.
- Calculation of daily amount of feed.
- Each tank should have its own container of feed.
- Feeding frequency and technique.
- Data record-keeping for feed conversion ratio (FCR) calculation.

Monitoring production

Sampling

- Determine the average weight of fish in the different tanks at an interval of 1 to 2 weeks to follow fish growth.
- Record the weight of fish on the information sheet that is attached to the tank and in paper/computer/cellular phone recording sheets.
- The following tips show whether fish are growing well or not and allow farmers to take measures if needed:
  - Take three samples, at least, per every 200 fish (after removing the larger and smaller ones). Weigh each sample.
  - Count the number of fish in each sample.
  - Divide the weight by the number of fish.
- Calculate the average body weight of the three samples (add the three body weights and divide by three).
- Record the average body weight on the information sheet that is on the tank.

Fish sorting

Before transferring fish from one unit to another, including nursery, grow-out ponds or selling to another farm, fish should be graded to obtain a homogeneous size.

- Stop feeding the fish one day before the transfer.
- Install three hapas (1 m × 1 m × 1.2 m) to sort three different sizes of fish.
- Proceed in the early hours of the day (to avoid heat).
- Grade fish in three sizes: small (15 percent), medium (80 percent) and large (5 percent).
- Use a grader of 4 to 17 mm for fingerlings and 18 to 35 mm for large fish and put the graded fish in the respective hapas.
- Use proper handling nets, with no rough or torn edges.

- Use aeration in the case of tilapia.
- Grade in small batches. It is preferable to have various samples of small batches as it provides more accurate information about the fish size, length, body weight, average growth, and observation of health conditions, etc.
- Move the sorted fish as soon as possible to their recovery or destination areas.
- Record the number of fish and body weight on the information sheet that is attached to the tank.

Record-keeping of data

Record-keeping is crucial for hatchery and farm management. Without records, a farmer will have difficulties to properly follow his or her production and ultimately the business may fail (FAO, 1992). A few records, as the ones mentioned here, can make a difference in seed production:

- Excel file
- Input stock management (expenses)
- Breeding record and analysis
- Water parameters record and analysis
- Feed record and analysis (feed conversion ratio)
- Farm biomass record and analysis
- Cost-effective and profitability analysis

Monitoring fish health

Sampling, identification of parasites and treatment

- Use the sampling form.
- Type of information that should be recorded and frequency of collection.
- Take immediate action in response to a health problem.
- Fish examination:
  - Gills
  - Skin
  - Fin clip
- Identification of parasites.
- Treatment.

Basic tasks are required for the observance of farm/hatchery biosecurity. Table 20 summarizes the tasks.

Table 20: Biosecurity tasks on farms and in hatcheries

Key biosecurity task	Critical control point	Frequency
Vehicles	For high-risk situations, all vehicles entering site should pass through a wheel dip filled with disinfectant	On arrival
Personal biosecurity		
Foot dips	Place foot dips at all entrances, piers and cages	On passing through area
Skin hygiene	Hands should be washed and sanitized between areas using the hand hygiene disinfectant	On passing through area
Protective clothing	Rinse clothes with clean water, immerse in disinfectant for 10 minutes and hang to dry	After each period of use
Equipment		
Transport tanks and equipment	Cleaned with soap (visibly clean), disinfected and dried in sunlight	After each period of use
Carry bins, hand nets, weighing equipment	Cleaned with soap (visibly clean), disinfected and dried in sunlight	After each period of use
Dipnets and tank brushes	Immersion of at least 2 minutes	Daily after use
Grading equipment	Clean with solution then disinfect thoroughly	Daily after use
Waste disposal		
Waste disposal area, including skips and bins	Rinse area with clean water; immerse items in disinfectant for 10 minutes and air dry	Daily
Biosecurity barriers		
Paths and roadway	Brush or rake and then disinfect with solution	Weekly basis

EXERCISES RELATED TO THE ECONOMIC MODULE

Table 21 lists the exercises for this module and a referral to the section it refers to.

Table 21: Exercises for the Economic Module (Module 3)

TITLE OF EXERCISES
Budgeting for commercial farming and business plan development
Accounting for commercial farming
UTIDA: User-Friendly Tool for Investment Decision Making in Aquaculture

After these exercises, participants will know how to
Make a budget
Make and use a balance sheet
Make and read a financial analysis
Use UTIDA and apply it to personal enterprise

Using the FAO User-Friendly Tool for Investment Decision Making in Aquaculture

During this lecture, a demonstration on how to use the FAO User-Friendly Tool for Investment Decision Making in Aquaculture (UTIDA) will be proposed to participants as a prerequisite to perform the UTIDA Working Group (WG) exercises.

For the exercises, each WG will nominate a chairperson to lead the discussion, a rapporteur to perform data entry, and a spokesperson to report results into the plenary session practising the FAO UTIDA.

Getting to know the tool

WG exercise 1 is intended to help you learn how to use the beta version of UTIDA in order to assess the profitability of aquaculture operations to facilitate evidence-based policymaking and sector management.

Suppose that the government provides you with 12 hectares (ha) of land to promote aquaculture development. The land can be used to construct ponds with a total surface area of 10 ha. The use of the land is free of charge, but you would need to give it back to the government after 10 years.

Suppose that you have USD 100 000 of your own funds for long-term investments (item no. 1 in Table 22). This money may not be enough to cover the investment costs for building ponds and other facilities and buying machinery or other fixed assets, but you can take a long-term investment loan from the bank to cover the shortage. The terms of credit available are specified in Table 22 (No. 14 and No. 15).

You can also borrow money to cover any shortage of operating funds. Assume that the interest rates for the operating loans are the same as the long-term investment loans.

Use UTIDA to calculate some key production and financial indicators of the aquaculture operations specified in Table 22, as follows:

- Choose the aquaculture operation specified in Table 22: Tilapia monoculture pond-based farming.
- Enter the technical and financial parameters in Table 22 in UTIDA.
- Based on the information provided, UTIDA will produce a series of standard financial forms and offer customized advice based on the results of the analysis: use these results to fill in the key indicators listed in Table 22.

Please take note of the following key points:

- The parameters in Table 22, which were based on case studies in the literature, may not be entirely consistent with the experience of all participants.
- In order to facilitate the comparison of the results of different groups, please do not alter these parameters but take them as given.
- In order to simplify the exercises, Table 22 only specifies key technical or financial parameters, while UTIDA allows the user to input more detailed information.
- While inputting data in UTIDA, treat the parameters NOT specified in Table 22 as zero.
- Pay attention to the measurement units in Table 22 and the measurement units requested in UTIDA.
- If not otherwise specified, replicate the data in Table 22 in UTIDA from year 1 to year 10.

Table 22: Technical and financial parameters of tilapia pond culture

No.	Technical and financial parameters	Tilapia
1	Start-up funds for long-term investments* (USD)	100 000
2	Business planning horizon (years)	10
	FIXED ASSETS	
3	Total farm area	12
4	Total pond area (ha)	10
5	Average pond area (m^2)	2 000
6	Cost of pond construction* (USD/ha)	20 000
7	Life span of pond* (years)	10
8	Diesel-powered pump* (unit)	1
9	Cost of purchasing powered pump* (USD/unit)	15 000
10	Life span of pump* (years)	10
11	Buildings, including stores, workshops and canteens* (set)	1
12	Cost of building construction* (USD/set)	15 000
13	Life span of buildings* (years)	10
	LOAN	
14	Annual interest rate on investment loans** (%)	10
15	Repayment term for investment loan* (years)	10
16	Annual interest rate on operating loans (%)	10
	SEED	
17	Size of fingerlings (g)	15
18	Fingerling price (USD/piece)	0.12
19	Stocking density (piece/m^2)	2.50
20	Survival rate (%)	75
	FEED	
21	Feed conversion ratio of commercial feed (ratio)	1.8
22	Price of commercial feed (USD/kg)	0.6
	FERTILIZERS	
23	Use of manure (kg/year)	1 500
24	Price of manure (USD/kg)	0.5
	OTHER MATERIAL INPUTS	
25	Fuel (USD/year)	10 000
26	Electricity (USD/year)	3 000
27	Maintenance and repair (USD/year)	3 000
	LABOUR	
28	Permanent field workers (No.)	6
29	Wage for permanent field workers (USD/person/month)	300
30	Managers (No.)	1
31	Salary of manager (USD/person/month)	3 000
	PRODUCTION	
32	Production cycle (months)	8
33	Average fish size at harvest (g)	500
34	Price of fish harvested (USD/kg)	2.5

* Please convert this amount in Zambian kwacha (K).
Note: ha = hectare; m^2 = square metre; g = gram; kg = kilogram.

With regard to Table 23, the solutions for the exercise in the table are found in Table 24.

Table 23: Economic and financial performance of tilapia pond culture

No.	Performance indicators	Tilapia
	AVERAGE INCOME STATEMENT	
1	Total revenue (10-year average; USD/year)	
1.1	Production of the targeted species (10-year average; kg/year)	
1.2	Price of fish harvested (10-year average; USD/kg)	
2	Total cash expenses (10-year average; USD/year)	
2.1	Total variable cash expenses (10-year average; USD/year)	
2.1.1	Seed (10-year average; USD/year)	
2.1.2	Feed (10-year average; USD/year)	
2.1.3	Fertilizers (10-year average; USD/year)	
2.1.4	Veterinary and pharmaceutical products (10-year average; USD/year)	
2.1.5	Total (permanent and occasional) employees (10-year average; USD/year)	
2.1.6	Maintenance and repairs (10-year average; USD/year)	
2.1.7	Fuel and lubricants (10-year average; USD/year)	
2.1.8	Electricity (10-year average; USD/year)	
2.1.9	Water (10-year average; USD/year)	
2.1.10	Interest on the operating loans (10-year average; USD/year)	
2.2	Total fixed cash expenses (10-year average; USD/year)	
2.2.1	Interest on investment loans (10-year average; USD/year)	
3	Net cash farm income (above cash expenses) (10-year average; USD/year)	
4	Depreciation of fixed assets (10-year average; USD/year)	
5	Net farm income from operations – NFIO (above cash and non-cash expenses) (10-year average; USD/year)	
6	Net income (profit) per farm/year (10-year average; USD/year)	
7	Net income (profit) per ha/year (10-year average; USD/ha/year)	
	CASH FLOW	
8	Total cash inflow in year 1 (USD)	
9	Total cash outflow in year 1 (USD)	
10	Cash balance available before any new operating loan at the end of year 1 (USD)	
11	Cash balance after new operating loan at the end of year 1 (USD)	
	BALANCE SHEET	
12	Total assets at the end of year 10 (USD)	
13	Total liabilities at the end of year 10 (USD)	
14	Net worth at the end of year 10 (USD)	

Note: ha = hectare; kg = kilogram.

Table 24: Solutions for Table 25 (Economic and financial performance of tilapia pond culture)

No.	Performance indicators	Tilapia
	AVERAGE INCOME STATEMENT	
1	Total revenue (10-year average; USD/year)	351 562.50
1.1	Production of the targeted species (10-year average; kg/year)	140 625.00
1.2	Price of fish harvested (10-year average; USD/kg)	2.50
2	Total cash expenses (10-year average; USD/year)	287 651.12
2.1	Total variable cash expenses (10-year average; USD/year)	279 494.22
2.1.1	Seed (10-year average; USD/year)	45 000.00
2.1.2	Feed (10-year average; USD/year)	145 800.00
2.1.3	Fertilizers (10-year average; USD/year)	750.00
2.1.4	Veterinary and pharmaceutical products (10-year average; USD/year)	0.00
2.1.5	Total (permanent and occasional) employees (10-year average; USD/year)	57 600.00
2.1.6	Maintenance and repairs (10-year average; USD/year)	3 000.00
2.1.7	Fuel and lubricants (10-year average; USD/year)	10 000.00
2.1.8	Electricity (10-year average; USD/year)	3 000.00
2.1.9	Water (10-year average; USD/year)	0.00
2.1.10	Interest on the operating loans (10-year average; USD/year)	14 344.22
2.2	Total fixed cash expenses (10-year average; USD/year)	8 156.90
2.2.1	Interest on investment loans (10-year average; USD/year)	8 156.90
3	Net cash farm income (above cash expenses) (10-year average; USD/year)	63 911.38
4	Depreciation of fixed assets (10-year average; USD/year)	-23 000.00
5	Net farm income from operations – NFIO (above cash and non-cash expenses) (10-year average; USD/year)	40 911.38
6	Net income (profit) per farm/year (10-year average; USD/year)	40 911.38
7	Net income (profit) per ha/year (10-year average; USD/ha/year)	4 091.14
	CASH FLOW	
8	Total cash inflow in year 1 (USD)	499 750.00
9	Total cash outflow in year 1 (USD)	578 444.40
10	Cash balance available before any new operating loan at the end of year 1 (USD)	-78 694.40
11	Cash balance after new operating loan at the end of year 1 (USD)	265 375.00
	BALANCE SHEET	
12	Total assets at the end of year 10 (USD)	507 988.83
13	Total liabilities at the end of year 10 (USD)	0.00
14	Net worth at the end of year 10 (USD)	507 988.83

Assessing profitability: Working Group exercise 2

In this exercise, you will assess the economic profitability and financial feasibility of aquaculture farms with the parameters of your choice.

WG exercise 2 is intended to help you learn how to use the beta version of FAO's UTIDA to assess the profitability of aquaculture operations in order to facilitate evidence-based policymaking and sector management.

Suppose that the government provides you with 12 ha of land to promote aquaculture development. The land can be used to construct ponds with a total surface area of 10 ha for pond culture.

The use of the land is free of charge, but you would need to give it back to the government after 10 years.

1. Suppose that you have USD 100 000 of your own funds for long-term investments.
2. You can conduct one aquaculture operation, i.e. tilapia or African catfish, in pond.

Exercise

Use UTIDA to assist you in deciding whether to invest or not invest in this project under the above scenario. If you decide to invest, please use UTIDA to help you to choose the fish species and the farming system.

First, please specify the technical and financial parameters based on the fish species to farm, i.e. tilapia or African catfish in pond culture (trainers provide table with specific parameters),

Please note that:

- You CANNOT change the scenario, i.e. the values in the first four rows in Table 25 (USD 100 000 for funding long-term investments, a business planning horizon of 10 years, total farm area of 12 ha and total pond area of 10 ha for pond culture).
- If available in UTIDA, you can add, remove and/or modify the other parameters in Table 23 according to your specification.
- In UTIDA, insert the technical and financial parameters you specified in Table 25. Based on the information you provided, UTIDA will produce a series of standard financial forms and offer customized advice based on the results of the analysis.
- Please use these results to fill in the key production or financial indicators listed in Table 25. Based on these indicators, you will decide whether to farm tilapia or African catfish in a pond, or decision not to participate in or invest in this project.
- Please save your results to perform WG exercise 3.

Plenary session

Please describe the rationale behind your decision whether to farm tilapia or African catfish, in a pond, or decision not to participate in or invest in this project.

In order to help others understand your decisions, you should complete Table 25 and Table 26:

- Present the results from Table 24 and Table 25.
- Highlight the key parameters you deem more important.
- Explain why the selected parameters are important.

Table 25: Technical and financial parameters of pond culture: tilapia or African catfish

No.	Technical and financial parameters	Tilapia	African catfish
A.	**SCENARIO**		
1	Start-up funds for long-term investments* (USD)	100 000	100 000
2	Business planning horizon (years)	10	10
A	**FIXED ASSETS**		
1	Total farm area	12	12
2	Total pond area (ha)	10	10
3	Average pond area (m^2)		
4	Cost of pond construction (K/ha)		
5	Life span of pond (years)		
6	Cost of aquaculture support infrastructure (K)		
7	Life span of aquaculture support infrastructure (years)		
8	Cost of aquaculture equipment and machinery (K)		
9	Life span of aquaculture equipment and machinery (years)		
B	**LOAN**		
1	Annual interest rate for investment loan (%)		
2	Repayment term for investment loan (years)		
3	Annual interest rate for operating loan (%)		
C	**SEED**		
1	Size of fingerlings (g)		
2	Fingerling price (K/piece)		
3	Stocking density (piece/m^2)		
4	Survival rate (%)		
D	**FEED**		
1	Feed conversion ratio of commercial feed (ratio)		
2	Price of commercial feed (K/kg)		
E	**FERTILIZERS**		
1	Quantity of fertilizers used per year (kg/year)		
2	Average unit price of fertilizers (K/kg)		
F	**OTHER COSTS**		
1	Fuel and lubricants (K/year)		
2	Electricity (K/year)		
3	Maintenance and repair (K/year)		
4	Water (K/year)		
5	Other annual variable costs (K/year)		
G	**LABOUR**		
1	Permanent field workers (No.)		
2	Salary for permanent field workers (K/person/month)		
3	Managers (No.)		
4	Salary of manager (K/person/month)		
5	Guards (No.)		
6	Salary of a guard (K/person/month)		
7	[Please specify type of work and number ______] (No.)		
8	Salary of [please specify ______] (K/person/month)		
9	Total annual cost of occasional workers [please specify ______]		
H	**PRODUCTION**		
1	Production cycle (months)		
2	Average fish size at harvest (g)		
3	Price of fish harvested (K/kg)		

* Please convert this amount in Zambian kwacha (K).
Note: ha = hectare; m^2 = square metre; g = gram; kg = kilogram.

Table 26: Economic and financial performance of pond culture: tilapia or African catfish

No.	Performance indicators	Tilapia	African catfish
	AVERAGE INCOME STATEMENT		
1	Total revenue (10-year average; K/year)		
1.1	Production of the targeted species (10-year average; kg/year)		
1.2	Price of fish harvested (10-year average; K/kg)		
2	Total cash expenses (10-year average; K/year)		
2.1	Total variable cash expenses (10-year average; K/year)		
2.1.1	Seed (10-year average; K/year)		
2.1.2	Feed (10-year average; K/year)		
2.1.3	Fertilizers (10-year average; K/year)		
2.1.4	Veterinary and pharmaceutical products (10-year average; K/year)		
2.1.5	Total (permanent and occasional) employees (10-year average; K/year)		
2.1.6	Maintenance and repairs (10-year average; K/year)		
2.1.7	Fuel and lubricants (10-year average; K/year)		
2.1.8	Electricity (10-year average; K/year)		
2.1.9	Water (10-year average; K/year)		
2.1.10	Interest on the operating loans (10-year average; K/year)		
2.2	Total fixed cash expenses (10-year average; K/year)		
2.2.1	Interest on investment loans (10-year average; K/year)		
3	Net cash farm income (above cash expenses) (10-year average; USD/year)		
4	Depreciation of fixed assets (10-year average; K/year)		
5	Net farm income from operations – NFIO (above cash and non-cash expenses) (10-year average; K/year)		
6	Net income (profit) per farm/year (10-year average; K/year)		
7	Net income (profit) per ha/year (10-year average; K/ha/year)		
	CASH FLOW		
8	Total cash inflow in year 1 (K)		
9	Total cash outflow in year 1 (K)		
10	Cash balance available before any new operating loan at the end of year 1 (K)		
11	Cash balance after new operating loan at the end of year 1 (K)		
	BALANCE SHEET		
12	Total assets at the end of year 10 (K)		
13	Total liabilities at the end of year 10 (K)		
14	Net worth at the end of year 10 (K)		

Develop skills to evaluate the likely impacts of financial risks of aquaculture

Please use the data and the related results you obtained during WG exercise 2 as a base case scenario (scenario 1).

In order to evaluate the likely impacts of the production and market threats, please modify the technical and financial parameters of the fish species to farm, i.e. tilapia or African catfish, in pond culture obtained during WG exercise 2 and/or perform the sensitivity analysis.

Working Group (WG)	Assigned financial threats to address
WG 1	Seed low quality
WG 2	Feed limited availability
WG 3	Climate change
WG 4	Lack of skilled labour

Insert the new technical and financial parameters in UTIDA. Based on the information you provided, UTIDA will produce a series of standard financial forms.

Plenary session

In order to help others understand your decisions, you should present the results by:

- Highlighting the key parameters you selected to evaluate the likely impacts of the assigned production or market threat.
- Explaining why the selected parameters are important.

Financial risks and hazards in developing commercial aquaculture

During the lecture on financial risks and hazards in Module 3, a WG exercise will be proposed to participants to identify potential financial risks to aquaculture development in their specific location and to develop skills for the critical evaluation of financial risks.

Reminder of topics in the lecture:

- Definition of risk and hazards
- Definition of risk categories in aquaculture
- Definition and examples of financial risks and hazards in aquaculture
- Elements and implementation of a financial risk analysis in aquaculture
- Main risks of practicing aquaculture as a business

EXERCISES RELATED TO THE GOVERNANCE MODULE

Objectives

- Assess how well participants grasp the meaning and substance of the materials delivered through formal presentation by a training facilitator.
- Evaluate the extent to which participants can apply the acquired knowledge for problem solving.
- Assess the efficacy of the training provided for its potential to develop practitioners of good governance for smallholder fish farming.

Method

Following the presentation of Module 2, on Governance and Social Dimension of Sustainable Aquaculture, the training facilitator will ask the participants to form several groups and distribute the worksheet for the group exercise. Each group will consist of four participants. Three persons will provide inputs consistent with the worksheet for preparation of the group report. The fourth person will be responsible for organizing the information and presenting the group report. After the presentation of all group reports, the training facilitator will designate a moderator to synthesize the group reports and present the key findings.

The challenge

Group members should brainstorm the following questions, list their answers and prepare a group report for presentation to the class.

- Briefly explain your understanding of the principles of good governance.
- Use a definition of governance from the training module and show how well it reflects the principles of good governance.
- Explain how these principles can be incorporated into project design.
- Explain how activities planned in an initiative suffer if the principles of participation and accountability are inadequately addressed in project design.
- How do you approach the concept of measuring governance quality using different quantitative approaches?
- Are there any specific advantages or disadvantages of measuring governance quality?
- Explain how these structured attempts to measure governance quality affect the policymaking of national governments.
- Prepare a short report and present it to the class.

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The first version of this training curriculum and manual was primarily prepared for all sub-Saharan African countries interested in developing sustainable aquaculture. Upon request by the Government of the Republic of Zambia and numerous African aquaculture stakeholders for FAO to turn complex science and policy subjects into practical knowledge and make it useful for common people to develop the sector, the FAO Fisheries and Aquaculture Division prepared this comprehensive training curriculum and practical manual on sustainable aquaculture. The training curriculum and the manual are mostly dedicated to technical schools, aquaculture farmers and extension officers as well as those working with financial aquaculture businesses. This document benefited from the Unilateral Trust Fund "Technical Assistance to the Zambia Aquaculture Enterprise Development Project" (UTF/ZAM/077/ZAM), funded by the African Development Bank and the Government of the Republic of Zambia through the Zambia Aquaculture Enterprise Development Project (ZAEDP).

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