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Training Manual

On Household-Based Small-Scale Pond Aquaculture in Cambodia

Sustainable Aquaculture and Community Fish Refuge Management Project

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ABBREVIATIONS

AWB	Average Body Weight
DAD	Department of Aquaculture Development
DO	Dissolved Oxygen
FAO	United Nations Food and Agriculture Organization
FARDeC	Freshwater Aquaculture Research and Development Center
FCED	Fish Culture Extension Committee
FCR	Feed Conversion Ratio
FFS	Farmer Field School
FiA	Fisheries Administration
FiAC	Fisheries Administration Cantonment
GAqP	Good Aquaculture Practices
HH	Household
HURREDO	Human Resource and Rural Economic Development Organization
M&E	Monitoring and Evaluation
MFI	Microfinance Institution
NARDI	National Aquaculture Research and Development Institute
RUA	Royal University of Agriculture
SAFR	Sustainable Aquaculture and Community Fish Refuge Management Project
USDA CAST	United Stated Department of Agriculture - Commercialization of Aquaculture for Sustainable Trade
USAID HARVEST	United States Agency for International Development – Helping Address Rural Vulnerabilities and Ecosystem Stability

0 INTRODUCTION

0.1 ABOUT THIS MANUAL

This training manual was developed for and in the context of the **Sustainable Aquaculture and Community Fish Refuge Management Project (SAFR)** in Cambodia to support capacity building for sustainable small-scale aquaculture operations by 400 fish farming households (HHs) in Kampong Thom province of Cambodia. The aim of the aquaculture component of the SAFR project is to enable these 400 HHs to engage in a productive and sustainable way in small- and medium scale aquaculture operations.

With these experiences, **this training manual** provides a comprehensive technical and didactic framework that **enables aquaculture trainers to design, facilitate and promote learning experiences to rural communities in Cambodia** so that they can base their fish farming activities on knowledge and experience. In this way, they can make informed decisions about the type and scale of aquaculture they want to practice and are thus able to operate their fishponds **in an economically viable and environmentally sustainable manner**.

Specifically, the capacity-building concept outlined here includes a methodological and didactical approach, technical content and aquaculture related training materials. Also included is an M&E plan that allows for assessing the progress of capacity building and provides information on which of the contents taught in the training sessions are taken up and applied by the participants. Furthermore, the manual contains methodologies for monitoring fish growth, water quality and economic performance, as well as corrective measures to maintain monitored parameters within expected ranges.

0.2 TARGET GROUP

The manual is aimed at government and civil society organizations that work with poor and disadvantaged communities in rural Cambodia and are considering promoting fish farming as an additional source of income generation and building sustainable livelihoods.

By using this manual, trainers and extension officers, will be able to build rural communities' capacities in fish farming. Trainers and extension officers can use this manual, training materials, activities, and session plans to develop capacity-building programs for rural HH interested in aquaculture to improve their livelihoods by producing fish as an additional source of protein and food, supplement their income sources, or even create a small aquaculture business as a new income opportunity.

0.3 OBJECTIVE

At the end of such a capacity-building program, participants will be able to make informed and conscious decisions about the level and scale of aquaculture operations they want to set up. They will understand the economic implications of the various aquaculture options open to them and will be familiar with the different technical requirements for cultivating different species. They will understand the economic and commercial characteristics of different species, respective farming methods and related opportunities and risks. Furthermore, they will be able to design, build and expand aquaculture operations, which they deem appropriate for their respective HH, their available resources and that meet their objectives.

The **target audience** for the capacity-building program falls into **two broad categories**:

1. **People who have no experience** whatsoever in aquaculture, but would like to venture into fish farming, and

2. **People who already have current or prior experience** and background in aquaculture.

This second group may be called "emerging" fish farmers. These are people with some prior experience in aquaculture and are interested in sustaining, improving and/or expanding their farming. They may not have been able to sustain their previous fish farming because of economic losses, have given up and want to restart aquaculture activities.

Particularly **the first group** can be further categorized into those who are primarily interested in raising fish for their own consumption and not-for-profit operations and those who want to add another revenue stream to their farm and HH business to increase their income through the sale of fish.

Both subgroups require training in the fundamentals of aquaculture, from site selection and construction of ponds, pond preparation, species selection, stocking and management. The second group of more experienced farmers primarily need technical capacity-building in pond management for increasing their production and access to finance for the investment needed to expand their operations.

While all groups need skill development in farm planning and management to achieve their respective economic and financial objectives, the focus of this manual is to help interested farmers to gain basic knowledge and skills to start small-scale fish farming operations with an understanding of the financial implications and risks of increasing stocking and production rates for growing their business.

0.4 TRAINING CONCEPT

The training program as outlined will consist of **eight technical modules** divided into several units designed to provide both theoretical knowledge and practical skills for **small-scale aquaculture operations, hatchery management, fish feed production and fish processing**. Special emphasis is placed on demonstrations and hands-on learning. Demonstrations happen in various locational contexts, depending on the content, i.e., classroom settings, demo-farms and **farmer field schools (FFS)**. Practical learning will take place at the participants' own farms with **group mentoring** and on-site technical input from trainers and technical experts.

0.5 METHODOLOGIAL /DIDACTICAL APPROACH

With this manual, trainers will be able to design and facilitate learning experiences on small-scale aquaculture that enable households in rural Cambodia to acquire skills and competencies to operate economically, socially, and environmentally sustainable aquaculture operations that enable them to produce fish for self-sufficiency and small-scale commercial fish production.

The starting point for the development of this manual and its content was the following question: **What should the households be able to do at the end of the program?** The answer to this question provides the basis for defining the learning objectives as they describe the capacities fish farmers need to manage fish farming operations successfully.

Capacities to establish and manage sustainable aquaculture operations that are economically viable entail the ability to

1. Make decisions that are informed by sound technical knowledge and skills;
2. Take appropriate and required operational decisions, measures and actions for raising fish, and
3. Implement tasks and solve problems in a manner that is oriented towards achieving the operational and business goals of the fish farm.

LEARNING GOALS

The overall goal of the training program outlined in this manual is to enable participating HH to design and manage economically viable aquaculture operations that ensure animal-friendly conditions, meet health and safety standards for fish and fish products and minimize negative environmental impacts. Participants will be able to monitor the growth, health and stock development of their fish, and to determine the basic parameters for management such as fish stocking densities, feed and feed quantities and related costs, growth, water quality and the economic efficiency of the operations.

LEARNING GOAL 1: UNDERSTANDING AND EVALUATING THE OPERATIONAL CONTEXT

The participants learn to understand their respective HH as small enterprises or business units that consist of different branches or components, each providing a revenue stream and contributing to their livelihood (e.g., migrant labor, contract worker, rice production, vegetable production, animal husbandry etc.). They are able to estimate and calculate the contribution of each of these revenue streams to their HH income and are able to calculate their HH expenditures, allowing them to calculate how many human and financial resources they will be able to invest in aquaculture operations. They understand the basic concepts of intensification of aquaculture and can determine the level of aquaculture operations that are suitable and appropriate for their HH. They are informed about sources of technical assistance and further skill development to manage and potentially expand their aquaculture operations.

LEARNING GOAL 2: MANAGING AQUACULTURE FACILITIES

This constitutes the core of the capacity-building program. Participants gain an understanding of the operation of aquaculture facilities for raising fish. They learn procedures for rearing, growing, and keeping fish (fingerlings, fish for human consumption, brood stock) and understand the operational requirements (location factors such as topography and water sources). They understand and can apply management, maintenance measures suitable for their chosen level of production, such as maintaining an appropriate feeding regime, and pond management measures that ensure good water quality, and sufficient oxygen levels for the fish to thrive.

They are able to plan the rearing, fattening and keeping of fish in ways appropriate for their respective facilities, in line with their respective economic objectives and Good Aquaculture Practices (GAqP), thus creating fish-friendly conditions (temperature, water quality, stocking density). They are able to monitor and calculate the necessary parameters for the management (fish stocking, feed quantities, feed conversion ratio (FCR), feed cost, growth, harvest times, oxygen demand, oxygen content, nitrogen compounds) and the economic efficiency (direct cost-free performance, contribution margin) of the processes.

They understand and can calculate production factors and costs (fixed costs, variable costs) of operating resources to calculate prices, revenue and profits.

LEARNING GOAL 3: MARKETING OF FISH AND FISH PRODUCTS

Participants are able to inform themselves about markets for fish and fish products. They explore the market for fishery products (fresh fish, processed fish, and quality labels) and can take production factors and costs of their operations into account for determining prices and the profitability of their operations. They learn to explore local and regional market opportunities, taking sustainability and economic viability into account.

The following key training topics are considered mandatory to achieve these learning goals:

Farm preparation

Site selection, excavation of ponds; aspects for farm layout design, species selection for different environmental conditions, adaptation to climate change, practical and locally suitable biosecurity measures.

Operations

Stocking, feed management (details below), pond management, monitoring applied methods on fish health and growth, biosecurity measure, grading water quality management.

Production planning

Understanding relationships between key technical parameters and how they relate to management decisions, such as optimal stocking density, feed conversion ratio and economic decision-making about feed options, water quality and related decisions to influence health and growth rate.

Harvesting/Post-Harvesting

Choice of harvesting equipment, handling, storage and transport including hazards, **hygiene and quality concept**, time and temperature control for selling fresh fish, basic techniques and simple technology for **processing fish**, main elements of **marketing and practical application for smallholders**.

0.6 DIDACTIC AND PEDAGOGY

BLENDED LEARNING AS THE UNDERLYING CAPACITY BUILDING CONCEPT

This capacity-building program aims at developing comprehensive competencies for managing pond aquaculture facilities. To achieve the learning goals and to develop the participants' abilities to apply confidently and independently the acquired new knowledge requires a blended learning approach that focuses on providing as much practical learning experiences in real life situations as possible. **Active and experiential learning** are thus the core of the program. The aim is to enable participants to **integrate theoretical concepts, techniques and methods into their daily work life in their own fish farms**.

Action-oriented learning will thus complement conventional subject and technical teaching, which arises from real life situations and experiences the participants make while managing their own aquaculture operations. Consequently, learning experiences offered by each module are structured following an **action and experience-based learning cycle**. Individual modules and units of the program comprise technical teaching sessions followed by **interactive workshop-type sessions** during which participants discuss this technical subject matter in the context of their own HH and aquaculture operations and develop an action plan for applying this newly acquired knowledge in their respective farms.

This phase is followed by a period of **"field-practice"** during which the participants implement these action plans. The length of a "field practice" depends on the respective learning content of the preceding module. For Example, after an initial training on site selection, pond construction and pond preparation, the "field phase" will be the time required for these activities. During this time, **mentoring** will facilitate a practical learning experience that allows them to identify issues and problems in their application of the learned subject matter and to solve them independently. This approach will increase the effectiveness of learning as learners are enabled to practice and transfer newly gained skills and knowledge to their daily life.

This approach strongly suggests timing the learning sessions as and when needed by farmers and their farm operations progress. The design of **each module considers the life realities of the trainees**, who often are engaged in various other income generating activities and usually will not be able to participate in conventionally designed training courses that are offered over a certain period. Thus, the technical input and interactive "workshop style" sessions of each module are designed to be not longer than one day, followed by at least a couple of days for field practice learning.

0.7 LEARNING SUPPORT – TRAINING MATERIALS, SOCIAL MEDIA AND INDIVIDUAL MENTORING

Wherever possible and appropriate during these periods of practical learning and application of learned skills on their own farms, social media and individual mentoring will be used to supplement and support the learning experience. However, for many rural HH Cambodia conventional learning inputs and training handouts are not very effective, as illiteracy is still widespread. Messaging needs to be appropriate, but simple. As far as the technical infrastructure allows, social media and digital technologies can be used to support the learning experience.

However, continued illiteracy in some areas, limited access to power supply, the cost of technology such as smartphones and the cost of internet access may prevent some HH from benefiting from these technologies. There are different ways to address and meet these challenges. At the end of each module, outlines of session plans are presented, that can be used to design training activities. These have been tested with various communities and HHs in rural Cambodia. They focus on keeping the presentation of input short and focus on learning experiences such as interactive group work that considers the literacy level of participants and their respective level of experiences in aquaculture. Input presentations are visual and picture-based rather than text-based. Posters and picture cards that are sufficiently large for the audience to be seen when shown by the trainer (DIN A2) are preferred over powerpoint, as they can also be passed around the audience for further discussions and clarification.

Similarly, handouts or "take-away-training-material" are focusing on pictures, rather than text. Since text-based material cannot be totally avoided (such as farm records), it is suggested, wherever possible, to involve HH members who can read and write (such as youth) during the mentoring sessions.

As in Cambodia the Telegram messenger service is probably the most popular social media communication tool. Trainers and extension officers can set-up Telegram groups with trainee HHs and community leaders, that can be used as platforms for immediate feedback and technical advice on issues faced by the trainee HHs.

0.8 QUALITY STANDARDS AND M&E

The quality and success of each capacity building program is demonstrated by the successful application of the learned content by the participants. The perspective of the participants and their personal and professional progress is important to assess why some learning experiences are more successfully implemented than others.

Immediate training feedback

A commonly used method of evaluation is to survey participants immediately after a training session using a short, anonymous questionnaire that addresses five different areas (relevance of topics, learning success, quality of trainers, group experience, and personal well-being). However, in the local context of rural Cambodia and in line with the spirit of participatory, interactive training approaches, it is suggested to not use individualized questionnaires (participants may be illiterate), but to use media such as flip-charts instead. This practice allows for a visualization of the feedback questions. Participants can give their feedback by marking relevant categories on the flip chart and can provide comments either during a plenary discussion or during work sessions in small groups on colored Meta cards. If participants are illiterate, this can be done by the trainer. Time for such feedback will need to be allocated and indicated in each session plan, and examples of these will be included in the session plan outlines.

Assessing uptake of learning content

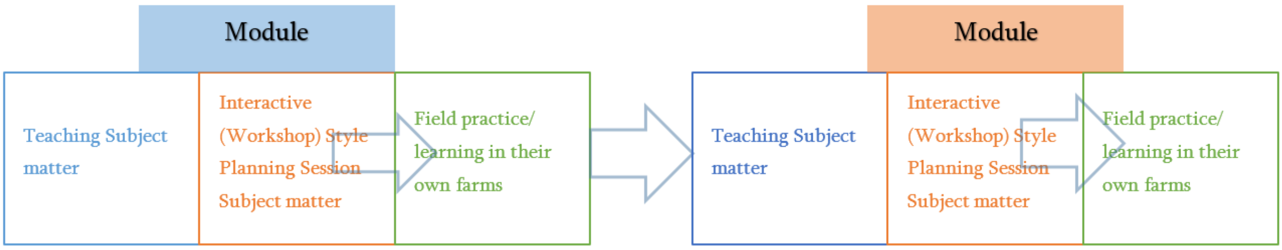
The modular training concept provides participants with time between the various modules to apply what they have learned on their own farms. Before the follow-up training module is organized, a participants' survey should be conducted to assess to what extend they applied the learned content in their own farms. This is to assess the training provided, whether teaching methods are appropriate, whether offered learning content is relevant or needs to be adjusted to meet local requirements and realities and whether some learning content needs to be re-enforced in follow-up training session or through mentoring.

Final evaluation

For the final evaluation, another questionnaire-based survey should be conducted. It could comprise topics that refer to the content of the course (subject, intensity, design) as well as quality of the handouts provided, usability of the training in one's daily work life, group work experience and logistics. In terms of methodology, the concluding evaluation combines multiple-choice questions and the opportunity for individual comments in written form. The accumulated results of this evaluation provide important information for the continuous improvement of materials and methods as well as a detailed review on the progress of the course and the teaching quality.

0.9 OVERVIEW OF THE TECHNICAL TRAINING MODULES

Modules can be taken sequentially, i.e., from module one to eight, or as stand-alone learning units, depending on the need of the trainees. These eight modules are considered **core modules**, containing key learning content, that each fish farmer is expected to be familiar with and able to apply. **Additional modules** and learning experiences will provide additional learning and capacity-building opportunities for farmers who want to expand and diversify their business into seed and fingerling supply, fish feed production or fish processing.



Module 1: Economic principles of fish farming and farm planning

As an introductory module, this module will focus on basic economic principles of aquaculture in small ponds. It will familiarize farmers with the core interrelationships between basic production parameters such as levels of stocking densities and feeding regimes from natural feed-based production with supplementary feeds to intensive production systems with high stocking densities and feeding regimes based on commercial pelleted feed. Understanding these basic principles will allow the fish farmers to assess their HHs' capacities to engage in fish farming and what type and level of aquaculture operations they might want to engage with the resources at their disposal.

Participants will learn about various species that are available to them for aquaculture, their suitability and economic potential. With this understanding of their respective HH farms, they will have the requisite knowledge to develop "farm business plans" that provide a framework for HH economic planning and investment decisions.

Module 2: Site selection and pond construction

This module aims predominantly at participants who intend to start fish farming activities and covers site selection and pond construction. However, it will also enable existing fish farmers to re-evaluate their ponds and location with a view on their suitability and potential and a possible need to re-work them.

The aim of this module is that participants will be able to

1. Understand and asses the suitability of their land for establishing ponds.
2. Excavate appropriate and safe new fishponds or rework existing ponds, e.g., slope design and gradients, stabilizing slopes.

Topics to be covered include

3. Pond location, soil type, water type and sources, vegetation etc.
4. Pond size, slope rate, depth, pond embankment, bottom etc.

Module 3: Creating and maintaining a healthy pond ecosystem

This module is about getting the pond ready for stocking. Participants will learn how to prepare the pond and create a pond environment that is conducive for fish farming. Moreover, participants learn about the role of lime application and fertilization to create a pond ecosystem that produces natural feed for growing fish.

1. Pond preparation (dry up, lime application, fertilizer application etc.)
2. Inspection and assessment of natural feed prior to stocking.

Module 4: Seed and fingerling selection, fish stocking and nursing

The module provides the participants with decision-making tools that allow them to select species for stocking, based on criteria such as their market value, local availability, resilience to climate change and changes in weather and water quality, complexity of farming requirements such as feeding, water quality and pond management, and being approved for farming by the government.

Key units of the module cover:

1. Selecting good quality fingerlings.
2. Fish seed and fingerling transportation and releasing.

Module 5: Fish feeding and feed production

At the end this module, the farmers understand the basic feed requirements, relationships between feed composition and growth rates, concepts of overfeeding and water quality and the economic consequences of various feeding regimes and systems:

1. Type of Fish Feed – Commercial feed versus home-made feed, natural and supplementary feed, economic considerations, ecological/water quality considerations, feed conversion ratio.
2. Feeding methods.
3. Growth monitoring and feeding requirements.

The focus is on producing natural feed through fertilizing the ponds and the use of supplementary feed in extensive and semi-intensive production systems.

The importance of feed conversion ratio (FCR) and the calculation of feed cost (money spent on feed/kg fish produced). We expect the majority of farmers to be unable to afford industrial feed. For them, we will cover the **production and utilization of home-made feeds as alternative feed sources. The focus here is on**

using ingredients that are freely (or cheaply) available for the households and that can be used to supplement the natural food in the pond.

Module 6: Water quality and fish health

In this module, farmers learn how to monitor the health and growth of fish and appropriate interventions in feeding regimes and water quality management to mitigate fish growth and health issues

1. Fish survival rate measure
2. Water quality management
3. Fish disease management

Module 7: Fish harvesting, handling and transportation

Farmers are able to decide when and how to harvest the cultivated fish and can choose appropriate harvesting technologies for:

1. Harvesting techniques
2. Partial and selective harvesting
3. Full harvest, as per their economic and farming objectives and respective management requirements

Module 8: Monitoring and economic analysis of production

With the technical knowledge and skills gained in the preceding modules, participants will already have a good understanding of economic implications of their pond management. Record keeping tools such as growth and production monitoring and feed records will be revisited as integrated and comprehensive tools for accounting and economic analysis of the farm operations.

This will allow farmers to identify areas and approaches to reduce production costs and increase productivity and develop a better understanding of the economics of their fish farming operation. They will learn to keep management diaries or record books to monitor and analyze the economic progress of their production and the respective costs of feeding and management. By integrating fish growth, consumption and mortality into tools such as income and expenditure recording and calculation of revenues and profits, they will be able to evaluate their fish farming more realistically than looking only at production costs (such as costs of feed) and income generated from the sale of fish.

MODULE 1

1 MODULE 1: ECONOMIC PRINCIPLES OF FISH FARMING AND FARM PLANNING

Many small-scale fish farmers in Cambodia start engaging in fish farming without having a clear plan about what they want to achieve and what is required for successful fish farming.

However, such planning is important, as fish farming has some risks that need to be considered and be prepared for. Business planning helps to assess the economic potential of fish farming and its profitability. A good business plan may help in accessing finance for investment into the farm. The business planning process will involve an assessment of potential sites and their suitability, species and market assessment. Land, water, capital, a market, access to supplies and management skills are essential to successful fish farming. Business planning includes setting objectives, determining market potential, production feasibility and financial feasibility.

The tools and inputs presented in this module enable HHs to draft initial farm plans for their aquaculture operations. They can analyze their HH economics and assess the potential to integrate fish raising into their HH economy.

Learning Objective

This module aims to enable fish farmers to understand the economic implications of engaging in fish farming. They will understand basic economic principles of various production systems from extensive (low stocking densities) to intensive (high stocking densities), i.e., the respective investment requirements and potential returns and benefits. This will enable them to decide which system and which species is "right" for them.

1.1 HH INCOME AND EXPENDITURE ANALYSIS

In a first step, the farmers need to understand whether and how much their HH can invest in starting or expanding fish farming operations. They can assess their total HH income and determine how much of this they can spare to invest in aquaculture.

The **HH Income and Expenditure Analysis Tool** allows participants to identify and evaluate their main sources of income in cash and expenditure. By comparing income and expenses, HHs can determine how much they may be able to invest (additionally) in aquaculture operations and reconsider expenditures for potential savings.

During the training, participants will practice the tool in small groups and then be able to create an income and expense for their own respective HH.

This exercise is important, as many farming HH in rural Cambodia already are in debt and often need to borrow money for financing their respective livelihoods. Ideally, new and additional investments in fish farming should be financed without taking (further) loans and not increase the HH debt.

Table 1: Exercise - HH Income and Expenditure Analysis Tool

HOUSEHOLD INCOME AND EXPENDITURE ANALYSIS TOOL	
Objective	Participants understand the various revenue streams and expenditure of their respective HH
Method	Small-group work
Time	60 minutes
Who	All participants in small groups, facilitated by the trainer
Materials	Flipchart with example matrix

1. Ask the participants to list all activities that generate income and contribute to their HH livelihoods. Explain that activities that are dedicated to produce food for the HH are also to be listed (e.g., vegetable production) in the first column.
2. Ask them to estimate the income they are able to generate per year with each of these activities.
3. In the third column, they will list all major areas of expenditure and estimate the amount of expenditure spent on each of these items per year.

Table 2: Example calculation estimates HH yearly income & expenditure

SOURCES OF LIVELIHOOD AND INCOME	REAL INCOME (RIEL/YEAR)	EXPENDITURE ITEMS	REAL EXPENDITURE (RIEL/YEAR)
A1 Rice production		E1 Food	
A2 Daily labor		E2 Land lease	
A3 Vegetable production		E3 School	
A4 Livestock (chicken, pig, cattle) production		E4 Clothing	
A5 Cassava production		E5 Transport	
A6 Fish farming		E6 Debt servicing	
A7		E7...	
A8 ...		E8...	
Yearly total		Total expenditure	
Amount available to invest/spend on fish farming			
If Balance is negative: Sources of investment for fish farming			
S1: Reduced spending on/Saving Clothing			
S2: Reduced spending on...			

If the income is greater than the expenditure, ask them to consider how much of this they can or want to invest in aquaculture operations.

If the income is lower than the expenditure i.e., the balance is negative, they need to consider:

- In which areas they may be able to reduce their expenditure or in which areas they may be able to increase their income.
- Whether a temporary increase of their HH deficit for investment in aquaculture may lead to an increase of income that in the medium and long term can reduce the deficit and even lead to a profit.

Building the capacity to answer the last question and being able to decide on the economic role and contribution fish farming may play for an individual HH is the focus of the following sessions.

For some participants in the training, it may be too difficult to make the above estimates and fill in the table, particularly when estimating on an annual basis. In this case, ask them, how much money they can afford to spend on fish farming per month. This will help in deciding the production level, i.e., stocking density, they can afford. Often, farmers just want to stock many fish without understanding the management requirements and the economic and financial implications of high stocking densities. Many farmers stock their ponds at high densities and then are not able to afford feed and potentially other management inputs that would be required to achieve good and profitable farming results.

Taking a decision on stocking density requires an understanding of the basic principles and interrelationships between stocking density, feeding regimes and water quality management and the respective economic implications and financial requirements

1.2 BASIC PRINCIPLES OF INTENSIFICATION IN AQUACULTURE

Farm and business planning for pond and farm operations need to be based on the objectives, capacity and resources of the farmer. The production system (stocking density, species, feeding regime, etc.) that the farmer will establish needs to be able to farm the selected species at production costs that are lower than the potential sales value of the farmed fish at the end of the production cycle.

The farmer needs to set production targets in line with their financial and technical capacity and resources. Accordingly, an appropriate stocking density and respective feeding and management system will be developed and applied. Stocking density and potential production depend on the carrying capacity of a pond and the extent to which that carrying capacity can be increased through water quality management and feeding

However, increasing the carrying capacity of a pond through appropriate water quality management and feeding regimes requires higher investments and increases the risk of losing money in case of theft, flooding or diseases.

The number of fish the farmer is going to raise, that is, the stocking density, depends on the available resources and the farmer's economic capacity. Depending on the species chosen, stocking densities can vary considerably, and levels of intensification are fluid, but generally can be separated into extensive (low stocking densities), semi-intensive and intensive (high stocking densities).

Table 3: Basic production systems for aquaculture (extensive, semi-intensive and intensive)

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Extensive farming system

Low stocking density and dependency on natural feed. The very high protein content of the natural feed should be supplemented with some amount of freely and easily available carbo-hydrate rich inputs that are available on the farm like rice bran, maize bran, broken rice. If time allows additional feed can be collected like duckweed, Azolla, and termites. Some fish also feed on kitchen scraps/vegetables etc.).

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Figure 1: Extensive farming (Supplementary feeding with termites)

Source: GFA

1. Stocking density between of 0.5-2 fish/m^2
2. Management effort after releasing fingerlings focused on increasing natural productivity of the pond through fertilization
3. To supplement the available natural feed and make use of its high protein content, carbo-hydrate rich agricultural by-products such as rice bran can be used to feed the fish

Figure 2: Example of an extensively managed pond
Photo credit: Nget Touch/GFA, SAFR Project

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Semi-intensive

In this approach, the farmer relies to some extent on natural feed production in the pond through fertilization.

However, stocking densities are too high to rely on the protein from nature only and additional protein is needed to meet the nutritional requirements of the fish. This feed can be home-made or commercial feed. The farmer needs to carefully consider the costs of producing home-made feed (ingredients, time and effort).

The higher the stocking density, the lower the contribution of the natural feed. higher the feed requirements, and the farmer will reach a point, at which home-made feeds will have a negative impact on water quality. Well-formulated commercial feeds are digested much better by the fish and therefore produce less organic load in the pond.

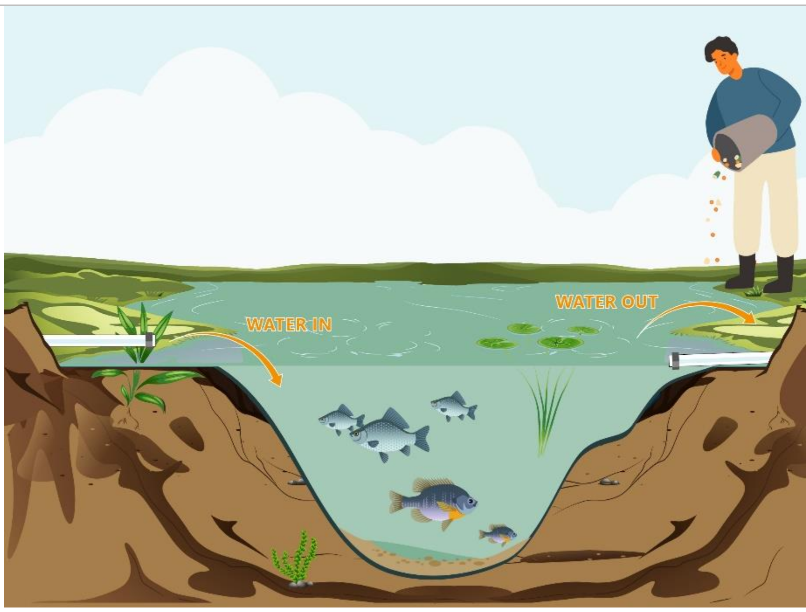


Figure 3: Semi-intensive farming
Source: GFA

1. Stocking density between of 3-5 fish/m^2
2. Management (application of fertilizer for creating natural food, exchange water if need, keep aquatic plants)
3. Regular feeding with formulated feed, which can be home-made or commercial

Figure 4: Example of a semi-intensively farmed pond
Photo credit: Theo Ebbers/GFA, SAFR Project

Intensive

High stocking densities and the use of commercial, pelleted feed.

Additional technical inputs such as installations and equipment for water management are needed, as oxygen becomes a limiting factor (if not culturing air breathing fish) and water quality may suffer from too much fish waste.

Figure 5: Intensive farming
Source: GFA

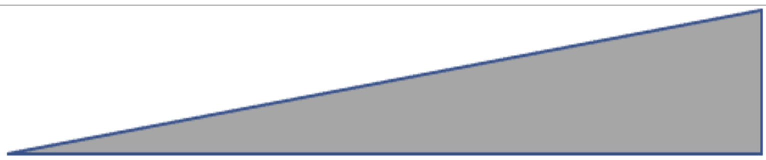
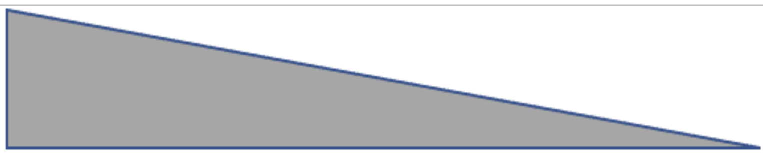
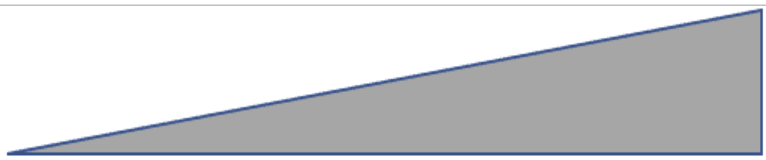
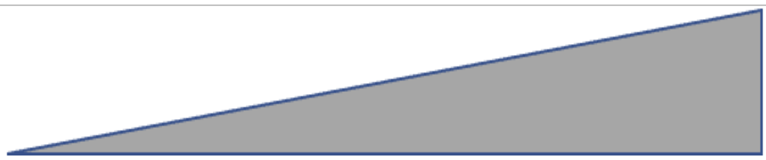
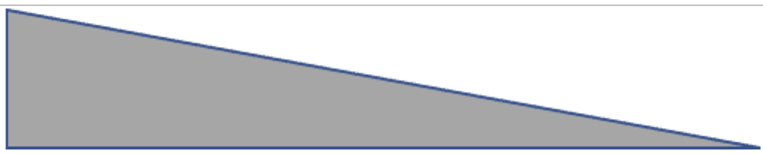
1. Stocking density between of 6-50 fish/m^2 or more depending on technical inputs
2. Regular water exchange, observe & monitor fish health and use water-treatment & medicine for infections, use mineral vitamins, install aeration system depending on fish species
3. Feed (regular and daily fish feeding with sufficient nutrients, usually commercial formulated feed)

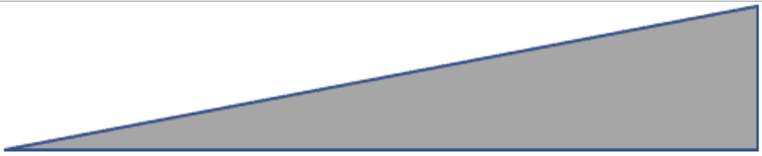
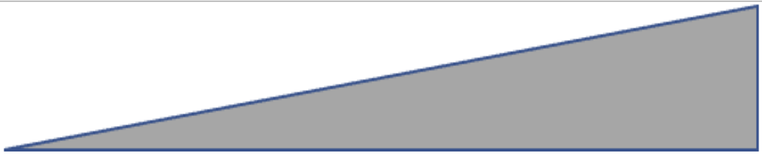
Figure 6: Example of an intensively farmed pond
Photo credit: Nget Touch/GFA, SAFR Project

The more intensive the production system, the more investment is needed and the higher the operation costs. While the overall production in intensive systems is high, the production costs (Riel/kg) is much higher than in extensive systems.

The trainer can visualize this relationship with the following chart. Sample production calculations for various species below further illustrate these relationships:

Figure 7: Principles of intensification in aquaculture

Low Socking Density		High Stocking density
High Contri-bution and dependency on natural feed		Low Contribution and dependency on natural feed
	With a low stocking density, the farmer can rely more on natural feed.	
Low de-pendence on artificial feed		High dependence on artificial and commercial feed
	At higher stocking densities farmer relies more on artificial and commercial feeds	
Lower risk		Higher risk
	With increasing stocking density and the required higher in-puts, there is an increasing risk for the farmer, because fish have a greater chance to suffer from water quality issues (oxy-gen deficiency, too high ammonia, unstable pH, etc.), also more diseases are found at higher stocking densities, preda-tion and theft may also increase.	
Profit per kg fish raised		
	With a low stocking densityand a high contribution of natural feed (no inputs of commercial feed) the total kg of fish per m^2 of pond is less, but the profit per kg of fish is high. **Left side you make more money/kg with less kg, and on the right side, you make less money/kg with more kg.**	With increasing effort, i.e. increasing inputs (investment in feed and

Increasing total profit potential		technology) production and profit can be increased up to a point at which any inputs do not generate additonal gains
	With a high stocking density the total profit per kg fish is less, but the quantity of fish is more. With high investment and good management overall profit can increase with increasing stocking density.	
Increasing technical economic capacity		
	To manage a fish pond with a high stocking density requires more capital to invest (e.g., in feed) and more technical knowledge and experience to manage the pond and maintain water quality.	

Using these guiding principles, farmers can identify the economic “sweet spot” that represents the appropriate level of investment for their respective business goals.

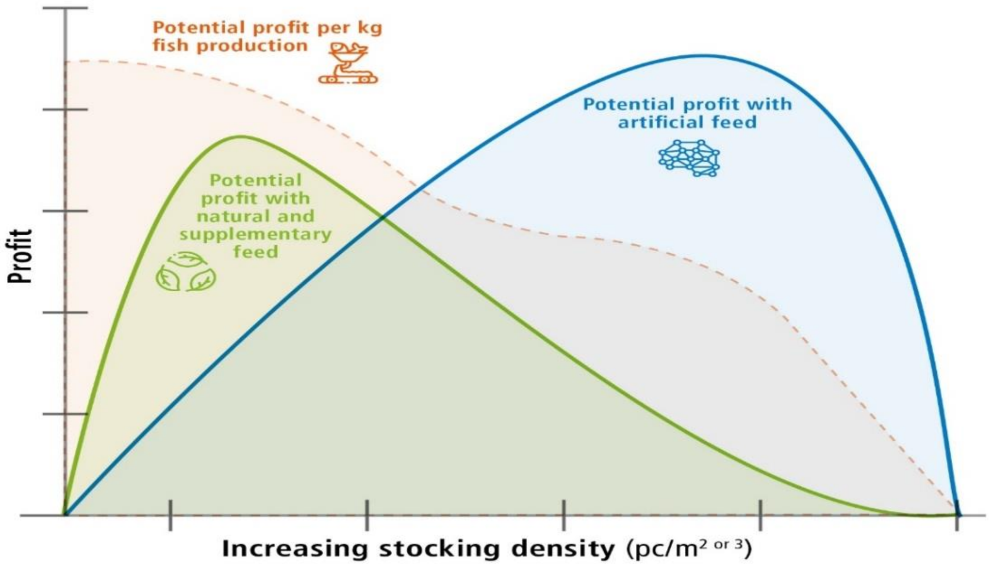


Figure 8: Increasing stocking density (pc/m$^{2 \text{ or } 3}$)
Source: GIZ

With little investment (natural and supplementary) feed, the farmer produces fewer fish with a higher profit per kg and less overall risk. When feeding artificial feed (also depending on the price of the feed), the investment increases significantly and farmers can run into debt as soon as the growth reduces due to e.g., poor water quality. This happens quickly at high stocking densities because oxygen and water quality suddenly become limiting factors for fish growth. Fish will still eat but will grow very little. The energy from the feed is spent to survive by fighting the poor living conditions. Little energy is left for growth. At this point, the blue curve quickly drops below zero profit.

1.3 BASIC FARM PLANNING

Stocking, feeding and harvesting need to be carefully planned, as these determine most of the cash flow of the HH or farm. If a farmer has several ponds, these can be stocked at different times; to spread the expenses for seed and feed. Income will also be spread over time if seasonality and availability of fingerlings allows. However, a disadvantage of this is that harvest and transport need to be done more frequently. Therefore, the farmer should look at his financial situation as well as the market to decide what the most suitable production plan is. Before buying seed, the stocking density needs to be decided. After a few batches, the farmer will know how fast the fish grow so that harvesting can be planned more carefully.

Before stocking, think of your objectives first. If you intend to sell your fish, find out what size of fish is preferred by the market and for what price you can sell the fish. Growing fish up to a size that is both profitable and easier to sell. Calculate the number of fish that can be stocked in the farm and the costs of the fingerlings. Then calculate the amount of feed you need for these fingerlings to grow to market size and the investment you have to make for this amount of feed.

If you set up a new aquaculture production, you need to have enough money to set up a farm, i.e., pond construction, preparation and stocking, buying the fingerilngs and feed until the first harvest. After your first harvest, you can use your earnings to buy new fingerlings and feed.

Do not wait to look for a market until the fish are ready to be sold. Before stocking the fish, you should already know that there is a market to sell the fish unless you want to eat all the fish yourself.

Use the sample calculations below to assess whether your ideas about fish farming and your desired goals are economically feasible and what you may need to adjust about your plan.

Before considering engaging in aquaculture, it is also helpful to prepare a basic activity calendar, such as the one below, to assess whether your other seasonal activities, such as rice farming, overlap with potential fish farming activities and whether you would have the financial and human resources needed for fish farming.

Table 4: Seasonal activity calendar

Work Plan Calendar for Fish Production													
#	Activities	J	F	M	A	M	J	J	A	S	O	N	D
2	Dig fish pond												
3	Prepare fish pond												
4	Stocking fish												
5	Raising fish period												
6	Harvest fish												
Farming activities													
	Rice field preparation												
	Rice planting												
	Rice harvest												
	Cashew nut management												
	Cashew harvesting												

Work Plan Calendar for Fish Production													
	Others….												
Water Availability													
	Rainy season												
	Dry season												
	High water levels (river, lake, ground water)												
Expenditure burden													
	Festive Season (Water Festival, Khmer New Year, Pchum Ben)												
	Wedding												
	Community ceremony												
	Beginning of School, uniform												
	Others….												

Exercise (60 min): Participants prepare seasonal activity calendar.

Divide the participants into groups of around 10 people and give each group flipchart paper. Ask the groups to prepare a table with 14 columns, with the first column for activities & events, 12 columns for the months of the year and 1 column for comments.

Ask them to list all important economic and farming activities, social events and festivals in first columns and highlight these in the respective corresponding monthly columns. Let them add comments as needed.

Let the groups present their calendars and in the plenary discussion ask them to discuss and identify those months which are "less busy" and where they have the capacity to engage in fish farming.

The trainer/facilitator then takes one of the group outputs and adds a typical fish farming calendar, considering issues such as:

- Pond construction at/during the dry season
- Preparation with the onset of the wet season
- Harvest at the beginning of the dry season

FARM PLANNING EXERCISES AND EXAMPLE OF PRODUCTION PLANNING CALCULATIONS

Ask the participants to answer the following questions:

1. What product or service will your aquaculture operation provide? (Selling good quality fish, production of fish for own consumption)
2. Who will be your customers? (fish traders, hotels, supermarkets, your own HH)
3. Why will your customers buy from your business rather than from our competitors? (good size, high quality fish)
4. Will you plan in days, weeks or months? (as per growing cycle of fish)
5. What important equipment and supplies will be needed and what will they cost? (digging tools, feeds, seed)
6. What is your best guess of the total sales and expenses for each period? (How much are seed, feed and how much do you sell fish for?)
7. How much money is needed to start the business and keep it running until it makes a profit?
8. Who is going to provide this money? (farmer, loan)
9. Who is starting the business and what skills do they have that should enable them to succeed? Do they need training? Does the person have the right mind-set and attitude to start a business?

The tools and templates below will support farmers to draft basic farm plans that are appropriate for their respective levels of operations, including options for scaling up.

The example calculations provided below also are designed to further help the farmer understand the economic implications of different production levels (extensive, semi-intensive, intensive).

Table 5: Example of a simple production plan

Size of fish for market	At what size will you sell your fish?	500g
Growing period (months)	How long do farmers take/plan to grow their fish to this size?	10 months
Size of pond	Total area of the pond	600sqm
Stocking density/number of fish	2/sqm	1,200 total number of fish
Survival rate	90%	1,080 surviving fish
Harvest goal (total kg to be harvested)	How many kg in total is the expected harvest	1,080 fish & 0.5kg = 540kg
Amount of feed needed	Assume Natural feed, with some supplementary feed that is available to the HH	N/A
Cost of feed	Assume some cost of getting/applying some feed-supplements (such as solar light for attracting insects, feeding trays, transportation of feeds)	400,000KHR – 100$
Cost of seed	1,200 fingerlings 200KHR/fingerling	200KHR * 1,200 = 240,000KHR = ca 60$
Other costs	Transportation, equipment (nets for fencing, lime for pond preparation etc.) (Green net, lime, transportation, electricity, labor etc.)	400,000KHR – 100$
Total cost		1,040,000KHR – 260$
Potential sales	800g/fish * 1,080 fish @ 10,000KHR/kg	5,400,000KHR – 1,350$

Potential total profit	Potential sales – Total cost	5,400,000KHR – 1,040,000KHR = 4,360,000KHR – 1,900$

To help participants understand this example production plan and develop a plan that is suitable for them, i.e., a plan that is within their financial capacities and meets their fish farming objectives, below are some example calculations for four species (Tilapia, Walking Catfish, Striped Catfish/Pangasius and Silver Barb) at three different production levels, i.e., extensive, semi-intensive and intensive.

With these sample calculations, farmers can see and estimate the input costs required for these different production systems and use these in supporting their decision-making process of which species and which production system to use, based on the level of investment they can afford with the financial resources they have.

They show that, generally, extensive, natural-feed based systems are providing higher returns per kg of fish produced and are more suitable for farmers who cannot afford high investments.

Such systems are more appropriate, if farmers' main purpose of farming fish is to produce fish for their own consumption, and if they do not have much financial resources to invest in fish farming. The income through the potential sales in these examples is "indirect" income, as it represents the value of the fish consumed by the farmers and their HH.

Semi-intensive systems are suitable for farmers who have more financial resources to invest and are aiming to sell most of their fish.

Intensive systems, as shown in the calculations below, require comparatively large investments, and only farmers who are able to make these investments should consider these.

Table 6: Case 1 Tilapia – Comparison of extensive, semi-intensive and intensive production systems

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Size of fish for market What size will you sell your fish?	0.5kg	0.5kg	0.5kg
Growing period (months) How long do farmers take/plan to grow their fish to this size?	10 months	8 months	7 months
Size of the pond Total area of the pond (m^2)	600sqm	600sqm	600sqm
Stocking density/number of fish (m^2)	0.5 head	3 heads	6 heads
Total fish per pond (Head)	300	1,800	3,600
% Survival rate	95	90	80
Harvest goal (total kg to be harvested) How many kg in total is the expected harvest?	Example stocking density 0.5 head/sqm and targeted fish weigh 0.5kg/head. 300*95/100*0.5=**142.5kg**	Example stocking density 3 head/sqm and targeted fish weigh 0.5kg/head. 1,800*90/100*0.5=**810kg**	Example stocking density 6 head/sqm and targeted fish weigh 0.5kg/head. 3,600*80/100*0.5=**1,440kg**

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
(# stocked fish×% survival/100 ×targeted fish weight)			
Amount of feed needed (kg) Assume FCR 1,5 Commercial Feed and 2.5 for home-made feed (FCR×total target weight of fish production)	N/A	Option A 810kg * 3.5 = 2,835kg	1,440kg x 1.5 = 2,160kg
Total cost of feed (Riel) (total feed×price/kg) Home-made feed 1.500 ៛/kg Commercial feed: 3500 ៛/kg	0	2,835×1,500៛ =4,252,500KHR (1,063.1$)	(2,160×3500KHR =7,560,000KHR (1,890$)
Total cost of seed (KHR) (Total stocked fish ×price/head)	220KHR/fish × 300 fish = 66,000KHR (16.5$)	220KHR × 1,800 fish = 396,000KHR (99$)	220KHR×3,600 fish = 792,000KHR (198$)
Other costs (KHR) (pond fence net, lime, transportation, electricity, labor etc.)	200,000KHR (50$)	400,000KHR (100$)	600,000KHR (150$)
Total expenditure cost (KHR) Cost of feed + cost of seed + other costs	266,000KHR (66.5$)	5,048,500KHR (1,262.1$)	8,952,000KHR (2,238$)
Total potential income (KHR) (total fish production× expected fish price/kg)	142.5kg×8,000KHR = 1,140,000KHR (285$)	810kg×8,000KHR = 6,480,000KHR (1,620$)	1,440kg×8,000KHR = 11,520,000KHR (2,880$)
Potential profit (KHR) (Total potential income-total expenditure cost)	1,140,000KHR -266,000KHR = 874,000KHR **(218.5$)**	6,480,000KHR - 5,048,500KHR = 1,431,500 KHR **(357.9$)**	11,520,000KHR - 8,952,000KHR = 2,568,000KHR **(642$)**
Profit per 1$ spent : 1$ spent gain XXX$ = (Profit / total expenditures) Production cost per kg = (total cost/expected kg) Profit per kg = (Potential profit/expected kg)	3.3$ 0.47$ 1.5$	0.3$ 1.6$ 0.44$	0.3$ 1.5$ 0.45$
Exercise	Participants calculate for 1/sqm and targeted fish weight 1kg/head	Participants calculate for 5/sqm and targeted fish weight 1kg/head	Participants calculate for 10/sqm and targeted fish weight 1kg/head

Table 7: Case 2 Walking Catfish – Comparison of extensive, semi-intensive and intensive production systems

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Size of fish for market What size will you sell your fish?	0.2kg	0.2kg	0.2kg
Growing period (months) How long do farmers take/plan to grow their fish to this size?	10 months	8 months	6 months
Size of pond Total area of the pond (m^2)	600sqm	600sqm	600sqm
Stocking density/number of fish (m^2)	1 head	5 heads	30 heads
Total fish per pond (Head)	600	3,000	18,000
% Survival rate	90	85	80
Harvest goal (total kg to be harvested) How many kg in total is the expected harvest (# stocked fish×% survival/100 ×targeted fish weight)	Example stocking density 1 head/sqm and targeted fish weigh 0.2kg/head. 600*90/100*0.2=108kg	Example stocking density 5 head/sqm and targeted fish weigh 0.2kg/head. 3000*85/100*0.2=510kg	Example stocking density 30 head/sqm and targeted fish weigh 0.2kg/head. 18,000*80/100*0.2=2,880kg
Amount of feed needed (kg) Assume FCR 1,5 Commercial feed and 2.5 for home-made feed (FCR×total expected weight of fish production)	N/A	1,785kg	4,320kg
Total cost of feed (Riel) (total feed×price/kg)	0	1,785×1,500៛ = 2,677,500KHR (669.4$)	2430×3,500៛ = 15,120,000KHR (3,780$)
Total cost of seed (KHR) (Total stocked fish ×price/head)	150KHR × 600 fish = 90,000KHR (22.5$)	150KHR×3,000 fish = 450,000KHR (112.5$)	150KHR×18,000 head = 2,700,000KHR (675$)
Other costs (KHR) (pond fence net, lime, transportation, electricity, labor etc.)	200,000KHR (50$)	400,000KHR (100$)	600,000KHR (150$)
Total expenditure cost (KHR) Cost of feed + cost of seed + other costs	290,000KHR (72.5$)	3,527,500KHR (881.2$)	18,420,000KHR (4,605$)
Total potential income (KHR)	108kg ×10,000KHR = 1,080,000KHR (270$)	510kg×10,000KHR = 5,100,000KHR (1,275$)	2,880kg×10,000KHR = 28,800,000KHR (7,200$)

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
(Total fish production× expected fish price/kg)			
Potential profit (KHR) (Total potential income-total expenditure cost)	1,080,000KHR - 290,000KHR = 790,000KHR (197.5$)	5,100,000KHR-3,527,500KHR = 1,572,500KHR (393.2$)	28,800,000KHR-18,420,000KHR = 10,380,000KHR (2,595$)
Profit per 1$ spent : 1$ spent gain XXX$ = (Profit / total expenditures) Production cost per kg = (total cost/expected kg) Profit per kg = (Potential profit/expected kg)	1.5$ 0.7$ 1.8$	0.5$ 1.7$ 0.8$	0.56$ 1.6$ 0.90$
Exercise	Participants calculate for 2 fish /sqm and targeted fish weight 0.2kg/head	Participants calculate for 5 fish/sqm and targeted fish weight 0.2kg/head	Participants calculate for 50/sqm and targeted fish weight 0.2 kg/head

Table 8: Case 3 Striped Catfish/Pangasius (Trey Pra) – Comparison of extensive, semi-intensive and intensive production systems

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Size of fish for market What size will you sell your fish?	1kg	1kg	1kg
Growing period (months) How long do farmers take/plan to grow their fish to this size?	10 months	9 months	8 months
Size of pond Total area of the pond (m^2)	600sqm	600sqm	600sqm
Stocking density/number of fish (m^2)	0.5 head	3 heads	30 heads
Total fish per pond (Head)	300	1,800	18,000
% Survival rate	95	90	85
Harvest goal (total kg to be harvested) How many kg in total is the expected harvest (# stocked fish×% survival/100 ×targeted fish weight)	Example stocking density 0.5 head/sqm and targeted fish weigh 1kg/head. 300*95/100*1=285kg	Example stocking density 3 head/sqm and targeted fish weigh 1kg/head. 1800*90/100*1=1,620kg	Example stocking density 30 head/sqm and targeted fish weigh 1kg/head. 18,000*85/100*1=15,300kg

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Amount of feed needed (kg) Assume FCR 1,5 Commercial Feed and 2.5 for home-made feed (FCR×total weight of expected fish production)	N/A	5,670	22,950
Total cost of feed (Riel) (total feed×price/kg)	0	5,670×1,500៛ = 8,505,000KHR(2,126.3$)	(22,950×3,500៛ = 80,325,000KHR (20,081$)
Total cost of seed (KHR) (Total stocked fish ×price/head)	120KHR×300 fish = 36,000KHR (9$)	120KHR×1,800 head = 216,000KHR (54$)	120KHR×18,000 head = 2,160,000KHR (540$)
Other costs (KHR) (pond fence net, lime, transportation, electricity, labor etc.)	200,000KHR (50$)	400,000KHR (100$)	600,000KHR (150$)
Total expenditure cost (KHR) Cost of feed + cost of seed + other costs	236,000KHR (59$)	9,121,200KHR (2,280$)	83,085,000KHR (20,771$)
Total potential income (KHR) (total fish production× expected fish price/kg)	285kg×6,000KHR = 1,710,000KHR (427.5$)	1,620kg×6,000KHR = 9,720,000KHR (2,430$)	15,300kg×6,000KHR = 91,800,000KHR (22,950$)
Potential profit (KHR) (Total potential income-total expenditure cost)	1,710,000KHR-236,000KHR = 1,474,000KHR (368.5$)	9,720,000KHR-9,121,200KHR = 598,800KHR (149.7$)	91,300,000KHR-83,085,000KHR = 8,715,000KHR (2,179$)
Profit per 1$ spent : 1$ spent gain XXX$ = (Profit / total expenditures) Production cost per kg = (total cost/expected kg) Profit per kg = (Potential profit/expected kg)	6.3$ 0.21$ 1.3$	0.07$ 1.41$ 0.09$	0.11$ 1.36$ 0.14$
Exercise	Participants calculate for 1/sqm and targeted fish weigh 1,5kg/head	Participants calculate for 5/sqm and targeted fish weigh 1,5kg/head	Participants calculate for 20/sqm and targeted fish weigh 1,5kg/head

Table 9: Case 4 Silver Barb – Comparison of extensive, semi-intensive and intensive production systems

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Size of fish for market What size will you sell your fish?	0.3kg	0.3kg	0.3kg
Growing period (months)	10 months	6 months	5 months

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
How long do farmers take/plan to grow their fish to this size?			
Size of pond Total area of the pond (m^2)	600sqm	600sqm	600sqm
Stocking density/number of fish (m^2)	0.5 heads	3 heads	6 heads
Total fish per pond (Head)	300	1,800	3,600
% Survival rate	95	90	80
Harvest goal (total kg to be harvested) How many kg in total is the expected harvest (# stocked fish×% survival/100 ×targeted fish weigh)	Example stocking density 0.5 head/sqm and targeted fish weigh 0.3kg/head. 300*95/100*0.3=85.5kg	Example stocking density 3 head/sqm and targeted fish weigh 0.3 kg/head. 1800*90/100*0.3=486kg	Example stocking density 6 head/sqm and targeted fish weigh 0.3 kg/head. 36,00*80 /100*0.3= 864kg
Amount of feed needed (kg) Assume FCR 1,5 Commercial Feed and 2.5 for home-made feed (FCR×total weigh of fish production)	Assume freely available carbo-hydrate rich agricultural byproducts @ no costs	486kg x 3.5= 1,701kg	864kg x 1.5 = 1,296kg
Total cost of feed (Riel) (total feed×price/kg)	0	1,701kg×1,500KHR = 2,551,500KHR (637.9$)	1,296kg×3,500KHR= 4,536,000KHR (101,134$)
Total cost of seed (KHR) (Total stocked fish ×price/head)	220KHR×300 fish=66,000KHR (16.5$)	220KHR×1,800 fish = 396,000KHR (99$)	220KHR×3,600 fish = 792,000KHR (198$)
Other costs (KHR) (pond fence net, lime, transportation, electricity, labor etc.)	200,000KHR (50$)	400,000KHR (100$)	600,000KHR (150$)
Total expenditure cost (KHR) Cost of feed + cost of seed + other costs	266,000KHR (66.5$)	3,347,500KHR (836.9$)	5,928,000KHR (1,482$)
Total potential income (KHR) (total fish production× expected fish price/kg)	85.5kg× 10,000KHR = 855,000KHR (213.8$)	486kg× 10,000KHR = 4,860,000KHR (1,215$)	864kg× 10,000KHR = 8,640,000KHR (2,160$)
Potential profit (KHR) (Total potential income-total expenditure cost)	855,000 HR-266,000KHR = 589,000KHR (147.3$)	4,860,000KHR- 3,347,500KHR = 1,512,500KHR (378.1$)	8,640,000KHR- 5,928,000KHR = 2,712,000KHR (678$)
Profit per 1$ spent	1.5$	0.5$	0.5$

FACTOR	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
Production cost per kg = total cost/expected kg Potential profit/ kg	0.8$ 1.7$	1.71$ 0.8$	1.71$ 0.8$
Exercise	Exercise: participants calculate for 2/sqm and targeted fish weigh 0.5kg/head	Exercise: participants calculate for 5/sqm and targeted fish weigh 0.5kg/head	Exercise: participants calculate for 10/sqm and targeted fish weigh 0.5kg/head

As mentioned above, these examples help the farmers to understand the financial requirements and economic implications of different production systems. At a first glance, the total possible profits in intensive culture systems may seem to be attractive for the farmers. However, a look at the production cost required and the return per USD spent on production shows that high stocking densities mean high input costs, often of several thousand USD. Most small-scale farmers will not be able to afford this. During the previous exercise, they estimated how much they can afford to spend on fish farming and they can now compare and check, whether the amount available for fish farming is sufficient to sustain production at a high stocking density.

This issue of increasing input costs is exacerbated when considering the increasing risk of intensifying production. Risks in aquaculture range from risks of production, like floodings, theft of fish, disease and predators to market risks like low market prices at the time of harvest or spoilage of the produce during transportation to the pace of sales. To include risks into the calculation for potential profits, it is advisable to discuss how often what type of risk are encountered. How many floodings of your pond did you see in the last 10 years? How often did predators (e.g., birds) come to your pond and feed on the fish? How frequently is fish stolen from aquaculture ponds. With this information you can estimate how often your production will fail. Assuming a total loss of all fish every 5 years would convert into a risk of 20%. Especially for intensive systems the inclusion of potential risks is important, because the investment during production cycle is often in the same range or even larger than the income from the sales of the fish. If one production is lost, not only the income from that year is lost, but also the income from next year, because expenditures from the failed crop need to be recovered. For a more realistic estimation the respective production costs should be increased or the income reduced accordingly.

Some farmers may consider taking loans from micro-finance institutions (MFI), but then need to include the interest rate into the production cost, thus further reducing the return per USD spent. Depending on the MFI and the loan products they are offering, loans can range between 5,000USD – 200,000USD at monthly interest rates of 0.9% to 2%. For the majority of farmers who constitute the participants of this training, these loan products are likely to be unsuitable.

When looking at the total estimated cost and risks, as outlined above, farmers need to ask themselves what level is appropriate for their respective HH, i.e., whether they have the required financial resources. To improve the participants' understanding of these relationships between production systems, costs and potential benefits and risks, it is important that the farmers practice these calculations for different stocking densities, target size/weight, feed prices/costs, sales prices and risks. They can and should use figures from their own farm, such as the size of their ponds. Take note, that an increase of the target weight will most probably mean a higher market price can be expected, but also a longer period of feeding, probably with less growth when fish become very big and increasing risks.

Participants can use copies of the template below for further practicing these example calculations.

Here they can and should be encouraged to also calculate for other popular species, such as Climbing Perch, Silver Carp, Common Carp, and Indian Carp as well, based on current local market prices.

Table 10: Template for sample farm plan calculation

	KEY PLANNING QUESTIONS	ANSWERS
Size of fish for market/consumption	At what size will you harvest your fish?	
Growing period (months)	How long do farmers take/plan to grow their fish to this size?	
Size of pond	Total area of the pond	
Stocking density/number of fish	# of fish per sqm of pond	
Survival rate	What is the expected survival rate (90% - 80%)	
Harvest goal (total kg to be harvested)	How many kg in total is the expected harvest	
Amount of feed needed	Choose one of the options below Option A: Assume Natural feed, with some supplementary feed that is available to the HH Option B: Natural feed + home-made feed (FCR 3.5) Option C: Pelleted commercial feed, Assume FCR 1.5	
Cost of feed	As per the option chosen above	
Cost of seed	What is the expected cost of fingerlings?	
Other costs	Transportation, electricity, labor, equipment (nets for fencing, lime for pond preparation etc.)	
Total cost	Cost of feed + Cost of seed + other costs	
Potential sales	Expected market price/value per kg of fish * total expected production	
Potential total profit	Potential sales – total costs	

1.4 SELECTION OF SPECIES

Before engaging in fish-raising operations and starting fish farming, potential fish farmers and interested HH should consider and decide which species they want to cultivate. While the technical content of the following modules is rather generic and can be applied to raising various species, different species have different cultivation requirements and thus economic consequences for the farming operations.

In species selection, economic considerations such as market value of fish, "robustness" and resilience to changes in water quality, temperature, feeding regimes and type of feeds, potential growth rates and harvesting cycles need to be considered.

KEY PRINCIPLES AND CRITERIA OF SPECIES SELECTION

1. Which are popular preferred species by the consumer and have a high demand?
2. Which species have a good market value?
3. Which species are locally available (hatcheries/nurseries)?
4. Species that are resilient to changes in the water quality.
5. Species that have short growth cycles.
6. Species that do not have demanding feed requirements.

Table 11: Overview of popular fish species in Cambodia

NO	SPECIES	DESCRIPTION
1	 Silver Barb ត្រីឆ្ពិន	**Silver Barb** is an indigenous species with a good market value. Marketable weight of 0.3-1kg per fish can be achieved in 6-10 months, depending on culture system. Silver Barb is low tolerant to water quality fluctuations such as pH and temperature and does not take low oxygen levels as well. As an herbivorous species, it can easily be farmed in extensive systems and semi-intensive based on natural feed and supplementary feed such as plankton, earthworm, termites, algae, vegetable leave, tree leave, morning glory, duckweed etc. It can feed with supplementary feed, home-made or commercial feeds with an optimal protein content of 23 to 25%. In general, it cannot reproduce in aquaculture ponds. It prefers to live at upper and middle level of water. Suitable for both extensive and semi-intensive farming in poly-culture mixing Tilapia and Carp with good returns on investment. ▪ Growth 0.2-0.5kg/year; ▪ Mature age at 8 months; ▪ In pond culture with pond depth: 1.3 to 1.8m. Polyculture system is better than monoculture system.
2	 Tilapia/ត្រីទីឡាព្យ៉ា	**Tilapia** is an exotic species with a good market value. Marketable weight of 0.5-1kg per fish can be achieved in 8-10 months, depending on culture system. Tilapia has low tolerance to water quality fluctuations such as pH and temperature and does not take low oxygen levels well. As an omnivorous species, it can easily be farmed in extensive and semi-intensive systems. Its natural feed consists of plankton, algae, worms, termites, snails, crabs, insects, duckweeds, Azolla, vegetables, tree leaves and zoobenthos. Supplementary feeds like rice bran, maize bran, broken rice improves the utilization of natural feeds. For more intensive production maize, soybean meal, fishmeal, wheat flour, etc. must be added, or use commercial feed with an protein at 16 to 40%. This species is the mouth breather that prefers to live at the upper water body but is able to live in all layers of water. It is a prolific reproducer (spawning 6-10 times per year) and thus a potentially good fish for continuous harvest. However, the fast reproduction rate requires significant management efforts. Suitable for both extensive and semi-intensive farming with poly-culture systems and produces good returns on investment. Mature age at 4-6 months; and spawns 6 to 11 times/year. Reproduction is inhibited at water temperatures below 20ºC, slow in waters of 21 to 24ºC and most frequent in waters above 25ºC. Optimum temperature 25-30ºC for reproduction and growth. ▪ Optimal pH 5.6-6 and can live at ranges between 4-9 ▪ Optimal temperature 24-30ºC and can live 11-39º C ▪ Growth performance of 0.3-1kg/year, depending on culture system and feeding regimen. ▪ Intensive pond culture (pond depth: 1.5-2.5m).

NO	SPECIES	DESCRIPTION
3	 Stripped Catfish (Trey Pra)/ត្រីប្រា	**Striped Catfish (Trey Pra)** is an indigenous species. Marketable weight of 0.5-2kg per fish can be achieved in 6-10 months, depending on culture system. It is tolerant of water quality fluctuations such as pH, temperature and low oxygen levels as well. This species can breathe air, so oxygen levels are less important and is why this species is often cultured at very high densities. As an omnivorous species, it can easily be farmed in semi-intensive and intensive systems with additional feeding using home-made feed made of rice brain, maize, soybean meal, fishmeal, wheat flour, etc. or commercial feeds with optimal protein content from 26 to 30%. It prefers to live at middle and bottom layers of water bodies but can live in all layers of water. It cannot reproduce in an aquaculture ponds. Suitable for both semi-intensive and intensive farming with monoculture system. ▪ Growth 1-1.5 kg/year; ▪ Mature age 2 years; ▪ Intensive pond culture with pond depth: 1.5-4m.
4	 Walking Catfish/ត្រីអណ្តែង	**Walking Catfish** is an indigenous species. Marketable weight of 0.1-0.2kg per fish can be achieved in 5-7 months depending on culture system. It is tolerant of water quality fluctuations such as pH, temperature, low oxygen levels and polluted water as well. This fish is an omnivorous species and can breathe air. It can easily be farmed in semi-intensive and intensive systems with feeding additional home-made feed made of rice brain, maize, soybean meal, fishmeal, wheat flour, etc. or commercial feeds with optimal protein content from 30 to 40 %. It prefers to live at the bottom of water bodies but is able to live in all layers of water. It cannot reproduce in aquaculture ponds. Suitable for both semi-intensive and intensive farming with monoculture system. ▪ Mature age between 8 to 12 months, spawned 2-3 times/year; Spawn season ranges from April to September. However, optimal spawning is May to July; ▪ Growth performance of 150-250g per year; ▪ In intensive culture with pond depth: 1.8-2.5m.
5	 Silver Carp/ត្រីកាបស	**Silver Carp** is an exotic species with a good market value. Marketable weight of 1-2kg per fish can be achieved in 6-12 months, depending on culture system. Silver Carp has a low tolerance to water quality fluctuations such as pH and temperature and does not take low oxygen levels well. This fish is herbivorous and a filter feeder. Main natural feed consists of zooplankton and phytoplankton. It prefers to eat plankton at the surface. Silver Carp consume diatoms, dinoflagellates, chrysophytes, xanthophytes, some green algae and cyanobacteria (blue green algae), detritus, conglomerations of bacteria, rotifers and small crustaceans are other major components of their natural diet. In general, they do not reproduce in aquaculture ponds. They prefer to live in the upper and middle water layers. Suitable for both extensive and semi-intensive farming in polyculture system. This is better than monoculture systems where mixing Tilapia and Carp can provide good returns on investment. ▪ Growth 0.5-1kg/year; ▪ Mature age at early year 2; ▪ In pond culture, pond depth: 2 to 3m.

NO	SPECIES	DESCRIPTION
6	 Common Carp/ត្រីកាបសាមញ្ញ	**Common Carp** is an exotic species that lives at the bottom water of the water body. Usually seen in the rivers, lakes, streams, reservoirs etc. It has a good market value. Marketable weight of 0.5-1.5kg per fish can be achieved in 6-8 months, depending on culture system. Common carp has a low tolerance to water quality fluctuations such as pH and temperature and does not take low oxygen levels well. This fish is an omnivorous species and in nature fish can feed on stalks, leaves and seeds of aquatic and terrestrial plants, decayed aquatic plants, snails, crabs, worms, termites, insects, planktons, benthic organisms, and plant material, etc. Good production can be achieved by supplementing natural feed with carbohydrate rich byproducts from agriculture, like rice bran, maize bran or broken rice. At a higher stocking density carp can be fed with commercial feed or home-made feed made from rice brain, maize, bean, meat composition, etc. with protein content of 30-38%. In general. it cannot reproduce in aquaculture ponds. Suitable for both extensive and semi-intensive farming in polyculture systems where mixing Tilapia and Carp can provide good returns on investment. ▪ Mature age at 10 months; ▪ Weight 0.5-1kg/year; ▪ In pond culture, pond depth: 1.5 to 2m, in polyculture system is better than monoculture system.
7	 Indian Carp/ត្រីកាបឥណ្ឌា	**Indian Carp** is an exotic species with a good market value. A marketable weight of 0.5-1kg per fish can be achieved in 6-10 months, depending on the culture system. Indian carp has a low tolerance to water quality fluctuations such as pH and temperature and does not take low oxygen levels well. This fish is an omnivorous species. In nature it can feed on aquatic plants, snails, crabs, worms, termites, insects, duckweeds, Alzola, meat composition, etc. As for supplementary feed, it can consume commercial feed and home-made feed such as rice bran, maize, soybean meal, fishmeal etc. with optimal protein contains of 28-35% crude protein. In general, it does not reproduce in aquaculture ponds. It prefers to live at the bottom level of water. Suitable for both extensive and semi-intensive farming in polyculture systems. Indian carp is often combined with other carp species and feeding on different natural feeds. It can also be combined with Tilapia with good returns on investment. ▪ Mature age at month 16; ▪ Weight 0.5-0.7kg/year, but in the second-year growth fast around 2-3kg, in the marketable size: 1-2kg; ▪ In pond culture (pond depth: 1.3 to 1.5m), in larger production ponds, water can be maintained at a depth of 2 to 3m
8	 ត្រីក្រាញ់ (Climbing Perch)	**Climbing Perch** is an indigenous species that has high market demand. Climbing Perch is predominantly carnivorous and consumes protozoans, crustaceans, insects, worms, and fish larvae. It prefers to live at the low level of water, sometimes they move to upper and middle water level; It can be farmed in extensive systems, but because of its feed requirements semi-intensive and intensive culture systems using formulated feed are recommended. Formulated feed should have a protein content of 30% for grow out to 40% for rearing larvae or fry

NO	SPECIES	DESCRIPTION
		larvae. Depending on the culture system, a marketable size of 0.2-0.3kg can be achieved in 4-6 months ▪ Mature age from 6 to 8 months depending on food regimes; ▪ In general, it can reproduce in aquaculture ponds; ▪ Required pond depth: 1.2 to 1.5m; ▪ Climbing Perch is highly tolerant of water quality fluctuations such as pH, temperature, and low oxygen levels, as it can breathe air. ▪ This fish can walk out or escape the pond if the farmer does not fence their fishpond properly. Especially in the rainy season fish will try to get out of the pond.

SPECIES SELECTION EXERCISE

To decide which species to select, farmers can use the following matrix. Depending on their main farming objective, they can approach the criteria by asking questions such as below and assign scores 2 = Good, 1 = not so good 0 = not good

1. Which species has a good market value? Selling price: Good (2), not so good (1), Not good (0)
2. Do I want or need my fish to grow fast because I do not have water supply throughout the year? Is the species good for short culture period? Good (2), not so good (1), Not good (0)
3. Do I want a species that reproduces in the pond (because I want to do continuous harvesting for my own consumption)? Is the species good for reproduction in the pond? Good (2), not so good (1), Not good (0)
4. Are good quality fingerlings available nearby? Good = nearby, far = Not good. Good (2), not so good (1), Not good (0)
5. Is the species tolerant to high oxygen levels, changing water quality and high stocking densities? (Because there are seasonal water quality, changes and changes of water level in the pond) Good (2), not so good (1), Not good (0)
6. Which species is easier to feed? Good (2), not so good (1), Not good (0)
7. Which species has the higher output/production (kg) per sqm pond at low stocking densities? Good (2), not so good (1), Not good (0)
8. Which species has the higher production cost of feed per sqm pond at high stocking densities? Good (2), not so good (1), Not good (0)

Table 12: Species selection matrix

SELECTION CRITERIA	SPECIES					
	TILAPIA	STRIPED CATFISH	SILVER BARB	WALKING CATFISH	CLIMBING PERCH	SILVER CARP
Market value						
Culture period						
Reproduce in the pond						
Pond depth (shallower vs. deeper)						
Availability of fingerlings/seed						
Tolerant to low oxygen levels and high stocking densities						
Tolerant to water quality changes						
Easy to feed with natural feed & supplementary feed (lower protein demand)						
Higher output/growth per sqm pond at low stocking densities (natural feed dependence)						

SELECTION CRITERIA	SPECIES					
	TILAPIA	STRIPED CATFISH	SILVER BARB	WALKING CATFISH	CLIMBING PERCH	SILVER CARP
Production cost at high stocking densities						
Score						

By assigning a value of 2, 1, or 0 (to each species for each of these criteria and adding these, the farmer can reduce the choice of species, ideally to 1 favorite species. If several species are 'short-listed' with the same score, availability of quality fingerlings might be the deciding factor.

With these inputs and exercises above, prospective fish farmers are expected to have a good understanding of what to expect when starting fish farming operations. While based on estimates, the above calculations allow the prospective farmer to assess what level of production and production system is appropriate for them, i.e., matches their objectives and is affordable. Participants who are already engaged in fish farming and use the above tools to assess the consequences of making changes to their production systems, such as changing the species or increasing/decreasing the stocking density.

In the next module, prospective farmers will be familiarized with basic principles for pond site selection and pond construction.

1.5 SESSION PLAN OUTLINE MODULE 1

Module 1 is essential for understanding some basic principles of intensification of fish farming and for enabling the participants to make decisions in what level and of aquaculture they want to engage, i.e., which species at what stocking density they can afford to start producing.

Table 13: Session plan outline (full day training)

#	CONTENT/ACTIVITIES	METHODOLOGIES	MATERIAL REQUIRED	TIME ALLOCATION
1	Explaining the purpose of the session: Participants understand their capacity and available resources to engage in fish farming	Input – speech by trainer		10 min
2	Exercise: household income and expenditure matrix	Small group work and individual farmers At the end of the exercise, ask each farmer to take note of how much they can spend every month on fish farming	Flipchart with example matrix (see Table 2)	30 min
3	Basic principles of intensification in aquaculture	Game, plenary	Maybe candies, paper snippets which represent fish feed	30 min
		▪ Draw or outline a rectangular on the floor of the training room (depending on the location, draw on the ground, use a rope, or use chairs to indicate the bound-		

#	CONTENT/ACTIVITIES	METHODOLOGIES	MATERIAL REQUIRED	TIME ALLOCATION
		aries/walls of a fishpond; using chairs to "build a wall" would be ideal), also depending on the space available around 2 meter x 3 meter. This rectangular represents the fish pond. ▪ Ask 2-3 participants to be fish to enter the pond and swim around (simulating swimming movements like breaststroke. ▪ Throw a handful of candies/or paper snippets into the pond as feed and ask the "fish" to pick these up. ▪ Ask another 3-5 participants to become fish and enter the pond, swimming around, without overstepping the pond boundaries (if chairs are used, they would be an actual physical barrier to prevent the "fish" swimming outside the pond. ▪ Throw another handful of paper snippets/candies as feed (about the same amount as before) into the pond and ask the "fish" to pick them up. ▪ Ask another 5-8 participants or more, depending on the "pond size) to become fish and enter the pond, swimming around. ▪ The "fish" will now have not enough space to swim around (using the swimming movements) without hitting or bumping into each other/space is getting tight. ▪ Repeat the "feeding" activity. There will now not be sufficient space for all "fish" to bend down to pick up the "feed"; also, feed will not be enough for all the fish. ▪ End the game and ask participants to share their observations and "conclusions", such as space is limited, the more fish the less space for each fish, less feed for each fish/need to increase feeding etc.		
		Input presentation "basic principles of intensification"	Poster or PowerPoint presentation	30 min
4	Species selection	Plenary Brain storming: what species do you know and what do you know about these species (biology, farming, market prices)	Flipchart to record feedback from the plenary	15 min
		Input presentation: characteristics of popular species (Table 11)	PowerPoint or posters	20 min
		Species selection exercise	Flipchart with prepared selection matrix (Table 12)	20 min
5	Basic farm planning	Why planning is important, introduction by the trainer	Speech, presentation	10 min
		Introduction of seasonal calendar	Presentation	15 min
		Exercise: Seasonal calendar activity	Group work (see exercise details above)	60 min
		Simple farm planning exercises and sample production calculations	Input: presentation of template and sample calculations for several species and stocking densities Exercises: Small group work: participants practice sample calculations as per the templates provided above (Tables 7-9)	30 min 60 min 10 min

#	CONTENT/ACTIVITIES	METHODOLOGIES	MATERIAL REQUIRED	TIME ALLOCATION
			Plenary: discuss and summarize the results Individual participants: prepare a basic farm plan/sample calculation (table 10) based on data from their own farm (pond size) and species the prefer to cultivate following species selection exercise	30 min

MODULE 2

2 MODULE 2: SITE SELECTION AND POND CONSTRUCTION

In this module, participants will learn to assess the suitability of land for establishing fishponds. Selecting an appropriate site is the first step towards creating successful pond-based aquaculture operations. Location of the pond, its physical characteristics such as soil, water supply, size and depth and access are important parameters that influence the operational costs of the fish farming venture.

The selection of an appropriate site for locating a pond is important not only for environmental reasons but has important economic and financial consequences for farm operations. The selection of a site with proper soil conditions, adequate water supply and distance from the house of the farmer will reduce costs and risks involved in pond maintenance and management.

At the end of this module, participants will be able to assess the suitability of land and locations available to them for constructing a fishpond. They will be able to select a site and understand key considerations of pond construction such as depth and slope rates. For prospective fish farmers, the training can be organized as a workshop, during which participants are guided through some exercises such as mapping and a "SWOT" analysis of different potential locations, at the end of which they will be able to choose the location and pond size most appropriate for their objectives.

2.1 KEY CRITERIA OF SITE SELECTION

The selection of an appropriate site for the pond is the first step towards successful aquaculture operations.

The accessibility of the location and distances that need to be covered for management, monitoring, provision of inputs and markets need to be considered, as they all impact the operation costs: long distances increase costs for transportation, access conditions (by foot only or by motorized vehicle) influence factors such as amount of fish and inputs that can be transported, and the time needed for commuting to and from the pond.

Ponds that further away from the farmer's homestead are difficult to monitor and more difficult to protect from theft. Extra efforts may need to be taken for fencing and securing the pond. The availability and accessibility of water will influence the length of production cycles (if water availability depends on rain during the rainy season as the only water source) and the cost of production if water needs to be pumped for both filling the pond and draining the pond.

The following key criteria need to be considered for selecting an appropriate site for an excavated fishpond:

1. Soil type
2. Land area (topography, slope)
3. Water availability and quality
4. Distance from HH location
5. Risk of flooding

2.1.1 APPROPRIATE SOIL TYPE AND QUALITY

The most important characteristic of the soil is that it can hold water, particularly at the bottom and along the sides up to the height of the intended water level. To ensure this, the soil must contain sufficient clay.

Clay absorbs water and swells up, which seals the bottom and sides of the pond. It also protects the pond banks from erosion. The banks of ponds in sandy soil will erode easily and water leaks out. If the soils are sandy, the bottom and walls of a pond can be lined with a layer of clay to prevent seepage and stabilize the pond walls. But this generates higher cost for construction which must be considered.

Soil test – practical exercises

Wet a handful of soil with just enough water to make it moist. Squeeze the soil and it must hold its shape. Form a ball and let it fall from 1meter high to the ground. If the ball does not disintegrate, then the soil is good.

Water permeability test (for multi-day training)

Dig a 1 m deep hole in the ground above ground water level. Fill the hole with water to the top and cover the hole with leaves. The next day the water level will be lower since the soil has been saturated with water. Refill the hole to the top and cover with leaves. The next day, check the water level again. If the water level is still high, the soil is suitable for pond construction. If the water has disappeared, it will also disappear in a pond. The soil is not suitable for fish farming.

However, this does not work if the groundwater level is high the hole fills itself with water and will not leak at all. In this case the land might be suitable for pond construction if groundwater level remains high during the season. Seasonal fluctuations must be considered as well as possibilities to empty the pond for water exchange. Ponds built into the ground water level often dry up during the dry season, which is helpful for pond preparation, but make sure ground water level remains high enough during the culture season, because refilling of such ponds in sandy soil can become very costly.

2.1.2 LAND AREA, TOPOGRAPHY, AND USER RIGHTS

Ideally, the pond should be built on slightly sloping land, as this would facilitate water flow into and out of the pond by gravitation. A gentle slope between 2% and 5% (2-5 m slope over 100 m distance) is generally regarded as ideal. Such a slope also facilitates easier harvesting, if the farmer plans for a full harvest (see module 7) generally, areas such as the following should be avoided:

Low and flat areas, which are difficult to drain.

Areas that easily flood during the rainy season.

For many locations in Cambodia, this is difficult to achieve, as generally the land is

Trainer can visualize this by drawing sketches and simple demonstration with bucket as water source.

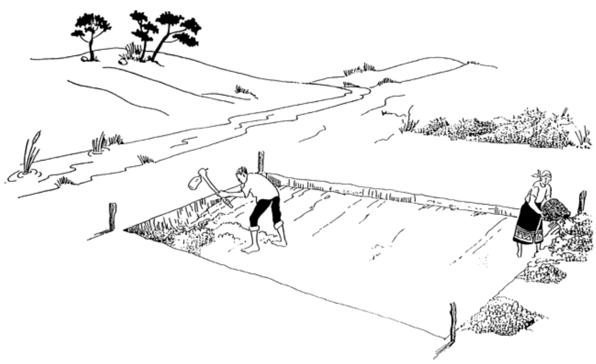


Figure 9: Pond digging on a slope
Source: FAO

very flat. Ponds should always be built with a sloping bottom, i.e., one end should be slightly deeper than the other end.

Land ownership and water user rights are strictly regulated in Cambodia. The prospective farmer needs to be sure to have either the ownership or user rights for the chosen location, approved by local authorities.

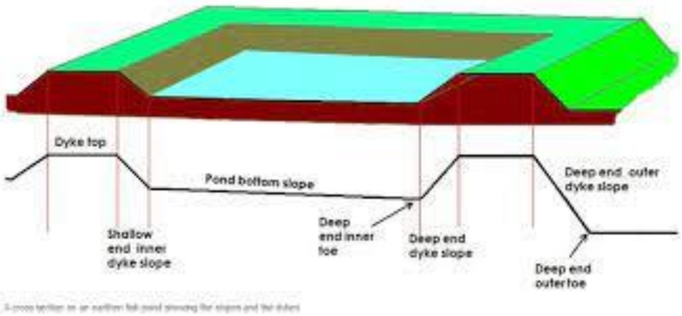


Figure 10: Side view sketch of basic pond design
Source: FAO

2.1.3 WATER SUPPLY – SOURCE AND QUALITY

A reliable water supply is the most critical factor for site selection. Water needs to be available to compensate for water loss through evaporation and seepage and to manage water quality by water exchanges if required.

If water supply is seasonal and not available throughout the year, aquaculture still is possible, with faster growing species that can be used for a short culture cycle, such as Walking Catfish or Common Carp.

Figure 11: Water supply by pumping
Photo credit : Nget Touch/GFA, SAFR Project

Water supply needs to be reliable for the duration of the production cycle. Availability and quality of the water should be considered when selecting the location for a pond and for the species to be cultured. The water source also is important, as water from different sources has different quality properties. Water from rivers and streams may guarantee a steady supply of water, but it might be contaminated from agriculture or industrial activities.

Rainwater may not be available throughout the year, as the climate is characterized by dry and rainy seasons.

If, for example, water is available only seasonally (such as rainwater) and the pond water cannot be retained and replenished during the dry season, the farmer may want to consider culturing a species that is more tolerant to generally lower water quality such as low oxygen levels and higher temperatures. These are usually air breathing fish like catfish or climbing perch. Such species require higher protein content than herbivorous species (see list of species). Commercial feeds provide sufficient protein to support good growth of these species. Use of protein rich feeds however increases production cost.

If the water can be replenished by pumping ground water into a pond with good water holding capacity, the farmer needs to consider the cost of pumping, the quality of ground water and the fact that ground water has lower temperatures.

If the farmer uses water from rivers or streams, an indicator of the water's suitability is the natural occurrence and abundance of fish. If events of fish mortality in such water are observed, the use of such water is very risky for aquaculture.

Ground water is a possible water source but often is cooler than rain/surface water and it can also contain toxic gases which must be removed by aeration before entering the pond. Ground water always requires additional cost for pumping.	

Table 14: Challenges and management responses for different water sources

WATER SOURCE	KEY CHALLENGES	MANAGEMENT CONSIDERATIONS, ACTIONS
Water can be diverted from streams, rivers or lakes.	Water from such water bodies contains animals, plants and rotting organisms that can cause diseases. They can carry pollutants, such as pesticides and wastewater from upstream.	Observe the water source: ▪ Is there or has there been any fish or other animal mortality? ▪ Is there any debris floating in the water? ▪ Does the water have bad smell? ▪ Install filters, such as fine mesh wire, at the pond inlet.
Rainfall Rainfall is the main source of water.	**Dependency** Rain-fed ponds depend heavily on amount of rain and seasonal fluctuations. In Cambodia, ponds often dry up during the dry season. They need to be harvested before water levels are getting too low. During the rainy season and abundance of water, these ponds can flood, posing a risk of wild predatory fish entering the pond and the cultured fish escaping the pond.	▪ Choose faster growing species, such as Walking Catfish or Common Carp ▪ Build dykes sufficiently high to protect the pond from overflowing during heavy rains (see pond construction section)
Wells Wells are places where ground water is pumped up. It is a good source for fishponds because it is usually clean and usually not contaminated. Often it contains toxic gases however, which can be removed by aeration.	**Oxygen levels and temperature are low** Measures need to be taken to aerate the water, which can be expensive	**When pumping ground water into the pond, ensure that it is "splashed" or "sprinkled" into the pond to increase oxygen levels.**  **Figure 12: Example of splashing when pumping water into the pond** Photo credit: Sopheap/GFA, SAFR project

In many areas of rural Cambodia, ponds are built into the water table, i.e., they are excavated to a depth below the ground water level. This subjects them to seasonal water level changes. This means water levels are low during the dry season, without the ponds drying up and very high during the rainy season.

2.1.4 ACCESSIBILITY

Ponds should be close to the homes of the farmers and easily accessible. This helps in safeguarding them from thieves as well as making transportation of inputs to and produce from the pond easier.

Pond should be away from agricultural land (such as rice fields, plantations) where **chemical fertilizer and pesticides** are used and where safeguarding and monitoring the pond is difficult.

The use of pesticides in neighboring rice fields and other farming activities can kill crustaceans, which represent most of the zooplankton. Chemical fertilizers are also an issue because they are usually ammonia-based. In water ammonia is quickly absorbed and nitrified; the addition of chemical fertilizer may increase plankton growth to such levels that oxygen levels deplete at night.

If the pond is near the home, where the land is also used for some small-scale home-based agricultural production such as vegetable growing, the pond water can be used for irrigation if there is another source that ensures the pond water can be replenished. Under intensive culture conditions, with high feed input the pond water is excellent for irrigation. It can reduce the need for chemical fertilizers because the water from intensive ponds contain high nutrient loads for plant growth. In extensive ponds the nutrients should remain in the pond to support plankton growth and you will want to exchange the water only when necessary.

If the ponds are located at a great distance from the farmers' homes, the additional costs in terms of time and transport need to be considered, as well as the potential security risk of fish being stolen, which is a common risk at remote pond locations.

Of the farmers supported by the SAFR project about 5% reported fish theft within 6 months of stocking, and all of the affected ponds were too far from their respective owner's home to be observed at night.

If ponds are surrounded by land that is used for agriculture, the farmer needs to ensure the pond water is not affected by pesticides, herbicides or fertilizer used in adjacent farming. This can be achieved by separating water flows by building dykes that prevent water from farmlands entering the pond.

Also, ensure that agricultural equipment that was used for application of pesticides are not cleaned in the pond.

Fishponds should not be in areas likely to flood during rainy seasons. It is difficult to protect the pond from wild fish entering the pond or the stocked fish from escaping during flooding, unless the pond is well fenced with a small-mesh sized net. Flooded ponds can have serious economic consequences through loosing fish either due to predator fish entering the pond or fish escaping.

Figure 13: Avoid areas prone to flooding
Photo credit: Soth Soviseth/GFA, SAFR project

To be avoided

Pond surroundings and dykes should be free from trees and bushy vegetation, as the roots can weaken the dykes. Predators can also use trees and bushes as cover. While some herbivorous species may benefit from leaf litter falling into the pond as additional feed, an excess number of leaves falling into the water may cause water quality issues when they decompose. For good plankton growth sunlight is required to enter the pond. Large trees give too much shade on the pond.

Figure 14: Avoid ponds with dense vegetation on the dykes
Photo credit: Nget Touch/GFA, SAFR project

Figure 15: Fenced pond with grass growing on dykes for stabilization
Photo credit Theo Ebbers,/GFA, SAFR project

Recommendations

Ponds should be close to the home and not allow open access. Ideally, the pond is away from farmlands and water from agricultural lands cannot enter the pond.

Figure 16: Example of a pond close to the farmer's home
Photo credit : Theo Ebbers/GFA, SAFR project

Planting grass on pond dykes helps to stabilize the dykes. Farmers need to protect fishpond banks from erosion during fish production, particularly during the rainy season. They also need to prevent soil particles from getting into the water of the fishpond and making the water turbid.	 **Figure 17: Planting grass on pond dykes for stabilization** Photo credit: Theo Ebbers/GFA, SAFR project

2.2 KEY PRINCIPLES OF POND CONSTRUCTION

The layout of the ponds should be aligned with the topography of the land, water sources and drainage.

Arranging ponds to allow for independent supply and drainage of water is ideal. This requires an inflow higher than the anticipated water level and an outflow lower than the pond bottom. Dikes constructed around ponds ensure water retention and provide protection for flooding. The ability to maintain an appropriate water level is important to regulate key parameters such as water temperature, control the growth of aquatic plants and to keep dissolved oxygen at appropriate levels. The ability to drain a pond is helpful to harvest the fish and important to dry the pond bottom as preparation for the next production cycle (see below pond preparation).

In rural Cambodia, these basic principles are often not applied, and ponds are built without inlets and outlets and often into the groundwater table. The implications this has for the farmer will be discussed further below.

2.2.1 SIZE, SHAPE AND DEPTH OF PONDS

	Small ponds versus larger ponds	
There is no "best" size and shape for ponds. Both depend on the purpose of production, its intensity, construction cost and production purpose and topography. Pond size can vary widely and range from as small as 50sqm to 5,000sqm for small-scale aquaculture as defined by the Cambodian government.	**Small ponds**	**Large ponds**
	▪ Easier to catch and harvest fish ▪ Easier to maintain fish and treat disease ▪ Potentially higher productivity (kg/ha). Smaller ponds usually perform better because they have more shoreline in relation to the pond surface and the shoreline has higher productivity.	▪ Higher overall production potential; ▪ Lower construction cost/sqm

Ideally, ponds should have a slightly sloping bottom to facilitate water flow for draining the pond through an outlet at the deeper end.

Preferably, pond water depth should be around 1.5m at the shallow end and increase gradually to 2.5m at the deep end, with 0.5-1m of freeboard. Ponds that depend on seasonal rains and/or ground water should be deeper to be able to hold water into or throughout the dry season.

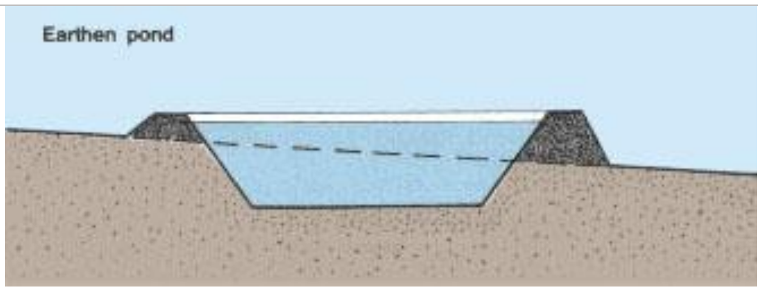


Figure 18: Side-view sketch of pond on sloping terrain
Source: FAO

Constructing ponds following these principles is difficult in Cambodia, as the topography is very flat. Thus, "sunken" or dug-out ponds are commonly built and found in rural Cambodia.

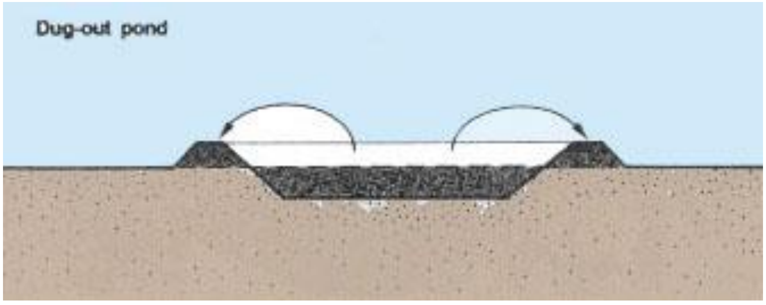


Figure 19: Simple sketch of dug out pond
Source: FAO

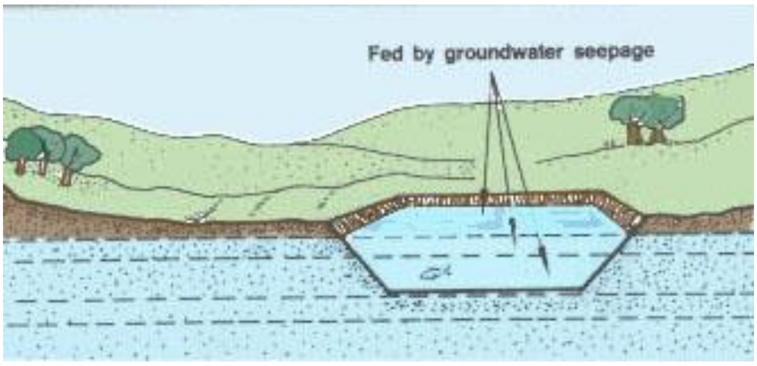


Figure 20: Sketch of groundwater-fed pond
Source: FAO

Though very common in Cambodia, such ponds are not preferable because it is difficult to fully drain and dry them. They need to be pumped and water immediately starts seeping back into the pond until the water level in the pond is level with the water table. This makes full harvests and pond preparation difficult and more costly as pumping causes additional costs. Harvest, draining and pond preparation thus need to be

	timed when ground water levels are low, i.e., at the end of the dry season or beginning of the rainy season.

2.2.2 POND DYKES

It is important to protect the ponds from drying up as well as from overflowing by floodwater during the rainy season. Dikes need to be protected from erosion with a cover of vegetation/grass. Slopes should not be too steep to prevent erosion. Slope rates of 26 to 33 degrees (1.5:1-2.0:1) are suitable.

Slope rates depend on the type of soil

Recommendation for Fish Pond Slope Rate

Soil Type	Slope Ratio	Slope (Depth*Slope rate)
Clay	1:1	Depth 1m= Distance 1m Depth 2m= Distance 2m Depth 4m= Distance 4m
Clay loam	1:1.5	Depth 1m= Distance 1.5m Depth 2m= Distance 3m Depth 4m= Distance 6m
Sandy loam	1:1.5-1:2	Depth 1m = Distance 1.5m-2m Depth 2m = Distance 3m-4m Depth 4m = Distance 6m-8m
Sandy	1:3	Depth 1m = 3m Depth 2m = 6m Depth 4m = 12m

While sandy soils are not suitable for ponds, slope rates for sandy soils are included here, as this is applicable to dug-out ponds, i.e., ponds dug into the ground-water level, which are so common in small-scale aquaculture in Cambodia. Often, the topsoil is sandy and has a high-water permeability. When digging the ponds, these soils are often used to build the dykes. These dykes are rather unstable and need a flatter slope rate to better protect them from erosion. Additional care needs to be taken to plant stabilizing vegetation on both the inside and outside of such dykes to enhance their stability.

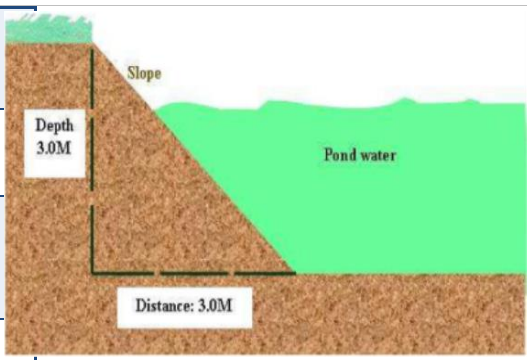


Figure 21: Slope rate side view (1:1)
Source: FAO

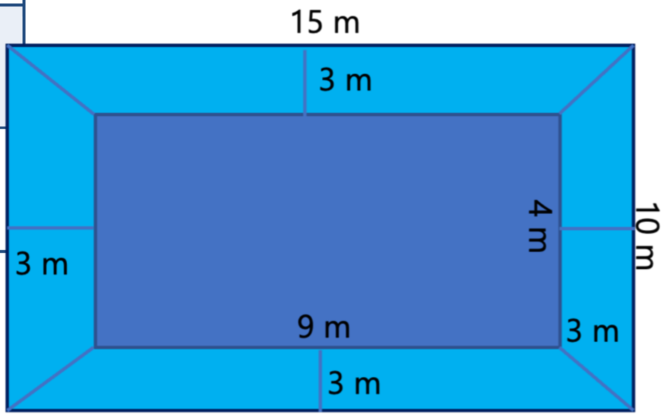


Figure 22: Slope rate 1:1 with an example of a 150 m² pond
Source: GFA

A pond of the size of 15m * 10m and a depth of 3m with a slope rate of 1:1 will thus be 9m * 4m at the bottom.

This can be "drawn" by participants in a group exercise on the ground of the training venue.

If the training site is near a proposed pond location, this can be used to outline the proposed pond in its real dimension scale 1:1.

If the excavated soil is used as dykes, a good practice is to pile the soil around the pond at some distance from the main pond border, creating a step between the dyke and pond.

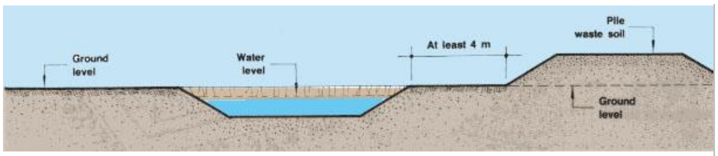


Figure 23: Simple pond schematics where soil from pond digging is used for dykes
Source: FAO

Figure 24: Dug out pond with "flat" and "stepped" slopes to protect against erosion
Photo Credit: Nget Touch/GFA, SAFR project

2.2.3 WATER INLETS AND OUTLETS

For ponds that are built on sloping land, gravitational water flow should be used to regulate the water level in the pond, fill and drain the pond.

Water inlets are used to take water into the pond, connecting the pond to nearby water bodies that are at a higher elevation and used as the main water source.

Inlets will be placed at the shallow end of the pond, which is higher on the slope, while outlets will be built at the deeper end of the pond, which is lower on the slope.

Pond outlets are used to:

1. Keep the water in the pond at its optimum level, which should be

In many local situations, it is not possible to build ponds that have an inlet and an outlet because of the local topography. Typically, these are dug-out ponds, which are either fed by rainwater or groundwater seepage or a combination of both.

These ponds cannot be drained – except by pumping – to prepare the pond for a new production cycle.

If there are no outlets and water needs to be pumped out, either for drying the pond or partial drainage to replenish the water and improve its quality, the cost of pumping needs to be considered in planning farm operations.

This is true for filling the pond as well. If the surrounding topography cannot be used to channel water from a natural water body such as a lake or river to the pond and needs to be pumped, these costs need to be considered as well.

When designing and constructing an inlet:

1. Place the inlet at the shallow end of the pond;

the maximum water level designed for the pond;
2. Allow for the complete draining of the pond and harvesting of the fish when necessary.

2. Make sure that the bottom level of the inlet is at the same level as the bottom of the water feeder canal and at least 10cm above the maximum level of the water in the pond.
3. Design the inlet structure to be horizontal, without a slope.
4. Make it so that water splashes and mixes as much as possible when entering the pond, provide a screen to keep unwanted fish and other organisms out.

When constructing an outlet, ensure that:

1. The flow of the draining water is as uniform as possible to avoid disturbing the fish excessively.
2. Fish are not lost even during the draining period.
3. Water can be drained from any pond levels.
4. Overflow of excess water is possible.
5. The pond can be cleaned and serviced easily.
6. Construction and maintenance costs are kept at a minimum.
7. Suitable materials are used to construct pond outlets and inlets, e.g., bamboo, PVC pipes, wood, bricks, cement blocks or concrete.

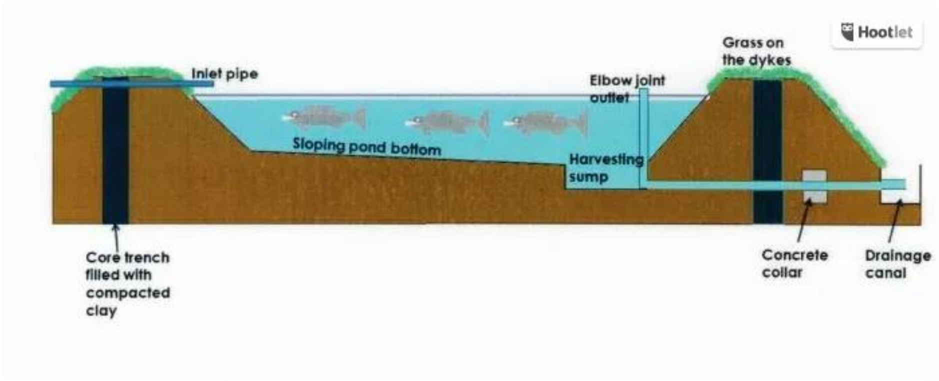


Figure 25: A cross section of a completed pond showing the position of various elements
Source: The FishSite

2.2.4 SITE SELECTION MAPPING EXERCISE

1. Divide the participants into small groups of 4-5 members, if possible, based on geographic neighborhoods/proximity of their respective HH/farms.
2. Provide each group with a flipchart and color pens.
3. Instruct the groups to draw maps of their respective neighborhoods/locations, including the following (30 min).
   a. The general outline of the location
   b. Their HHs location and the land/plots they own
   c. The location they are considering for their ponds
   d. Water bodies (streams, rivers, lakes, community ponds, CFRs), if no water bodies, availability of ground water and depth of water table
   e. Soil types

If the proposed pond location is not on their own plot/near the house, indicate means of access such as roads/pathways to the pond.

Ask the groups to present their maps (each group 10 min). Use the following guide questions for assessing the suitability of each proposed pond location:

1. If the pond is located away from your house, "What is the distance from your house to the pond?"
2. How do you go there? Can you take a motorbike, or walking only?
3. How long does it take to go there?
4. How do you secure the pond against theft of fish?
5. What are the estimated costs of commuting/measures?

All ponds:

1. For how many months does the proposed pond hold water?
2. What is the water source?
3. What is the proposed size of the pond?

Using these guide questions, group the proposed ponds according to their suitability based on their proposed location and water availability.

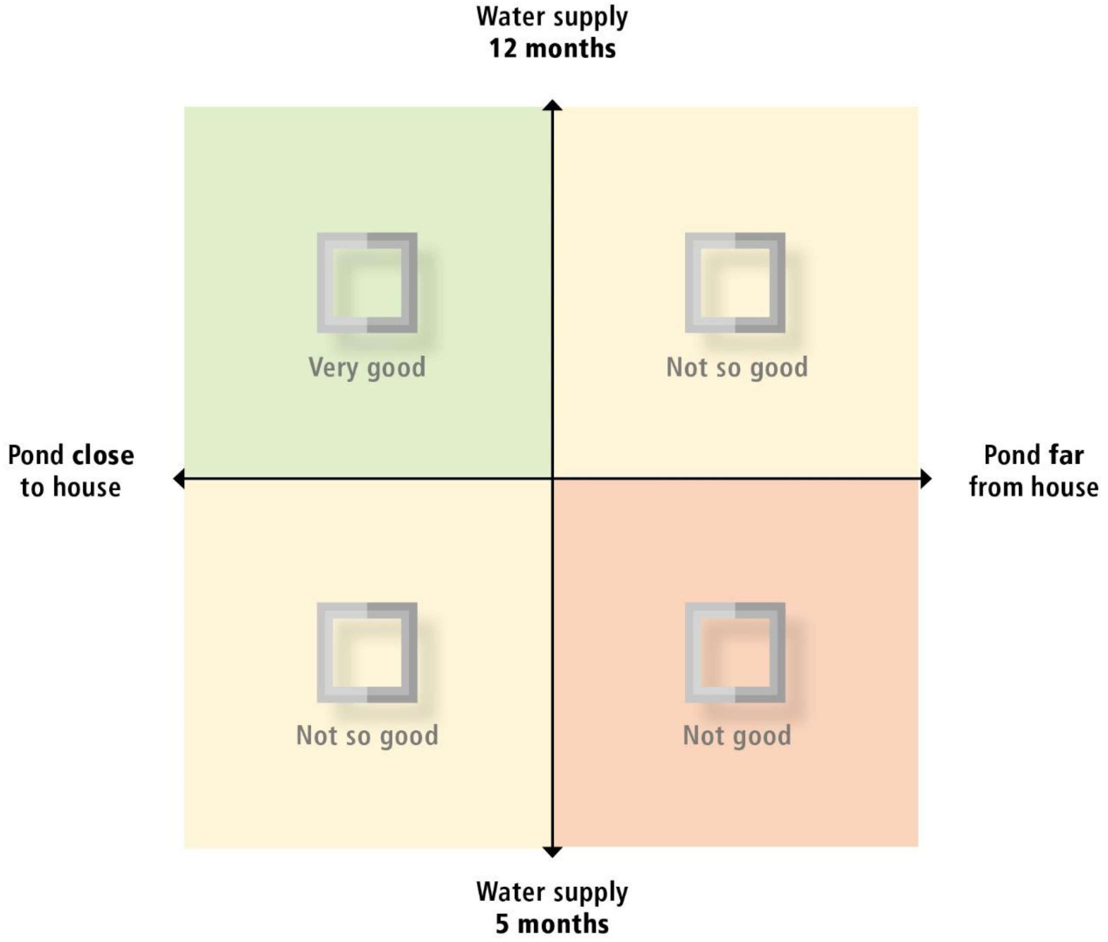
For this group exercise, the site selection worksheets below will be distributed to participants for individual site mapping and assessment.

2.2.5 SITE SELECTION WORKSHEET: MY HOUSEHOLD POND LOCATION

Please use symbols similar to the ones below to draw **a map of your pond location** in relation to your house.

Please draw the map of your pond location in the green frame.

2.2.6 POND LOCATION ASSESSMENT



Very good	Not so good	Not good
▪ More time for production ▪ No cost for transport ▪ Easy to monitor ▪ Low cost production	▪ Shorter production cycles ▪ Need cost for transportation ▪ Lead to high cost production	▪ Shorter production cycles (potential higher investment feed) ▪ Need cost for transportation ▪ Note easy to monitor/ need cost for protection (Risk) ▪ Lead to high cost production

Figure 26: Pond location assessment matrix
Source: GFA

Table 15: Sample plan outline for site selection and pond construction

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
POND SITE SELECTION			
30 min	Clarification of training objectives and expectations Course Objectives and expected outcome	Brainstorming and note on colored papers/meta cards.	Marker pen and color paper, flip chart
120 min	Soil characteristics Water sources Whole and surrounding fish pond and foot path connect	20 min: Input presentation 15 min: Soil testing exercise 15 min: Plenary: review and brainstorming about pond site selection criteria. Guide questions: ▪ What are the consequences of inappropriate soil? ▪ What are the consequences of distance of pond location from farmers' home? ▪ What are the advantages and disadvantages of different water sources? ▪ What are the respective cost-implications? 60 min: Site selection mapping exercise 10 min: Summary and conclusion	Flip chart, marker pen, paper tape. Photos/ Poster, Samples of different soils (clay, sandy, sandy-loam)
POND CONSTRUCTION			
100–130 min	Pond size and depth Slope rates and dykes, Water inlet and outlet	45 min: Input presentation: present photos/posters of pond schematics Present photos/ posters 30-60 min: Group exercise(s) calculating slope rates and drawing pond with slopes from top view; if proposed pond location nearby stake out and outline pond scale 1:1 (requires more time) 15 min: Brain storming – how to make filters for inlets/outlets with local materials 15 min: Sample calculations on costs of pond digging based on locally relevant costs for using excavator 15 min: Brainstorming – how high is the risk of theft and how can the ponds be better secured against theft? 10 min: Plenary – review and conclusions	Flip chart, color paper, marker pen, paper tape, measuring tape

MODULE 3

3 MODULE 3: CREATING AND MAINTAINING A HEALTHY POND ECOSYSTEM

After pond construction, it is important to prepare the pond for stocking. Pond preparation aims to create conditions that provide a healthy environment with natural feed for the fish to grow without much risk from being infected by diseases. Fish farms thus need to take measures that reduce stress for the fish and thus the risk of disease and create a pond environment that ensures productivity and well-balanced microbiology in the water.

Physical measures such as nets and netted fencing, filters at water gates help to prevent the intrusion of potential carriers of disease, such as wild fish, household animals and wild animals. Measures, such as the application of lime, are used to clean the pond area from potentially harmful organisms and to improve the soil of the pond to create better conditions for a productive pond system that contributes to the growth of natural feed in the pond. This natural productivity is further enhanced by pond fertilization, i.e., the application of organic or inorganic fertilizer to the pond. Both fertilization and the application of lime are also important interventions to maintain a well-balanced pond ecosystem that produces natural feed during the culture period. The pond ecosystem is a balance of fish, bacteria and plants that all support each other. The components of a pond ecosystem include both biotic (living) and abiotic non-living elements. Biotic (living) fish, aquatic animals, microbes, plants, phytoplankton follow a food chain interaction. Abiotic (non-living) components include physical and chemical interactions. These components create a food chain (or food-web) in which larger organisms feed on smaller organisms.

Learning Goal: In the following sessions, participants learn how to create such a pond eco-system through some basic measures to be taken during the pond preparation phase.

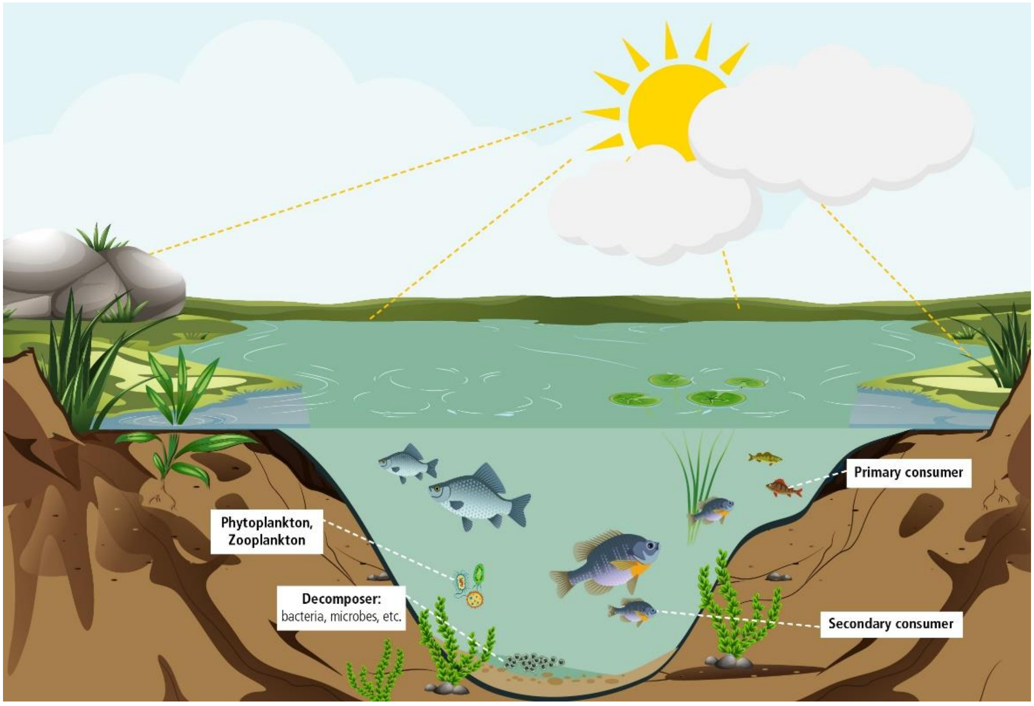


Figure 27: Pond ecosystem
Source: GFA

The pond preparation process outlined in this manual starts with a dry pond. For a newly excavated and constructed pond as per the pond construction techniques describe in module 2 of this manual, pond preparation can start, when the excavation is completed. For old ponds that need to be prepared for a new production cycle, the process begins with emptying the pond of all water and drying the pond bottom. The following measures, such as the application of quicklime and fertilizer are the same for both new and existing ponds.

3.1 PREDATOR AND PEST CONTROL MEASURES

For old ponds, all the water must be pumped out and the pond dried to eradicate wild predators that may have entered the pond, such as snakehead fish, water snakes, frogs, eels, and crabs. The pond bottom needs to be cleaned by removing the mud. Dykes and slopes repaired and reconstructed as needed and any holes in dykes such as from crabs or rats need to be filled.

Ponds should be fenced with small mesh nets and barriers to prevent livestock and predators from entering the pond area as they destroy the vegetation planted to stabilize the dykes and erode the dykes which makes it more difficult get in and out of the water. They also can contaminate the water and carry diseases. If necessary, other physical barriers that prevent livestock from entering the pond should be constructed.

Figure 28: Pond in farmland with dykes damaged by cattle
Photo credit: Nget Touch/GFA, SAFR Project

If ponds are not protected by fences, animals such as buffalos may easily enter. They not only disturb and pollute the pond ecosystem, they also cause physical damage to pond dykes.

The picture below shows a simple fence that prevents larger livestock from entering the pond area. The pond itself is affected by erosion, because the slope is not covered with grass – **see module 2** on site selection and pond construction for measures to prevent or reduce dyke erosion.

Figure 29: Simple fencing to prevent cattle and other large animals from entering the pond
Photo credit: Nget Touch/GFA, SAFR Project

The photo on the right shows predator fish (Walking Catfish) being prevented from entering the pond by a net fence.

Figure 30: Fencing a pond with a small mesh net
Photo credit: Nget Touch/GFA, SAFR Project

Figure 31: Monitoring and checking a pond's mesh net
Photo Credit: Nget Touch/GFA, SAFR Project

3.2 LIMING THE POND

After fencing the ponds, lime should be applied. Liming of earth ponds reduces toxicity of harmful compounds including disinfecting the environment. Thus, after pond construction and between production cycles, the application of lime in the dry pond is one of the main interventions for controlling pests and disinfecting the pond area. Animals like birds, snails, frogs and snakes need to be kept out of the pond as they can carry diseases or are predators, which consume fish. Fence the ponds with small mesh nets and cover inlets with nets.

More than eradicating pests, application of lime on dried earthen ponds has important benefits for creating a productive pond ecosystem.

Treating the ponds with various substances rich in calcium (Ca), such as quick lime (CaO), slaked lime ($Ca(OH)_2$), agricultural lime $CaCO_3$ or dolomitic lime $CaMg(CO_3)_2$

has three important benefits:

- Liming can enhance the effect of fertilization;
- Liming helps prevent wide swings in pH;
- Liming also adds calcium and magnesium, which are important in animal physiology.

Liming accelerates decomposition of organic matter and increases pH levels. It will result in faster and more efficient exchange of minerals and nutrients between the soil at the bottom of the pond and the water as well as reduced demand for dissolved oxygen.

Application of lime is also an important tool during fish cultivation to buffer pH-level fluctuations.

Water's total alkalinity is the measurement of the total concentration of substances like calcium (Ca) and magnesium (Mg), which are typically alkaline, in carbonates and bicarbonates.

Figure 32: Liming ponds and pond dykes
Photo Credit: Nget Touch/GFA, SAFR Project

Liming

- Improves the structure of the soil in the pond
- Improves and stabilizes water quality
- Facilitates manure's ability to efficiently increase the availability of natural food
- Helps to unlock nutrients from soils
- Reduces toxicity of harmful compounds including disinfecting the environment
- Modifies the total alkalinity of water in a pond
- Supplies calcium (as Ca_2^+) and carbonates helping to buffer carbon dioxide in water, thus stabilizing pH
- Prevents wide fluctuation of pH by establishing a buffer of CO_2 -CHO- $CaCO_3$
- Counteracts toxic effect of excess magnesium, sodium and potassium ions
- Acts as a prophylactic by killing unwanted fish, bacteria and other fish parasites
- Is justified If the pH of the soil at the bottom of the pond is lower than 6.5
- Will improve soil conditions if the bottom of the pond is very muddy because it has not been emptied and drained regularly
- Can help in drained ponds if there is a risk of contagious disease or if you need to fight enemies of fish
- Is advised if there is too much organic matter, either in the soil at the bottom, or in the water
- Is justified if the water's total alkalinity is lower than 25mg/l $CaCO_3$

For liming a dried pond, quicklime can be used for liming the pond during the production cycle to improve water quality and enhance natural feed production. Agricultural lime should be used.

When using quicklime, it is important to at least wear gloves and a facemask to protect your skin from exposure and breathing in the quicklime dust.

Figure 33: Protective measures before liming: Wearing gloves and face masks
Photo credit: Theo Ebbers/GFA, SAFR Project

Table 16: Liming requirements

pH OF POND SOIL	LIME REQUIREMENTS KG/HA (KG/M²)		
	Calcium Carbonate	Agricultural Lime	Quick lime
4.0	1,500 (0.15)	1,660 (0.166)	1,380 (0.138)
4.5	1,250 (0.25)	1,390 (0.139)	1,150 (0.115)
5.0	1,000 (0.1)	1,110 (0.11)	920 (0.092)
5.5	750 (0.075)	830 (0.083)	690 (0.69)
6.0	500 (0.05)	550 (0.055)	460 (0.046)
6.5	250 (0.025)	280 (0.028)	230 (0.030)

Soil and water pH-levels can be tested with easily available pH-test kits.

For soil testing before pond preparation and assessing lime requirements, pH test strips are the easiest method.

For testing pH levels of pond water, pls. refer to module 6 on water quality and fish health.

Source: Flipchart

	Gently dip part of the paper into a soil. Wait for sometime and you will notice the color change in the pH paper strip. Compare the color obtained on the pH strip with the pH chart to measure the pH.
	  **Figure 34: pH-level testing exercises** Photo Credit: Nget Touch/GFA, SAFR Project

3.3 FILLING THE POND WITH SAFE WATER SUPPLY

After the application of lime, leave the pond for about one week to allow the lime to take effect. Then fill the pond to about 30%. Not filling the pond completely speeds-up the production of natural feed after the application of fertilizer in the next step (see below).

When filling the pond ensure that no fish from the wild, any predators, plants and rotting organisms enter the pond. It is thus important to protect the water inlets with screens to filter out unwanted organisms that may impact the fish and the pond eco-system negatively. Such filters can be made from local materials such as bamboo, screen or wire mesh, a clay pot or a bucket with holes punched in it, a basket, a net strung over a bamboo frame, etc.

Make sure to check the screens for damage and trapped debris on a regular basis to avoid damage and blockage.

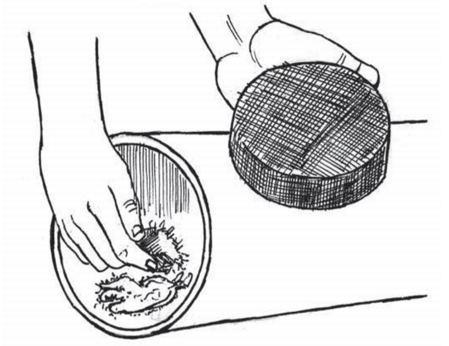
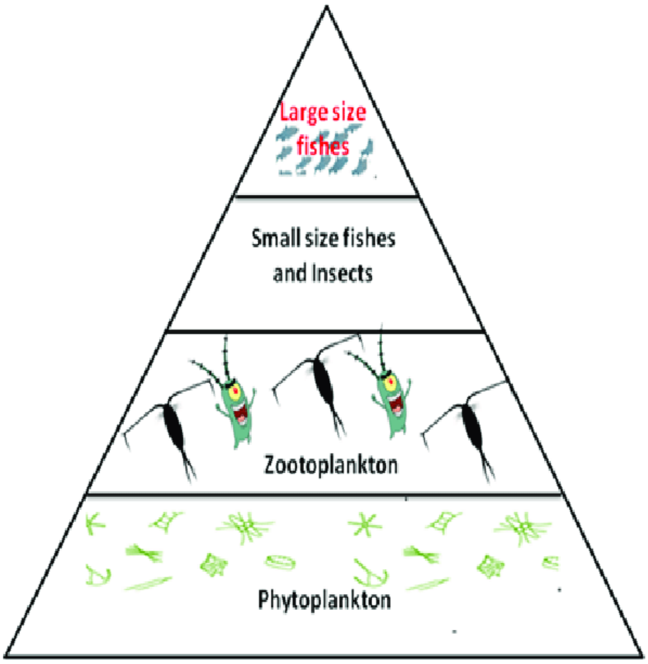


Figure 35: Simple inlet screen to filter water
Source: FAO

3.4 POND FERTILIZATION

With the pond partially filled, apply fertilizer. The application of fertilizer will help to create and boost the production of natural feed in the pond.

The purpose of fertilization is to create a food chain that will increase the productivity of the pond. Nutrients are added to ponds to stimulate the natural production of phytoplankton, zooplankton and bacteria that serve as food for the cultured fish (e.g., Tilapia) or for natural prey that in turn serve as food for the fish.



Source: https://www.researchgate.net/figure/Typical-food-chain-in-Freshwater-pond_fig6_317641556

There are different types of fertilizers. Fertilizers act by enhancing the primary production of the pond. The success of a pond fertilization strategy depends on the initial drying and liming of the pond bottom. The fertilization strategy used to enhance fish production will depend on the management system (extensive versus semi-intensive), stocking density and type of fertilizers used (organic, inorganic or a combination). Dung from livestock such as cows and buffaloes are a cheap and efficient source of organic fertilizer that can be collected by the farmer and spread or stirred into the water. Suspending a fertilizer bag into the pond is a common practice but not really recommended as it is not efficient due to the anoxic conditions inside the bag, leading to denitrification.

Adjust fertilization rate and frequency to maintain light-green pond water with a 30 cm Secchi disk reading – see water quality section. If the water is green enough, no additional fertilizer should be added.

Do not exchange the water in fertilized ponds or reduce the exchange rate to the lowest level unless there is an emergency. If water is not kept in the pond, the fertilizer is washed out and lost for the production of phytoplankton.

3.4.1 TYPES OF FERTILIZER

There are two basic types of fertilizers:

Mineral or inorganic fertilizers
These fertilizers are composed of mineral nutrients only and contain no organic matter; they are produced industrially and used in agriculture for enhancing production. Organic fertilizers, which contain a mixture of organic matter and mineral nutrients; they are produced locally, for example as wastes from farm animals or as agricultural wastes.

Organic fertilizers
They are a mixture of organic matter and mineral nutrients and can be produced by the farmer from animal manure, plant material residues from harvested crops and vegetables, leaves etc. They provide relatively low levels of plant nutrients as compared to inorganic fertilizers but serve as a bust rate for the growth of bacteria, protozoans and zoo plankton.

Both types have advantages and disadvantages that the farmers should consider.

Table 17: Inorganic fertilizer – advantages and disadvantages

ADVANTAGE	DISADVANTAGE
Easy to store, long storage possible, easy to apply and distribute, consistent mineral content, no decomposition	Cannot be directly consumed by the fish, no improvement of soil structure only commercially available, high price

Inorganic fertilizer often is composed of several important nutrients, i.e., nitrogen (N), phosphorus (P) and potassium (K). The composition is usually indicated on the fertilizer bag by its NPK grading.

- For good growth of planktonic algae in fishponds, **phosphate fertilizers** are often the most effective, as naturally supplied water often lacks phosphorus.
- Sometimes **nitrogen fertilizers** are useful, especially for avoiding blue-green algae blooms caused by a high P:N ratio. In the tropics, however, they are less needed, as fixation of nitrogen by bacteria and algae is much higher. In older ponds with a good layer of mud, they are usually unnecessary. Nitrogen fertilizers such as ammonium and urea-based fertilizers are not recommended as they are acid forming and can impact the water pH negatively and additional liming might be required.

- **Potassium fertilizers** are usually not necessary, they may be helpful in in ponds with a hard bottom and little aquatic vegetation.

As inorganic fertilizers can be expensive most farmers may prefer to use organic fertilizer, as they can produce them from easily available ingredients on their own farm.

Table 18: Organic fertilizer – advantages and disadvantages

ADVANTAGE	DISADVANTAGE
Low price, can be produced by farmer, can improve the soil, can serve as food for fish	Difficult to store, only short time, difficult distribution and application, low and variable mineral content, decomposes consuming oxygen in the pond

3.4.2 PRODUCTION OF ORGANIC FERTILIZER AND ITS APPLICATION

The farmer can use chicken, cow or pig manure or produce compost from organic waste available at the farms.

Preparation of organic fertilizers and compost

Often green manure is put in the water to decompose in the water and create compost to fertilize the pond. This is NOT recommended as it consumes oxygen in the water. INSTEAD, compost should be prepared on land and consume the oxygen from the air. After decomposition, the compost can be applied as fertilizer to the pond without the negative effect on oxygen consumption.

Figure 36: Compost
Source: www.bing.com

Figure 37: Animal manure
Source: www.bing.com

For animal manure application:

a) Stir and spread over pond water (wet manure)

For wet manure, put manure into a bucket with pond water and stir into liquid solution;

Distribute evenly over pond water surface.

The application of fertilizers depends on its type. For liquid fertilizer it is recommended to spread it evenly on the entire pond surface to avoid overconcentration in certain parts of the pond, which can be toxic to fish.

If fertilizer or compost is solid, it can be put in porous bag and suspended from the pole into the water, just below the water surface.

If the farmer uses chemical fertilizer, it should be dissolved in a water bucket before applying to the pond. Never apply solid fertilizers to the pond since they will fall to the bottom and will not be available for the plankton.

Fertilizers are usually less active and effective on cloudy and rainy days because there is less photosynthesis activity by algae to absorb nutrients.

Aquatic plants are competing with the phytoplankton for the nutrients provided by the fertilizer. Thus, generally it is recommended to remove aquatic plants to maintain the effectiveness of the fertilizer and phytoplankton growth. However, if there are too many nutrients and the water is too green or too dark, floating aquatic plants could be added to cover 10 - 15% of pond water surface.

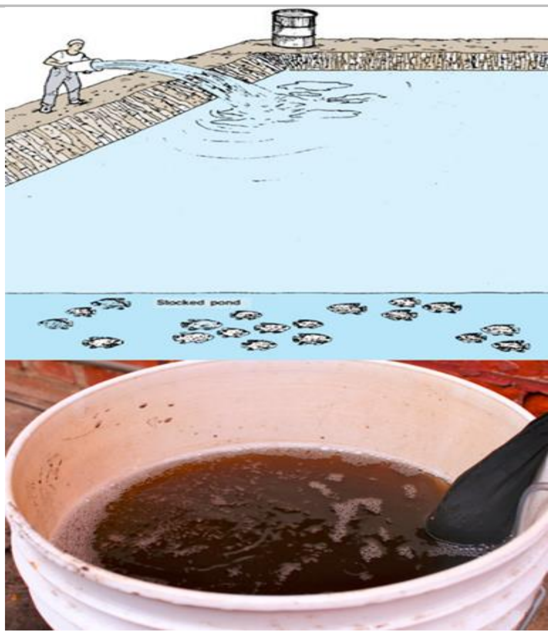


Figure 38: Preparation, application of liquid organic fertilizer
Source: FAO

b) Pulverize animal manure into manure powder for dry manure

For dry manure, crush into powder and spread over the entire pond surface.

c) Organic fertilizer can also be applied before water is filled into the pond

This will support a long-term fertilization effect. Fertilizer is spread across the pond and mixed with the soil. The nutrients are released by the soil, depending on the concentration of the water.

Figure 39: Application of fertilizer before pond filling
Source: FAO

Table 19: Application of fertilizer for fish pond

Fertilizer Application for fishpond per (kg/100m2)	
Fertilizer Type	KG/100sqm
Wet cow/buffalo manure	40-60kg
Wet pig manure	25-40kg
Wet chicken/duck dung	15-20kg
Compost	40-60kg
Green manure	30-40kg

3.5 ASSESSING AND MONITORING AVAILABILITY OF NATURAL FEED IN THE POND: WATER COLOR AND TURBIDITY

After the first application of fertilizer during the pond preparation process, wait about one week to let the fertilizer work and get natural feed production started. After about one week, fill the water to the level it was designed for and let fertilization and natural feed production continue for another 3 to 7 days.

For herbivorous species, the farmer can add floating wooden or bamboo sticks or tree branches to the pond. They provide an additional substrate for algae growth creating a biofilm for the fish to feed.

Turbidity and watercolor can be used as representations to assess, whether the pond is ready for stocking and the number of phytoplankton and micro-algae, which are key components of the natural food chain that we want to create in the pond. This is, because the natural food in the pond (small insects, phytoplankton and zooplankton) is very small and hard to see.

Figure 40: Fertilized pond with green water indicating good water quality
Photo credit: Nget Touch/GFA, SAFR Project

A light-green water color indicates sufficient amounts of phytoplankton, which forms the basis of the natural food chain in the pond.

Since color and turbidity of the water are caused by various factors, such as sediment, algae, chemicals, they can be used as approximations of the levels of natural feed available in the pond.

3.6 ASSESSING AND MONITORING WATER QUALITY: TURBIDITY

Turbidity is the measure of the clarity or transparency of the water. It is caused by small particles of organic and inorganic matter in the water and can severely affect fish growth.

The particles may originate from soil erosion, agricultural runoff, industrial or sewage discharge, presence of other fish species. They may have a direct toxic effect, or induce pH fluctuations, or may cause physical harm to the gills that trigger stress and secondary diseases. Prevailing high levels of turbidity can cause gill damage and prevent the fish from breathing. Turbidity levels below 100mg/L will cause little effect to most species.

High levels of turbidity reduce light penetration and thus the production of oxygen through photosynthesis by phytoplankton.

Turbidity can be measured using a Secchi disk or just by dipping your hand and arm into the water.

The Secchi disc transparency can be used as a simple method for measuring water transparency or turbidity in a fishpond. **A Secchi disc can easily be made (please see figure below)** by cutting out a circle of diameter 20 cm from a piece of wooden board or metal. Paint it white and black in equal quadrants. In the center, drill a small hole and pass a string or piece of wood through. Attach a small weight like a stone below the disk and graduate the piece of string or wood at 10 cm intervals.

Turbidity can be controlled by

1. Clearing the pond bottoms of excess mud as when fish moves around in the pond, they stir the water thereby bringing about turbidity.
2. Applying right quantities of manure/fertilizer to avoid algal bloom that can also bring about turbidity.
3. Screening water from inlet canals and making settling tanks can help in minimizing turbidity brought about by water.
4. Pond liming before fish stocking helps to control turbidity in the pond water.

Measuring turbidity using a Secchi disk:

Step 1: Take Secchi disc readings during the day at about mid-day when there is no shadow.

Step 2: Position yourself such that there is the least amount of shadow falling over the Secchi disc. Hold the rope or board from which the Secchi disc is suspended upright and release the Secchi disc into the water, so that it is lying flat.

Step 3: Slowly lower the Secchi disc into the water to the point where it starts becoming invisible and you cannot clearly see it. Read from the measurement.

Step 4: Slowly raise the Secchi disc out of the water until it just starts to become visible. Measure this depth.

Step 5: Get the averages of these two readings. This will give you the Secchi depth.

Hand method
Stretch one arm and immerse it vertically into the water until your hand disappears from sight.

Note the water level along your arm:

If it Is well below your elbow, plankton turbidity is very high;

If it reaches to about your elbow, plankton turbidity is high;

If it reaches well above your elbow, plankton turbidity is low.

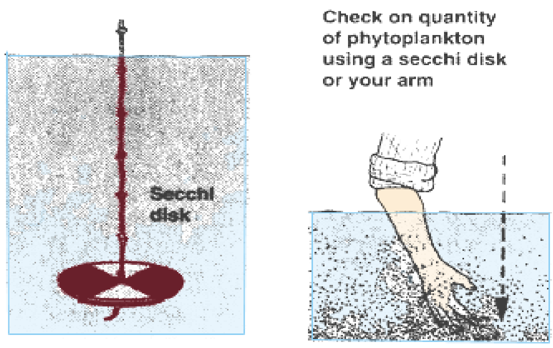


Figure 41: Assessing water turbidity using Secchi disk and hand method

Source: FAO

5. Adding fresh and clean water can clear turbidity brought about by fertilizers applied in the pond water.	

Figure 42: Fish farmer checking water transparency
Photo credit: Nget Touch/GFA, SAFR Project

Exercise: Making a Secchi disk

A Secchi disk can easily be made from a piece of wood or white plastic (e.g., bottom of a bucket) and a rope. Cut the wood/plastic in a circle of 20 cm. Paint it black and white in equal quadrants. In the center, drill a small hole and pass the rope through, securing it with a big knot. Mark the rope in centimeters. A small weight should be attached to the bottom.

Materials needed

- Wood or plastic pieces
- Weight
- Paint (white and black)
- Thick rope
- Marker pens
- Tape measure
- Drill
- Saw
- Paint brush

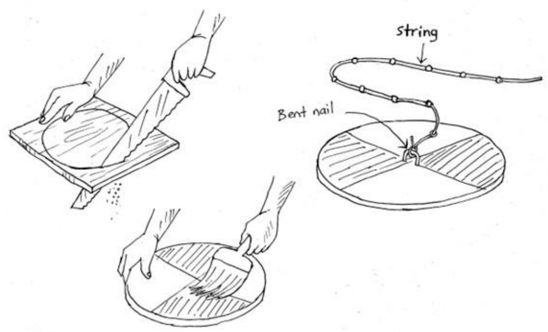


Table 20: Assessing water transparency with Secchi disk and arm method

SECCHI DISK READING (CM)	ARM METHOD	MEANING
Less than 20cm	Well below elbow	Pond too turbid. If pond is turbid with phytoplankton, there will be problems with low dissolved oxygen concentrations especially at night. Do not add more fertilizer or manure. When the turbidity is

SECCHI DISK READING (CM)	ARM METHOD	MEANING
		from suspended solids (e.g., clay) productivity will be low. If there is a foul smell, flush the pond.
20-30cm	Reaches about elbow	Turbidity is good for tilapia production. Do not add more fertilizer
30-45cm		Turbidity (from phytoplankton) is in a good condition, but tilapia growth will improve if more plankton can be produced so continue fertilizer applications. In addition, a simple glass filled with pond water can be used. When looking closely (if available with a magnifying glass), zooplankton can be seen, indicating good availability of natural feed.
45-60cm	Reaches well above elbow	Phytoplankton is becoming scarce. Add more fertilizer to you pond. If you do not get a bloom, you may have to check your pH. Also, make sure the pond is not leaking and being flushed.
More than 60cm		Water is too clear. Inadequate productivity and danger of aquatic weed problems. If there are aquatic weeds growing in the pond, remove them before fertilizing the pond.

Table 21: Sample session plan outline for pond preparation

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
30 min	Introduction	Training objectives and expectations	
120-180 min depending on location of training venue	The Pond eco-system Steps in pond preparation (drying, liming, fertilization, repairs Check parameters: pH, transparency, turbidity and watercolor before the best stocking time.	**30 min**: Input presentation and group discussion – The importance to create an ecosystem in the pond that supports fish growth. **60 min**: Input presentation and plenary group discussion. Show different water samples in clear bottles/glasses (clear, light green, dark green, brown). Ask participants what they observe (light penetration) and what they think is good for fish farming. Explain, what color and turbidity (which sample) represents suitable water quality. **30 min**: Introduction of Secchi disk for water turbidity assessment and how to make a Secchi disk from local material. If pond nearby for demonstration. **60 min** for demonstration of water quality assessment. Ask participants to assess the water quality by color and turbidity. Demonstrate the use of Secchi disk. Discuss and explain measures such	Flip chart, color paper, marker pen, paper tape, Posters/Photos Water samples, quicklime and animal manure/compost/ liquid compost Secchi disk

		as fertilization. Use plain, transparent drinking glasses to take water samples and let participants look at the sampled water through magnifying glasses (x 30 magnification).	

MODULE 4

4 MODULE 4: SEED AND FINGERLING SELECTION, STOCKING AND NURSING

In Module 3, farmers learned how to properly prepare their pond for culturing fish. Following the outline of their farm plans developed in module 1, they already know what species they want to culture and how many fish they want to raise.

While preparing their ponds for farming, they should start exploring where to source the fish seed or fingerlings of the species they want to stock.

Module 4 is about selecting good quality seeds and fingerlings. At the end of the training, the farmers will know how to identify good quality seeds; they are familiar with the requirements of safe transportation of seed and fingerlings and the process of stocking, i.e., releasing the fish into their ponds. They will learn what to look for if they intend to buy directly from a hatchery. As fish procured directly from a hatchery usually is very small (around 1 gram) they will learn to raise such small fish in nursery ponds until they have reached a size at which they can safely be transferred to grow-out production ponds.

Seed should be bought from a reliable source. It should be uniform in size, free from disease and healthy. By observing the movement, color, shape, size and responses to feed, the quality can be assessed, as detailed below. Transport of seed from the hatchery to grow-out farms should be carefully planned. Constant vigilance is necessary to ensure that good water quality is maintained and that the fish reach their destination in time. Accessibility and road infrastructure are important when locating a hatchery to ensure easy movement of fish. Usually, seed are transported using polyethylene bags in insulated polystyrene boxes or in open-air containers. During transportation, live fish can face stress resulting from the decrease in water quality if fish are not handled properly. They should be purged before transport and provided with clean water and oxygen throughout the journey. In cool water, fish are less active and thus consume less oxygen and produce less ammonia and CO_2. Temperatures and pH should be adjusted slowly as not to expose fish to sudden temperature and pH changes.

Fish production will normally increase with the number of fish stocked per unit area until the optimum stocking density is reached. Choosing the optimal stocking rate for a pond results in the highest quantity and quality of fish production and thus the most profit. The carrying capacity of a fishpond is largely determined by management practices. When stocking fish in the ponds, they need to be slowly acclimatized to their new environment to avoid stress.

4.1 KEY PRINCIPLES OF SEED SELECTION AND STOCKING

4.1.1 OBTAIN GOOD QUALITY SEEDS AND FINGERLINGS

Hatcheries usually sell their fish seed at very small sizes of about 1g. As this poses several challenges for farming, the farmer should seek to buy larger fingerlings of at least 5g average bodyweight or even larger that are more suitable for stocking. For larger fingerlings, there are specialized nurseries, which procure	Fingerlings should be healthy, about the same age and size and free of injuries and deformities. What to look for when selecting fingerlings: **Indicators of poor health:** ▪ Inconsistent, spotted skin color, red spots ▪ Bulging eyes on some fish, or a swollen belly

fish seeds from hatcheries and raise (nurse) these to a size appropriate for stocking.

Farmers should check and explore whether such nurseries are operating in the vicinity of their farms and contact them one to two months before they intend to stock their ponds so that the nursery farmers have sufficient time to procure fish seed and nurse them to an appropriate outgrow bodyweight of at least 5g.

Looking for and buying larger fingerlings is better, as they are more robust:

- Survival rates of smaller fish often is 50% or less compared to 90% for the larger fish and thus requires higher management effort.
- Smaller fish are more sensitive to poor water quality and changes to water quality such as temperature and pH.
- Smaller fingerlings of air breathing species cannot yet breathe air and suffer when transferred into the new pond environment.
- Fish that are comparatively old for their size, i.e., still small (e.g., 2g) at an age of 3 months will have a slower growth rate than fish that are younger but are of the same size.
- If smaller fish is stocked, it will take longer to reach the desired size for selling and consumption. This means higher production costs for the farmer.
- It is more difficult for the farmer to monitor and observe mortality of small fish, as they are harder to see when they are dead, and the farmer may not be aware that there are fewer fish in the pond than expected. This may lead to excessive feeding with negative impacts on the water quality.
- Deformed bodies such as crooked spines
- Injuries
- Thin and long bodies
- Inactive; just hanging in the water.

Figure 43: Deformed fingerling
Source: www.forbes.com

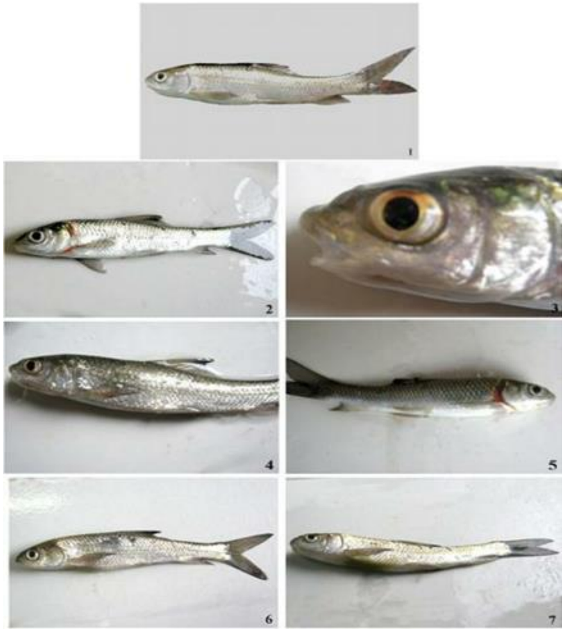


Figure 44: Fingerlings with thin and long body
Source: www.researchgate.net

Figure 45: Fingerlings with bulging eyes, swollen abdomens and red spots

Source: www.vibo.com.vn

<table>
<tr>
<td></td>
<td>Indicators of good health:
▪ Proper skin color, no injuries and no missing scales (if scaled species)
▪ Body proportions are normal, no body deformations or swollen bellies
▪ Fish are active, not just floating passively in the water
Examples of healthy fingerlings:</td>
</tr>
<tr>
<td>Fingerlings with size: 5g about 6 weeks and 8g for 8 weeks.</td>
<td>
Figure 46: Good quality and healthy Silver Barb fingerlings
Photo credit: Keo Kimsean/FARDeC</td>
</tr>
<tr>
<td>Fingerlings with size: 5g about 5 weeks and 10g for 8 weeks.</td>
<td>
Figure 47: Good quality and healthy Tilapia fingerlings
Photo credit: Keo Kimsean/FARDeC</td>
</tr>
</table>

Fingerlings with size: 5g about 6 weeks and 10g for 8 weeks.	 **Figure 48: Good quality, healthy Striped Catfish fingerlings** Photo credit: Keo Kimsean/FARDeC
Fingerlings with size: 3g about 4 weeks and 7g for 7 weeks.	 **Figure 49: Good quality and healthy Climbing Perch fingerlings** Photo credit: Keo Kimsean/FARDeC

Not all hatcheries and nurseries have high quality production standards and appropriate biosecurity measures to ensure good genetic quality. Seeds or fingerlings should be purchased only from a reliable source. Seed should not be bought from another production farmer or caught from the wild. Catching seeds from the wild is a common practice among small-scale farmers in Cambodia.	Ideally, the farmer or nursery operator should visit the hatchery before deciding to buy fingerlings. To get a realistic impression of the hatchery, the farmer should not announce his visit. Observe the hatchery facilities and surroundings. ▪ Are they kept clean? ▪ How are waste and effluents disposed? ▪ Look for production schedules and tables, probably on white boards. If no white boards ask for breeding plans and schedules. **Ask questions such as**: ▪ How old (how many weeks) are these fingerlings? (Are they at a size that is to be expected at this age?) Examples:

	– Walking Catfish, Pangasius, Silver Barb around 1g after 4 weeks, 5g after 8 weeks. – With Tilapia, male fish are usually bigger than female fish. With Silver Barb the growth rate of females is faster than that of males. If the hatchery produces mono-sex fingerlings, farmers will get additional advantage in term of growth rate. ▪ How many family lines are maintained by the hatchery? (More family lines reflect higher genetic diversity and quality, i.e., no inbreeding. ▪ What are the sources of the brood stock? ▪ How often is the brood stock changed? ▪ Brood stock should not be recruited from their own fish production to avoid inbreeding

4.1.2 TRANSPORTATION OF SEED AND FINGERLINGS TO THE FARM

Getting the fish seed or fingerlings from the hatchery to the farm safely and without losses poses several challenges. Transportation can cause a lot of stress to the fish and even mortality, particularly on some rural roads. Make arrangements with the hatchery a couple of days before the planned stocking date, so that the hatchery can prepare and condition the fish for transportation. If possible, ensure that fish are prepared and transported during the cooler times of the day – after sunset until early morning. If fingerlings are transported during the daytime, try to use and air-conditioned vehicle or keep the container in which the fingerlings are transported cool by surrounding with ice. Fish can be transported in **polybags, Styrofoam boxes, and plastic containers and tanks**, which can be mounted on a pick-up truck or even fixed to a motorbike. Whichever method is chosen, sufficient **oxygen supply** is the most critical factor during transportation. Air breathing species such as Walking Catfish and Striped Catfish (Trey Pra) can be more easily transported in open containers, while species such as Tilapia and Silver Barb need oxygenated polybags.	**To reduce mortality during transportation** 1. Fish must conditioned for travel for 24 to 36 hrs. before actual travel. This includes providing good water quality and sufficient oxygen as well as no feeding and allowing fish to defecate during this period before packing and transportation. Fish with full stomachs need larger amounts of oxygen for digestion. 2. Fish feces can also contaminate the water leading to high levels of ammonia, which in turn reduces the oxygen level in the water and causes stress for the fish. 3. Sufficient levels of oxygen need to be provided. 4. Water temperature must be kept low (18-22°C). The higher the temperature, the higher the oxygen demand. Make sure that the containers or bags used for transportation are shaded and transport the fish at night or early morning or with shade and cool transport during the daytime. 5. You can cool the boxes by putting Ice around them or on their top. **Tanks** 1. Rectangular, circular or elliptical tanks can be mounted on a vehicle and supplied with air or oxygen. 2. Insulation materials can be used as filler between tank walls as a jacket covering the tank.

In Cambodia fingerlings are usually transported in 10L-water plastic bags (0.4cm x 0.7cm size) or 15-30L-water open containers (gasoline cans). The quantity of fingerlings per bag or container is related to the size of seeds:

For plastic bags (0.4 x0.7cm; 10L-water):

Fry: 20000-30000 head/bag

Size 0.5cm: 2500-3000 head/bag

Size1-1.5cm: 1000-1500 head/bag

Size 2.5-3cm: 200-500 head/bag

For open containers (30L-water)

Fry: 100000-120000 head/container

Size 0.5cm: 3000-3500 head/container

Size1-1.5cm: 1500-2000 head/container

Size 2.5-3cm: 300-350 head/container

Figure 50: Using plastic containers for fingerling transportation
Photo credit: FARDeC

Figure 51: Open container transport (30L-gasoline can)
Photo credit: FARDeC

Plastic bags

1. Common method to transport post larvae, fry and fingerlings
2. Normally pure oxygen is used to fill the bags
3. Corners of bags should be rounded to avoid creating traps
4. Standardize the numbers put in each bag
5. Gradually release oxygen into the bag to avoid shock caused by high pressure
6. Avoid sharp objects wherever plastic bags are to be placed.

Figure 53: Gasoline canister with cut-out prepared for fingerling transportation
Photo credit: Nen Phanna/GFA - SAFR Project

Figure 54: Preparing oxygenated plastic bag transport
Photo credit: Krich Songly/NARDI

Figure 52: Oxygenated and filled poly bag
Photo credit: Nen Phanna/GFA – SAFR Project

Figure 55: Short-distance transport of fingerlings by small-scale household-based farm
Photo credit: Nen Phanna/GFA - SAFR Project

4.1.3 STOCKING AND RELEASING SEEDS AND FINGERLINGS TO THE POND

Ensure that seed is transported at a cool time such as early morning, night time, evening or at daytime but without direct sun. It's better to arrive at the farm site during the cool time of the day for stocking. Fingerlings should be released into the pond in the morning between 8am to 10am or in the late afternoon or early evening.

The fingerlings need time to adjust to their new environment. A sudden release can cause shock and lead to mortality. If the mode of transportation is bags, let the bags with the seed or fingerlings float on the pond for at least 15 minutes before releasing them into the pond to avoid shocks and so the fingerlings can adjust to the new temperature and the water chemistry.

Allow fish to recover from the stress of transport and start feeding only 1-2 days after stocking depending on duration of transportation from nursery to farm.

EXERCISE: Demonstration of stocking

At the pond, show the trainees how to acclimatize the fish. Use a plastic bag with cold water and air and some floating objects inside (if actual seed is not available, wood or plastic objects can be used so they can be easily removed from the pond afterward). Ideally use a thermometer to verify the temperature.

Ensure to point out the difference in the bags and the pond before floating the bags in the pond. Float the bags in the pond for at least 15 minutes and do not expose them to direct sunlight. Mix pond water into the bag slowly. Let the fish get used to the pond water. Once the temperature and pH of the water in the bag is the same as in the pond, the fish can be released into the pond with care. Open the bag and sink the open side into the water so the fish can swim out by themselves. Observe how the fish swim. If they lie on the pond bottom, this is a sign of being over-stressed from transport, to the point where they might die.

Figure 56: Acclimatization and release of fingerlings
Photo credit: Theo Ebbers/GFA - SAFR Project

4.2 NURSING

Fish are often supplied to farms at very small sizes of around 1g or smaller. Releasing such small seed into ponds can cause high rates of mortality and is inefficient. To ensure efficient feeding, small seeds should be reared in nursery ponds or hapas for several weeks, until they reach a size of 5g when they should be moved to grow-out ponds.

Nursery ponds are usually fertilized ponds. The principal objective of rearing juvenile fish in fertilized ponds is to provide an environment in which fish survive and grow rapidly. This relies on the maintenance of an appropriate size and abundance of food organisms (phytoplankton, zooplankton and macro invertebrates), while simultaneously maintaining water quality suitable for survival and growth. It is important to time preparation and filling of ponds to coincide with stocking to ensure that when juvenile fish are ready to be stocked into the ponds, there has been sufficient time for the ponds to develop suitable blooms of plankton. See section on fertilization later in this module.

4.2.1 NURSING FISH IN HAPAS

To increase the survival rate, hapas can be placed in ponds to nurse fry for a few weeks before releasing them into open pond water. Hapas can be setup in grow-out ponds, as a hapa of around 90cm to 120cm water depth. A hapa with that water depth can accommodate around 100 Tilapia seed/sqm.

Another advantage of the hapa is that you can easily count the number of fingerlings. As hapas are often fouled by uneaten feed, fish feces and attached microbial growth, they should be cleaned with a brush weekly.

Figure 57: Rearing fingerlings in hapas
Photo Credit: Theo Ebbers/GFA - SAFR Project

4.2.2 FISH GRADING

If fingerlings are not graded according to their size, the bigger fingerlings will consume most of the feed and the smaller fish cannot get sufficient feed. For carnivorous species, there also is the danger of cannibalism, with the bigger fish eating smaller fish (e.g., Walking Catfish and Snakehead).

Grading also is important as the farmers should stock their ponds with uniformly sized fingerlings to ensure consistent growth across the cohort.

Grading fry by size is achieved by sieving fish through netting of different mesh sizes, e.g., using scoop nets or plastic mesh. Several sizes of graders will be necessary depending on the species and size of fish that will be graded.

After grading, the stocking density should be adjusted to the fish size.

For example, fry of non-air breathing species can be stocked at a density of 200 to 250 head per m^2, e.g., Tilapia, Silver Barb, Carp, etc., and for air breathing species. The stocking density can be 500 to 1000 /m^2 for Walking Catfish, Striped Catfish, Snakehead, etc.

Figure 58: Grading equipment
Photo credit: Nen Phanna/GFA - SAFR Project

Figure 59: Using grading equipment
Photo credit: NARDI

Figure 60: Grading fish with a different type of grader
Photo credit: Keo Rathada

Grading fingerlings can be done by using scoop nets or screen buckets with 3 or 4 different mesh sizes. This has two main purposes.

a. Grading fingerling during rearing from fry larvae to fingerling stage ensures rearing of same or nearly same size fingerlings.

1. < 1g fingerling
2. 1g - < 3g fingerling
3. 3g - 5g fingerling
4. 6g - 10g fingerling

Grading can be done every two weeks and graded fingerlings moved to different hapas according to the size for further rearing.

b. Grading of fingerlings is equally important to meet the requirements of the customers and their order. Some may want to order smaller fingerlings; others may prefer larger fingerlings and the nursery should be able to meet that respective requirement of the farmer.

	<u>Counting fingerlings:</u> **Step 1:** Farmers can use a balance or scale for weighing fingerlings without water. Weigh 3 separate groups of fish fingerlings each weighing about 1 kg. **Step 2:** Count the number of head for each sample. For example, fingerling of Pangasius with size 8-18mm or 6-10g: Sample 1: 1kg = 110 fingerlings Sample 2: 1kg = 120 fingerlings Sample 3: 1kg = 130 fingerlings **Calculation** Average per 1kg <u>Formula</u>: Sample1+Sample 2+Sample 3)/3 <u>Example</u>: = (110+120+130/3) = 120 fingerlings per kg. Example If total weight of fingerling in the hapa is 100kg **So, total number of fingerlings = average number of fish per kg x total weight of fingerlings in hapa** **= 120 fingerling x 100kg** **= 12,000 fingerlings**

Table 22: Sample session plan for module 4

DURATION	ACTIVITIES/TOPICS	METHODOLOGIES	MATERIALS
15 min	Course objectives and expected outcome	Speech, presentation	
90 min	**FISH SEED SELECTION TRANSPORTATION AND STOCKING**: ▪ Introduction to farmer on how to select good fingerlings; ▪ How to transport fingerlings; ▪ How to release fingerlings into the pond	▪ Brainstorming ▪ Interactive presentation of good fingerlings, transportation, and release of fingerlings ▪ Question linking with pictures or poster ▪ Game of training (small fish & big fish)	Marker pen and color paper. PowerPoint or poster presentation Plastic bag for release of fingerlings demonstration
60 min	Field practice on filling polybags and releasing fingerlings	▪ Field practice and demonstration at pond ▪ Distribute empty polybags to participants	Plastic bags for practice

DURATION	ACTIVITIES/TOPICS	METHODOLOGIES	MATERIALS
		▪ Demonstrate preparation of bags (filling with water and air) and ask participants to follow your demonstration ▪ Take polybags to the pond and demonstrate release of fingerlings (floating the bag, open the bag and mixing pond water into the bag and release fingerlings into the pond). ▪ Ask participant to follow your demonstrations	
30 min	Training evaluation	Participatory plenary	Training evaluation questionnaire forms Flipcharts
15 min	Summary: What did we learn today?	Invite one participant to summarize	Give a speech

MODULE 5

5 MODULE 5: FISH FEEDING AND FEED PRODUCTION

Feed is the most critical cost factor in aquaculture operations. The higher the stocking density and targeted production, the greater the dependence on commercial feed. Thus, feed needs to be cost-effective to meet the economic objectives of farming. High productivity requires high quality feed that is formulated for the cultured species. High quality feed also contributes to good fish health. With lower feed conversion rates than home-made feed, commercial feed offers faster growth, lower mortality and better water quality, as less feed is wasted.

In this module, participants will be familiarized with basic principles of fish feeding. They learn how to optimize their feeding regimes for achieving desired growth rates of fish at minimum costs. This requires the understanding of basic feed components and their importance. For small-scale fish farmers who are operating semi-intensive culture systems, it is important to understand and to be able to provide an inexpensive, balanced diet for their fish. Participants will learn to use and process a variety of farm by-products available at their households and farms as nutritionally valuable ingredients in home-made fish feed for their farm operations.

As the sample calculations of production costs in Module 1 have shown, feeding is the largest cost component in semi-intensive and intensive production systems and **farmers need to understand the costs and economic implications of different feeding systems and feed compositions**.

At the end of this module, participants will understand:

- Nutritional requirements of fish and how to meet them with different production systems
- Advantages and disadvantages of different types of feed
- Importance of different key ingredients
- Different ways of feed administration

They will be able to:

- Apply various feed formulations and produce feed at home
- Apply feed at appropriate rates and have practiced feed formulations
- Analyze the economics and cost-efficiency of their feeding system

5.1 NUTRITIONAL REQUIREMENTS OF FISH

Food availability is the most critical factor for fish growth and yield in a fish farm. This is closely related to stocking density and fish size. In a natural eco-system, fish depend on food produced by this ecosystem. This food is called natural feed and it is an important basis on which to build a farming system. The nutritional value of the natural food supply in ponds is important, even when fish are cultured intensively, especially in outdoor systems.

As natural feed production alone would allow only for a low stocking density, the farmer needs to provide additional feed, if the stocking density exceeds the natural carrying capacity of the pond.

In fertilized ponds with a good production of natural feed, the protein content can be as high as 80% or more, while for species such as Tilapia and Carps 30% would be more than sufficient. The farmer can bring down the overall protein content of the feed in the pond to 30% by feeding "supplementary" feeds, such as carbo-hydrate rich agricultural by products like rice bran, oil cake, broken rice, etc., which are cheap and not normally utilized for human consumption.

We call this feed supplementary feed, as it complements the available natural food in the pond.

Such supplementary feed is not to be confused with home-made feed. When stocking densities are getting too high for natural and supplementary feed to provide sufficient protein, carbohydrates and fats to the fish, formulated feeds are needed to meet these nutritional requirements of the fish. Such formulated feeds can be produced by the farmers (home-made feed) or bought as ready-made commercial feed from the market.

Often home-made feed is recommended, as commercial feeds are considered expensive and ingredients such as rice, soya beans, maize and other agricultural products commonly used for home-made feed are considered cheap and easily available.

As compared to commercial feeds, home-made feeds have a low digestibility, even when cooked. The milling of the feed is important to improve its digestibility. The composition is also important because fish can only grow as fast as the most limiting factor in the feed. Furthermore, home-made feeds take time for preparation and cooking.

The alternative to making home-made fish feed is to purchase commercial pelleted feed. Commercial feeds come with different protein content to match the need of the species under culture. Commercial feeds also come in different qualities. Pelletized feeds can be differentiated from extruded feeds. The process of extrusion improves digestibility and also makes the pellets float, so consumption by the fish can easily be observed.

While different fish species have different nutritional requirements, they all depend on the following key nutrients:

Table 23: Key nutrients

NUTRIENT	DETAILS	REQUIREMENT (% BY DRY DIET)	SOURCES
Proteins	Proteins are important building blocks of fish tissues. Proteins in fish nutrition are needed for the growth and regeneration of tissues. Proteins can be plant based or animal based.	32-45%	Fish meal and meat-based meal (from animal scraps), soy bean, rapeseed
Fat	Used as a source of energy. There are different types of fatty acids, and generally freshwater fish fatty acids of the so-called linoleic (w-3) and (w-6) series.	4-28% (should contain at least 1-2% of the w-6 or w-3 essential fatty acid series)	Fish oil, soy oil
Carbohydrates	Carbohydrates are energy-providing feed components composed of carbon, hydrogen, and oxygen. The energy they provide powers muscular movements. A local source of carbohydrates is rice	10-30%	Rice bran, wheat flour, cassava meal
Minerals	Minerals are inorganic nutritional elements, such as calcium, phosphorous, magnesium, iron, copper, manganese, zinc, iodine, and selenium. Minerals are important for the blood and tissue composition	1.0-2.5% fed as a multi-mineral premix	Mineral pre-mix
Vitamins	These are inorganic substances required in trace amounts. Vitamins are important for a balanced fish nutrition. They are essential, irreplaceable micronutrients that are required for normal physiological functions including growth, body development and reproduction, as well as animal well-being and general health status	1.0–2.5% fed primarily as a multi-vitamin premix. Vitamin C and choline are added separately from the premix because of their chemical instability.	Vitamin pre-mix

To know the feed type a fish species requires, the farmer also needs to understand the feeding behavior of the fish. For example, omnivorous fish require different feed types and nutrient levels than carnivores. Pelagic fish that are living in the water column require floating feed while benthic fish, living and feeding at the pond bottom require sinking feed. For further details on nutritional requirements and feeding behavior or different fish species, see Table 24: Overview of popular fish species in Cambodia.

5.2 PRODUCING NATURAL FEED THROUGH POND FERTILIZATION

Fertilization as the key element to creating a natural food chain in the pond was introduced in Module 3. If the natural productivity of the pond declines, it is necessary to continue fertilizing the pond. The purpose of fertilization is to create a food chain that will increase the productivity of the pond. Nutrients are added to ponds to stimulate the natural production of phytoplankton, zooplankton and bacteria that all serve as food for fish such as Tilapia or Silver Barb as well as omnivorous fish such as Striped Catfish or Walking Catfish.

In a natural ecosystems there are far fewer carnivorous fish on the 4th trophic level than herbivorous fish on the 2nd trophic level. Pure phytoplankton feeders have 10 times more food available than pure zooplankton feeders. Fish that feed on small fish, which feed on zooplankton, already have only 1/100 of the primary production available. For this reason, carnivorous fish on the 4th trophic level depend much more on protein and are more costly to feed.

To support the growth of phytoplankton on the 1st trophic level, fertilization of the ponds is required. This is particularly important for culturing fish that feed on phytoplankton, such as carps and Tilapia. There are different types of fertilizers; inorganic fertilizers that enhance the primary production of the pond and organic manures that can also act as an immediate source of food for the fish. The success of a pond fertilization strategy depends on the initial drying, tilling and liming of the pond bottom. The fertilization strategy used to enhance fish production will depend on the management system (extensive versus semi-intensive), stocking density and type of fertilizers used (organic, inorganic or a combination). Use of chemical fertilizers is not recommended as it is more costly than manure. However, it is a good method of enhancing phytoplankton in the fishpond since they are nutrient dense and easy to handle.

It is recommended to use organic manure produced by the farmer with local resources available at the farmers' household, such as cow dung or chicken manure or compost, as commercial inorganic fertilizer usually is expensive.

5.2.1 KEY PRINCIPLES OF POND FERTILIZATION

<table>
<tr>
<td>Adjust fertilization rate and frequency to maintain light-green pond water with a 30cm Secchi disk reading, see Module 3.

If the water is green enough, no additional fertilizer should be added.</td>
<td>The natural food in the pond (small insects, phytoplankton and zooplankton) is too small to see.

Figure 61: Green pond water indicating high level of phytoplankton/algae as natural feed
Photo credit: Theo Ebbers/GFA, SAFR Project</td>
</tr>
</table>

Secchi Depth	Management Response	Color Code
> 60 cm	Water is too clear. Inadequate algae production. Danger of aquatic weed problem. Increase fertilizer use.	
60–45 cm	Algae becoming too scarce. Increase fertilizer use a little.	
45-30 cm	Ideal algae density.	
20-30 cm	Algae becoming too dense. Reduce fertilizer use a little.	
< 20 cm	Algae too dense. Risk D.O. problems every night. Stop fertilizer use.	

Figure 62: Secchi disk reading and management response
Source: USAID HARVEST Project

Normally pond water is green, brown, reddish or transparent. Muddy brown water is usually caused by soil particles suspended in the water; it is often a sign that the pond is not fertile.

Liming application can help to reduce the clay turbidity. Brownish green indicates that the bloom has more zooplankton while dark brown indicates the presence of phytoplankton (brown algae mainly diatoms). Green colors indicate plankton productivity (green algae mainly Chlorella sp.) Green can range from light green indication of good fertilization) and dark green (indication of over-fertilization). Some plankton turning too green and red floating as scum on water surface at some periods in the day indicates the presence of blue-green algae (Cyano-bacteria (green scum) or Euglena sp. (red scum). This is because the pond is rich of nutrient loads for long periods without cleaning. It can happen most easily during very sustained, hot weather.

Light green pond water as an indication of good water quality during culturing fish.

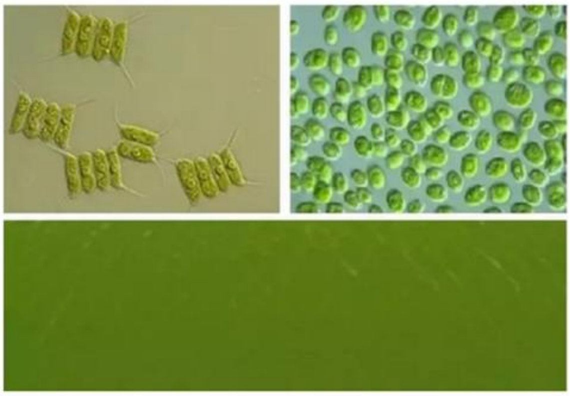


Figure 61: Microscopic algae
Photo Credit: Bing-wen Xi/FFRC-CAFS

The photo above shows green algae (right) and brown algae (left) and below indicating good green water color.

Figure 62: Zooplankton Cladocera and Copepod
Source: www.dosenpendidikan.co.id

Figure 63: Determining the presence of zooplankton
Photo credit: Nget Touch SAFR Project

The pictures above show farmers collecting and concentrating zooplankton and phytoplankton from their pond by using a cloth and a transparent glass to observe the presence of natural foods available in the pond water.

Indications of unhealthy ponds

The pond with muddy clay, green scum or red scum will prevent light penetration into the pond water leading to lower productivity of natural food for zooplankton and fish.

Figure 64: Muddy pond due to pond wall erosion
Photo credit: Nget Touch SAFR Project

Figure 65: Pond water with green scrum
Photo credit: Nget Touch SAFR Project

Figure 66: Red algae in pond
Photo credit: Nget Touch SAFR Project

Table 25: Observations of water color and required management actions

POND COLOR, STATUS	MANAGEMENT ACTION
Muddy	Use lime or organic fertilizer, or Alum (depending on the availability and cost of materials)
Dark green	Reduce fertilizer, reduce feeding. If external water source exists, exchange 20-30% of the water with clear, save (no pesticides) unfertilized water
Red	Reduce fertilizer, if possible, exchange 20-30% of the water with clear, unfertilized water
Clear	Add more fertilizer. If a pond with well fertilized water is nearby, add fertilized water from this pond.

5.3 SUPPLEMENTARY AND FORMULATED FEEDS

If the stocking density of a fertilized pond exceeds carrying capacity, i.e., it cannot produce sufficient natural feed for the stocked fish, the farmer needs to add additional feed to ensure appropriate fish growth rates. At low stocking densities in a well-fertilized pond, the farmer can add carbohydrate rich agricultural byproducts to enhance fish growth. In such ponds, the natural feed can contain up to 80% of protein, whereas many herbivorous species need only about 30% or less. Feeding carbohydrate-rich agricultural byproducts such as rice bran can bring down the protein proportion of the available feed to desired levels.

At higher stocking densities, this approach will not be sufficient, and the farmer needs to add formulated feed to the pond which must also contain sufficient protein. Formulated feed is a feed-mixture of various ingredients based on the nutrient requirements of fish. Such formulated feed can be made by farmers at home (home-made feed) or commercially produced pelleted feed.

By choosing between home-made feed and commercial feed, the farmer needs to carefully consider the costs.

An important factor to consider before making home-made feed is the feed conversion rate (FCR). The FCR is the amount of feed required to produce 1kg of fish. E.g., a FCR of 1.5 means that the farmer needs 1,5kg of feed to produce 1kg of fish; with a FCR of 2.5, growing 1kg of fish would require 2.5kg of feed. Home-made feed often has a FCR of 3.5 or higher, i.e., the amount of feed to produce 1kg of fish is much higher than with commercial feed. Thus, the farmer needs to consider the costs of producing home-made feed vs. the cost of buying commercial feed. Unless ingredients for home-made feed are cheaply or even freely available at the farm, home-made feed may be more expensive than commercial pelleted feed just because of the high amount of feed needed to meet the feeding requirements of the fish. Production of home-made feed also requires a lot of time and effort as the ingredients need to be prepared and well-cooked to increase the feed uptake capacity of the fish. For a good uptake of the nutrients provided in the feed the ingredients must be in powder form. The finer the grinding the better the uptake. Also, the composition is important because the fish can only grow as fast as the most limiting factor in the feed.

It is important to ensure that the fish are not underfed, as underfeeding will lead to slower growth.

Excess feeding on the other hand, can reduce water quality through biological and chemical contamination. More than that, it also is a waste of money, as unused costly feed will sink to the pond bottom without being consumed by the fish.

Feeding frequency should be adjusted to the fish size, with smaller fish requiring higher feeding frequencies than larger fish. When feeding, fish behavior should be observed to ensure fish are eating and to avoid under- or over-feeding. Low appetite is a sign of distress and is a reason to test water quality, check fish health, stocking densities and feeding practices. Feeding is normally performed manually. Feed should be given at least two times a day. Feeding frames for floating feeds and feeding trays for sinking or home-made feeds can be used to confine feed in a certain area and minimize loss. The places and times of feeding should be kept constant, and thus fish will become accustomed very quickly and consume feed efficiently.

Proper feeding practices can reduce the FCR, reduce feed usage and waste due to overfeeding, and prevent pond bottom and water quality deterioration due to excess feed accumulation.

5.3.1 SUPPLEMENTARY FEEDS

Supplementing natural feed in the pond with carbohydrate rich agricultural by products, e.g., kitchen left-overs, etc., works best for herbivorous species at low stocking densities, such as Carp, Tilapia, and Silver Barb. In addition to agricultural byproducts, ingredients can be collected from the wild. Grass and leafy vegetables should be cut, but generally can be added to the pond without processing.

For omnivorous species such as catfish, which require more protein, grass, leafy vegetables, Azolla are less useful; for these fish insects, termites and worms can be added.

Table 26: Examples of supplementary feed

COLLECTED FROM THE WILD	AGICULTURAL PRODUCTS FOR HUMAN CONSUMPTION	AGRICULTURAL BY PRODUCTS	LEFTOVER
Azolla	Fruits	Maize bran	Kitchen leftovers
Termites	Leafy vegetables	Rice bran	
Grass, leaves	Soya bean flour		

5.3.2 HOME-MADE FEED

Farmers can formulate his/her own feed using locally available ingredients such as agricultural products or their by-products.

These home-made feeds, which consist of a simple combination of locally available inputs, contain some key nutrients fish require for a healthy growth.

Local feeds are what a farmer can easily find within his or her locality to feed fish. These feeds can be used either as single feed or combined with several feedstuffs. The following should be considered as it relates to feedstuffs:

- When selecting ingredients for making fish feed, the farmer needs to consider the feeding preference of the fish. Ingredients should be selected according to fish feeding habits in their natural habitat. If the fish are omnivorous, ingredients can be selected from both plant and animal origin, if they are herbivorous, ingredients should only be of plant origin.
- For omnivorous and carnivorous species, animal protein is important, but also more costly than plant-based protein, if purchased.
- Good alternatives to fishmeal and other animal-based protein are leaves of plants such as moringa (Moringa oleifera) or cassava (Manihot esculenta).
- Easily available in Cambodia are aquatic plants such as aquatic ferns (Azolla spp.), duckweed (Lemnoideae spp.) and water lettuce (Pistia stratiotes). These ingredients have a good nutrient profile with respect to protein, vitamins and minerals.
- Home-made feeds can be in powder, crumble or dough form and they sink in water. As mentioned above, farmers should use a feeding tray so that feed does not stick to the mud at the bottom and farmers can monitor whether fish are eating the particular type of feed or not.

MAKING CRUMBLES/FLAKES

- Mix the ingredients according to the chosen formula
- Add a binder e.g., cassava meal or flour as a proportion of the total ingredients
- Add water to the mixture
- Make sure every part is thoroughly wet
- Make flat chunks
- Spread them out in the sun to dry

Table 27: Home-made feed mix basic formulas with locally available ingredients

	INGREDIENT	FORMULA FOR MAKING HOME-MADE FISH FEED - 100 KG

		FORMULA 1	FORMULA 2	FORMULA 3	FORMULA 4	FORMULA 5	FORMULA 6	FORMULA 7	FORMULA 8	FORMULA 9	FORMULA 10
1	Rice bran	25	50	25	10	30	40			26	25
2	Corn meal	25		20				32	29		
3	Soybean		30	30	60	40	30				
4	Greens	50									
5	Azolla		20	15							
6	Trash fish/pelleted feed (protein 40%)			10	20	20	20				
7	Broken rice				10	10	10				
8	Leucaena leaf meal							57		63	
9	Cassava							10	10	10	10
10	Taro leaf meal								60		64
11	Salt (Nacl)							1	1	1	1
	Total (Kg)	100	100	100	100	100	100	100	100	100	100

Figure 67: Ingredients for home-made feed
Source: FiA, USAID HARVEST & WorldFish

Figure 68: Making home-made feed
Source: FiA, USAID HARVEST & WorldFish

Home-made feeds should not be put directly into the pond, and tools such feeding trays are recommended. These allow the farmer to observe the uptake of the feed by the fish.

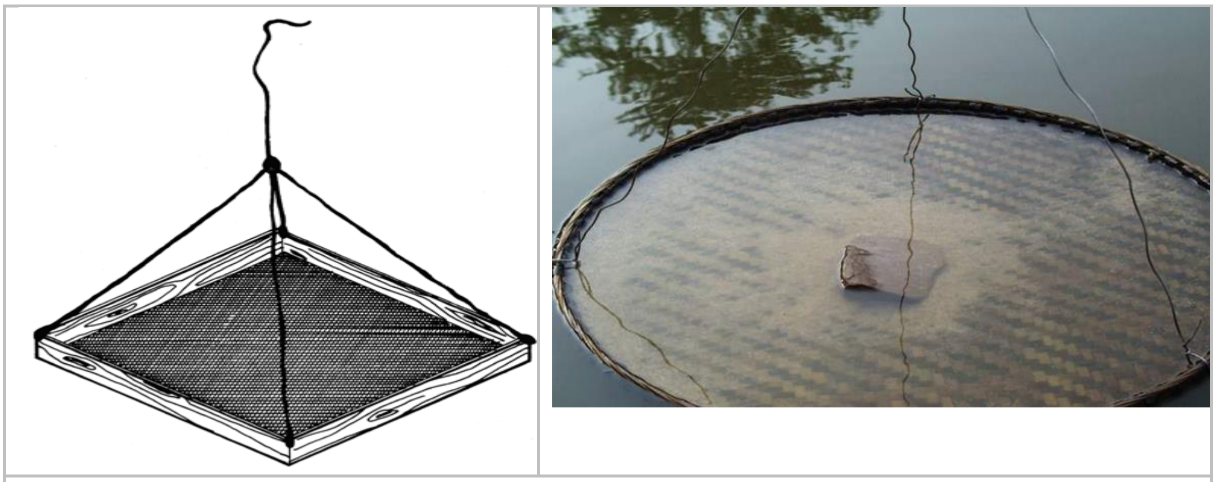


Figure 69: Example of feeding tools
Source: FAO

5.3.3 COMMERCIAL PELLETED FEED

At higher stocking densities, the use of commercial, pelleted feed becomes cheaper than home-made feed, simply because more home-made feed than commercial feed is needed per kg of fish.

If the farmer applies commercial feed, the following key principles should be followed:

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Feed should be purchased from a reputable manufacturer

Use high quality commercial feeds and buy directly from the feed mill or trusted dealers.

Floating pellets are recommended, as they remain on the surface until consumed and hence it is easier to monitor the fish and track their growth.

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<td>

Figure 70: Pangasius floating pelleted feed
Photo credit: Keat Socheat/HURREDO, SAFR Project

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<td>

Feed should be fresh

While this also applies for home-made feed, it is important for the farmer to check the production and expiry date of the purchased feed.

Before feeding, check whether the feed is fresh with uniform size and color and not moldy.

</td>
<td>

Figure 71: Dry fresh pellets, not moldy
Source: https://www.dreamstime.com/photos-images/pellet-feed.html

</td>
</tr>
</table>

Pellets should be of the right size Use the right size of pellets for your fish at each life stage. If the pellets are too big, the fish cannot eat them, since fish swallow feed whole. If the pellets are too small, the fish require much effort to eat enough and this will decrease the growth rate. Also, the protein requirements are different for different live stages of the fish. Fingerling feed is always much more expensive than grow out feeds because fingerling feed has a higher protein content. Feeding fish feed for early stages during grow out increases your production cost significantly.	 **Figure 72: Various sizes of pelleted feed** Source: www.afrimash.com
Use the right feed for your species Different fish species have different protein requirements. Since protein is the most expensive ingredient in fish food, you should not feed herbivorous fish with food intended for carnivorous fish (high protein content), otherwise you will lose money.	

Feed the right amount **Do not overfeed**: Uneaten feed will go to waste and decrease the water quality. It is also a waste of financial resources, as the farmer spends a significant amount of money on feed that is not used by the fish. **Do not underfeed**: Insufficient feeding will lead to poor growth. When using floating feeds, a floating hose ring or pipes can be used to contain the feed and stop it floating away to the pond margins where it attracts birds and is harder for the fish to consume. In the absence of a weighing scale, it is hard to calculate feeding quantities. Therefore, smallholders can opt to feed to satiation. Use of floating feed enables the monitoring of fish during feeding; feed should be consumed within 20 minutes of being offered to the fish. If fish do not consume all the pellets within 20 minutes, the quantity should be reduced. However, this method leads to a higher feed conversion rate, increasing the total amount of feed needed to produce each kg of fish. Fish will consume much more of the expensive feed than needed for maximal growth. Therefore, this should be done maximum once a week to observe the	**Use feeding instructions provided by the feed producer** When using commercial feed, information of how much feed should be given to the fish, based on the percentage of average body weight, is provided by the feed producer (printed on the bag) These instructions are based on optimum production parameters, which in reality usually are not achieved. Also, commercial feed often contains attractors, that make the fish feed more than they actually need. Following these instructions thus often leads to overfeeding, with feed not being consumed by the fish and thus wasting money. Following the recommendations on the left for observing feeding, is a first good approach to determine the appropriate amount of feed without determining average weight of fish through sampling. However, for better feeding results monitoring growth rate and average body weight of

maximum uptake. For normal feeding, you reduce the amount of maximum uptake feed by at least 20%.

Figure 73: Observing fish feeding behavior and feed uptake
Photo credit: Nget Touch/GFA, SAFR Project

Figure 74: Indicator of over-feeding – floating pellets not consumed by fish
Photo credit: Theo Ebbers/GFA, SAFR Project

fish through regular monthly sampling of fish should be done.

Sampling:

- Use small cast net to quickly catch around 20 to 30 fish as a sample, avoiding fish getting stressed.
- Weigh the caught fish on the scale with a bucket and note the total weight.
- Count the sampled fish in the bucket and return back to the pond and note the number of fish counted and the weight of empty bucket.
- Weight of sampled fishes = weight of fish and bucket - weight of empty bucket.
- Average weight per fish= weight of sampled fish/number of fish counted.
- Total weight of fish in the pond = average weight per fish x total number of fish in the pond.

Note: Must have a good estimate total number of fish and fish mortality in the pond

Figure 75: Weighing fish sample
Photo credit: Loeung Sannva/HURREDO- SAFR Project

5.3.4 CALCULATION OF THE FEED COST

Whenever fish are sampled the farmer can also control the efficiency of the feeding. As mentioned under 5.3. the FCR gives the ratio of the kg of feed needed to produce one kg of fish. Commercial feeds are well formulated to achieve the lowest FCR possible, but they also come at the highest price per kg. To understand the efficiency of your feed, you can calculate the feed cost. The feed cost is different from the price per kg of feed. The feed cost tells you how much Riel you pay for feed to grow 1 kg of fish. For example, a feed-cost of 4.000 riel/kg fish means, that you have fed your fish with feed worth 4000 riel while your fish has grown by 1 kilogram.

To calculate the "feed cost" you need the total money spent for feed divided by the total fish weight minus the fish weight at the time of stocking. Feed cost should be calculated every time you sample and weigh your fish.

Example how to calculate feed cost:

To calculate feed cost you need the **money spent for feed [Riel]** and the **weight gain of your fish [kg fish]**

Money spent for feed from day of stocking: sum up from your record book
e.g. *rice bran*
100 kg + 100 kg + 150 kg = 350 kg * 200 Riel/kg = **70.000 Riel**

Weight gain of your fish
1.) Day of stocking: Number of fish stocked e.g. 500 * average weight of fish e.g. 15 g = 7,5 kg
2.) Day of sampling: Number of fish stocked (500) – mortality (10) e.g. 490 * average weight of fish e.g. 110 g = 53,9 kg
3.) Weight gain of fish = 53,9 kg fish – 7,5 kg fish = **46,4 kg fish**

Feedcost:
1.) Money spent for feed = **70.000 Riel**
2.) Weight gain of fish = **46,4 kg fish**

Feed cost = 70.000 Riel / 46,6 kg fish = **1502 Riel / kg fish**

Supplementary feeds are usually very cheap, because they are byproducts from agriculture. At low stocking densities the contribution of natural feed is high and therefore the feed costs are low. Usually between 1,000 and 2,000 Riel/kg fish or even less. Homemade feeds are more expensive, because they contain quality products from agriculture. At higher stocking densities contribution of natural feed is less and feed cost increases to about 3,000 or 6,000 Riel per kg of fish. For formulated feeds you pay more Riel per kg (approx. 3,500 Riel/kg) because formulated feeds contain everything a fish needs and they are well processed. Although the price per kg is high, formulated feeds are usually more efficient than home-made feeds. Feed cost per kg of fish usually ranges between 3,500-4,500 Riel/kg fish, depending greatly on your feed management.

Table 27: Sample session plan for module 5

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
20 min	Session objectives and expected outcome	Interactive plenary with brainstorming of participant expectations	Marker pen, flip chart, and color paper.
180-200 min	Fish feed and Feeding		
	▪ (45-60 minutes) Introduction to farmers on key nutritional components of feed for fish (protein, carbohydrate, fat, mix vitamin and mineral)	▪ Interactive brainstorming on 3 key nutrients important for fish: 1. Development, 2. Energy, and 3. Protection (protein, carbohydrate, fat, vitamins, and mineral)	▪ Flip chart and marker

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
	▪ (15-30 minutes) Interactive reviewed on the importance of natural fish feed and how to grow it in the fishpond ▪ Supplementary feed ▪ Home-made feed (recipes and processing) ▪ Commercial feeds ▪ Feeding techniques ▪ Delayed feeding ▪ Reduced feeding ▪ Key principles of polyculture ▪ Assessing costs of home-made feeds	– Guide question about what is nutritious food for human health? Conclusion of the trainer for fish is the same. – What types of food ingredients at home do you have that have the same nutritional properties? – Collect answers on flip chart – Cluster/ sort ingredients to the nutrient category ▪ Poster presentation and brainstorming with farmers on what is natural feed and how to grow it. ▪ Interactive poster presentation ▪ Referring to the ingredient clusters developed in the brainstorming ▪ Interactive poster presentation ▪ Presenting poster ▪ Interactive plenary brainstorming of local prices for ingredients ▪ Sample calculations of costs for required feed amounts of home-made feed based on the formulas in Table 25 as well as commercial feed.	▪ Flip chart and marker ▪ Flip chart and marker ▪ Poster, paper tape ▪ Photos/Poster ▪ Flip chart and marker
120 min	Field practice		
	▪ Production of home-made feed ▪ Observation of natural feed	▪ Preparation of home-made feed ingredients, start to cook ingredients. ▪ While ingredients for home-made feed are cooking: ▪ Pond observation of natural live food and water samples: – Ask participants to take water samples with a transparent glass or bottle. If magnifying glasses are available, look at the sample using the magnifying glass. Zooplankton should be visible and observable. – Ask two participants to scoop and filter water through a cloth, such as a cotton sheet (Figure 63: Determining the presence of zooplankton). The "residue" in the cloth is phytoplankton and zooplankton. Individual organisms of zooplankton are visible and can be enlarged by a magnifier. ▪ Continue home-made feed production	▪ Local ingredient sources, pots, woods, and water ▪ Glass for sampling ▪ Cloth for collecting natural food ▪ Magnifier
20 min	Training evaluation	Distributing questionnaires and pens to each client HH	Questionnaires form pen

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
20 min	Conclusion and summary of the lessons learned	Invite one participant to summarize the learned key points	Speech

MODULE 6

6 MODULE 6: WATER QUALITY AND FISH HEALTH

Maintaining a productive pond-ecosystem with stable water conditions and the provision of sufficient feed for raising fish is the most important factor of successful fish farming. Fish are in good condition if the water is in good condition. If the water is in bad condition, the fish will get sick.

The previous modules explained extensively how to prepare and maintain the productivity of a pond with appropriate fertilization and feeding. However, when increasing stocking densities and adjusting required feeding regimes farmers need to pay attention to additional factors that are limiting the production capacity of a pond and can increase the risks of failure such as insufficient oxygen levels and other water parameters that may affect fish health and growth.

Of the many interrelated water quality parameters that influence the health and growth rate of fish, the availability of oxygen is the most important. Others are temperature and pH, ammonia concentration, CO2, nitrite, suspended solids and alkalinity.

In this module, participants learn how to determine and possibly measure these parameters and take corrective actions if these parameters are out outside of normal ranges appropriate for fish farming.

Participants will also gain knowledge and understanding of fish diseases, causes and types of diseases and how to prevent and treat parasites and diseases in aquaculture.

6.1 WATER QUALITY MANAGEMENT

6.1.1 REGULARLY OBSERVE AND MONITOR WATER QUALITY

Farmers should closely observe and assess the water quality of their ponds on a daily basis, if possible. Easily observable parameters such as transparency and watercolor have been discussed in the previous Modules. Transparency and watercolor are indicators of water quality and signal the amount and type of suspended particles and organisms such as phytoplankton, algae, zooplankton, and suspended solids in the water. These parameters can be measured using a Secchi disk or with the hand method. Light greenish, brown-green or greenish water is most suitable for fish culture. Dark brown and dark green are not good and corrective actions need to be taken (see Module 5).

6.1.2 TEMPERATURE

Temperature is one of the most important factors for the health of fish. Unlike humans, fish are not able to control their body temperature. Accordingly, fish life slows down at cold temperatures and increases when it gets warmer. Water that is too cold is not good for fish as the low temperature can inhibit necessary body functions. Water that is too warm is also not suitable. Fish adjust their body temperature and metabolic rate by moving into cooler or warmer water as necessary. All fish species have an "optimum" temperature range where they are most healthy and grow best. Optimum water temperatures for warm-water fish range between 25°C to 30°C.

At temperatures above or below their respective optimal range, fish growth is reduced and mortalities may occur at extreme temperatures.

Figure 76: Measuring water temperature using a thermometer

Source: ebay.com.au

Table 28: Temperature ranges for different species

SPECIES	OPTIMAL TEMPERATURE (°C)
Tilapia	25-30
Striped Catfish	27-30
Walking Catfish	26-30
Silver Barb	26-28
Climbing Perch	27-30
Chinese Carp	22-30
Indian Carp	26-30

In the event of extreme hot water temperature, some mitigating measures should be taken:
Increase water depth of the pond by adding cooler water. During periods of very hot weather and rising water temperatures, temporarily use aquatic plants (duck weed or Azolla) to cover the water surface 30 to 50%.

Avoid temperature shocks when adding or changing water and be aware that ground water usually much colder than pond water.

Make sure that when pumping ground water into the pond, the temperature is not decreasing too quickly. Do not change more than 30% of the total water volume.

Figure 77: Using floating aquatic plants to manage water temperature
Photo credit: Nget Touch/GFA, SAFR Project

6.1.3 DISSOLVED OXYGEN (DO)

Growth and FCR will be affected by chronically low DO concentrations. DO meters can be quite expensive and probably not affordable for small-scale, household-based and subsistence-based fish farmers. Observation of water transparency and color and fish behavior can however signal low oxygen levels. Such behavior would be:

- Gasping fish
- Fish swimming at surface
- Fish swim sluggishly
- Some dead fish with open mouths and gill covers

When observing these indicators, the farmer needs to consider that oxygen levels in ponds fluctuate on a 24-hour basis. This fluctuation is called a **diurnal oxygen cycle**. Oxygen increases during daylight hours when photosynthesis is occurring and decreases at night when respiration continues but photosynthesis does not. Thus, observations should be made in the morning, as this is the most critical time with low oxygen levels. Oxygen concentrations should be greater than 3 mg/L in the morning.

Common causes of oxygen depletion include cloudy weather, decomposing plant materials and dead algae in the pond, after algae blooms have crashed or died off, etc. Just two to three days of overcast weather can cause oxygen production to diminish.

Figure 78: DO meter probe
Source: www.enviroequipment.com

When the oxygen demand remains the same or increases, oxygen levels begin to decrease. Typically, oxygen levels are lowest just before dawn and highest in the late afternoon. As a rule of thumb, DO should be maintained above 3.0 ppm mg/L. Prolonged exposure to low, non-lethal levels of DO can cause chronic stress and cause fish to stop feeding, reduce their ability to metabolize ingested food and make them more susceptible to disease.

In commercial ponds with high stocking densities, technical measures such as water wheels that churn the water are used to add and maintain oxygen levels. For small-scale farming and production systems, semi-intensive with appropriate stocking densities such aeration systems should not be necessary and probably are too costly. If the farmer, however, observes low oxygen levels the following are simple and cheap remedies that can be applied:

- If the cause is too much algae (dark green water, algae mats on the surface), reduce nutrient levels, reduce feeding.
- If the farmer has a pump, exchange 20-30% of the pond water with fresh water that has less algae. The water pumped in should be sprayed or splashed on the water surface to add oxygen.
- In a small pond, "paddle" the water manually by hand.
- Reduce the number of fish by partially harvesting fish.
- Stop or reduce feeding temporarily.

Figure 79: Fish gasping for air on water surface
Photo credit: Len Rodgers

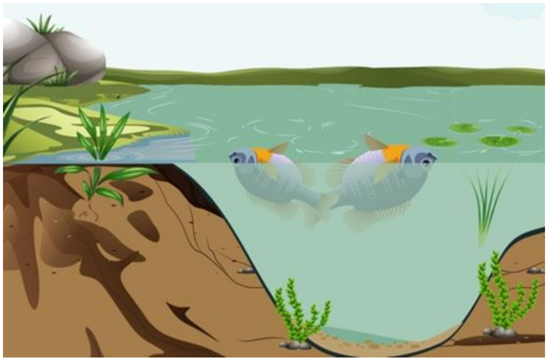


Figure 80: Dead fish with open mouths and gills
Source: GFA SAFR Project

Figure 81: Aeration for small-scale ponds by pumping fresh water into the pond
Photo credit: Sopheap/GFA, SAFR Project

Figure 82: Aeration by solar-powered water wheel
Source:www.alibaba.com/product-detail/Powered-400w-Solar-paddle-wheel-aerator_60592044585.html

6.1.4 PH LEVELS

pH – The concentration of bases and acids in the water determines the water's pH. A low pH is acidic and a high pH is basic; a pH of 7 is neutral.

Fish survive and grow best in water with a pH between 6.5 - 9. If pH readings are outside this range, fish growth is reduced. At values below 4.5 or above 10, mortalities occur.
pH is subject to change throughout the day from 5 in the morning to 9 at midday. Daily variation depends on the buffer capacity of the water. To see a trend in the pH development, pH measurement should always be taken under the same conditions, e.g., in the morning before dawn and at around noontime. In well-buffered ponds (with alkalinity over 50-100mg/L), pH typically fluctuates one or two units daily.

In the morning, carbon dioxide levels are high and pH is low as a result of respiration during the night (carbon dioxide forms a mild acid when dissolved in water). After sunrise, algae and other green plants produce carbohydrates and oxygen from carbon dioxide and water by photosynthesis. As carbon dioxide is removed from the water, pH increases**. The lowest pH** of the day is typically associated with the lowest level of dissolved oxygen. **The highest pH** of the day is typically associated with the highest level of dissolved oxygen.

Tilapia can survive a wide range of pH, from 5 to 10, but are said to grow best at pH 6 to 8. pH can be measured using pH strips or a meter probe.

When pH is high
At a pH value of more than 8.5 over several weeks of exposure, the toxicity of ammonia nitrogen will increase in the water and fish will have health problems such as gill rot and black, red or yellow gill diseases. To lower pH, some management actions should be taken:

- Partly change water (with better water).
- Reduce algae growth in the pond by reducing nutrient inputs or reduce photosynthesis activities by reducing sunlight or culture algae filter-feeder fish (Silver Carp) to control algae density.

Figure 83: pH test kit
Source: bigalspets.com

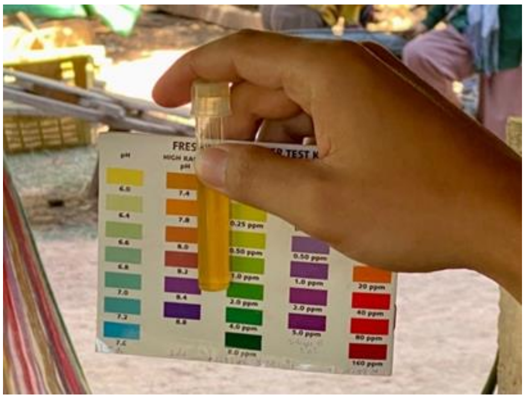


Figure 84: Demonstration of testing pH level of pond water
Photo credit: Theo Ebbers/GFA, SAFR Project

Figure 85: pH meter probe
Source: Alibaba.com

- Apply Alum (aluminum sulfate) start with 10mg/L of water, followed by 5-10mg/L. Overtreatment can cause a dramatic decrease in pH. Alkalinity is also reduced. Never use in water with alkalinity less than 20mg/L.
- Add organic materials, for example cracked corn, soybean meal, animal manure. As it decays, it releases carbon dioxide (CO_2). The application rate of organic material should be 10-15kg/ha/day for one week. Do not apply more than 20kg/ha/day.
- Use EM (effective microorganism) 1L/ha of pond.

When pH is low

When pH is below 6.5, pH capacity of aquatic animals' blood to carry oxygen is decreased. With extended exposure to low pH, physiological functions of fish (e.g., appetite, digestion, absorption of nutrients, metabolism, etc.) will be negatively affected. To increase pH some management actions should be taken:

- Change water (with better water)
- Add 120mg/L of Gypsum (Calcium sulfate)
- Add agricultural lime ($CaCO_3$) 20-25g/m^3
- Use sodium bicarbonate or dolomite powder

Figure 86: Alum for water quality management
Source cndbstco.com

Figure 87: Cracked corn for water quality management
Source: CountryMax.com

Figure 88: Agricultural lime for water quality management
Photo credit: Nen Phanna; SAFR project

6.1.5 AMMONIA (NH3)

Ammonia is the major end product in breakdown of proteins in fish. Fish digest the protein in their feed and excrete ammonia through their gills and their feces. The amount of ammonia excreted by fish varies with the amount of protein put into the pond or culture system, increasing as feeding rates increase. Ammonia also develops in the pond from bacterial decomposition of organic matter such as uneaten feed or dead algae and aquatic plants because these also contain proteins.

Figure 89: Ammonia test kit
Source: redwoodaquatics.co.nz

Total Ammonia Nitrogen (TAN) exists in two forms: un-ionized NH_3 (highly toxic) and ionized NH_4^+ (less toxic). The proportion of toxic un-ionized ammonia increases as the temperature and pH of the water increase. For every pH increase of one unit, the amount of toxic un-ionized ammonia increases about 10 times. The relative proportion of the two forms present in water is mainly affected by pH. Un-ionized Ammonia is the toxic form and predominates when pH is high. Ammonium ion is relatively non-toxic and predominates when pH is low.

In general, less than 10% of ammonia is in the toxic form when pH is less than 8.0. However, this proportion increases dramatically as pH increases.

Avoid concentrations of un-ionized ammonia greater than 0.1mg/L. Dangerous short-term levels of toxic ammonia, which are capable of killing fish over a few days, start at about 0.6mg/L. Chronic exposure to toxic ammonia levels as low as 0.06mg/L can cause gill and kidney damage, reduction in growth and oxygen-carrying capacity of the fish. Ammonia can be measured using test kits.

Treatment of high Ammonia levels

- If possible, partly exchange water by flushing water on the surface.
- Provide a small area near inflowing water where fish can go to find some relief.
- Maintain high dissolved oxygen level by aeration.
- Temporarily reduce feeding rates until ammonia levels decrease to an acceptable level.
- Use floating aquatic plants (10-20% of surface area) to absorb ammonia.

Figure 90: Floating aquatic plants to purify water and absorb ammonia
Photo credit: ZHU Juan/FFRC-CAFS

Because there is little that can be done to correct problems with ammonia once they occur, the key to ammonia management is to use fish culture practices that minimize the likelihood of such problems. This means stocking fish at a reasonable density, harvesting as often as practical to keep the number of fish in the pond from being too high, and using good feeding practices that maximize the proportion of the feed consumed by fish.

6.1.6 NITRITE (NO_2^-)

Nitrite enters a fish culture system after feed is digested by fish and the excess nitrogen is converted into ammonia, which is then excreted as waste into the water. The ammonia is then converted to nitrite (NO2) which, under normal conditions, is quickly converted to non-toxic nitrate (NO3) by naturally occurring bacteria. In balanced pond systems, concentrations of both ammonia and nitrite are very low relative to the concentrations of nitrate. However, the high protein inputs characteristic of most aquaculture systems may lead to a build-up of the intermediate product.

Nitrite is toxic to fish and causes "brown blood" disease. Brown blood disease occurs in fish when water contains high nitrite concentrations. Nitrite enters the blood stream through the gills and turns the blood to a chocolate-brown color. Hemoglobin, which transports oxygen in the blood, combines with nitrite to form methemoglobin, which is incapable of oxygen transport. Concentrations of 0.5mg/L have reduced growth and adversely affected fish. In culture water, nitrite concentration should be less than 0.2mg/L. To reduce high nitrite concentration in water:

- Exchange water (with better water)
- Reduce feeding rate

Figure 91: Nitrite test kit
Source: sacramentokoi.com

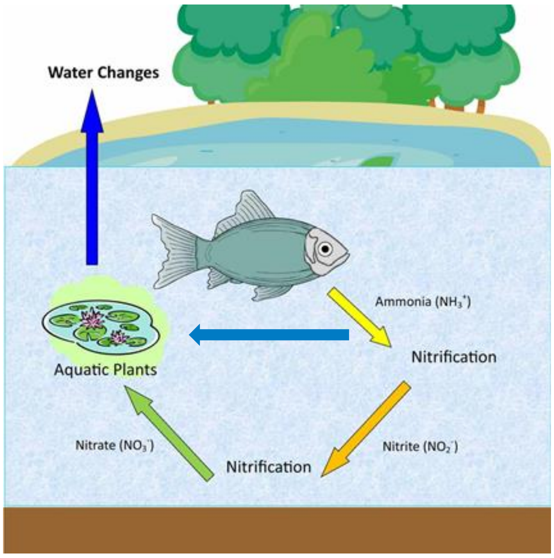


Figure 92: Nitrification process
Source: https://cafishvet.com/water-quality/the-nitrogen-cycle/

6.2 SUMMARY: WATER TREATMENT OPTIONS IF MEASUREMENTS ARE OUT OF NORMAL RANGE

Table 29: Fish observation, water quality and management measures

OBSERVATION OF FISH BEHAVIOR	POTENTIAL REASON	POTENTIAL ACTION
Little to no feeding, heavy breathing or gasping for air	High water temperature (>30°C). In warmer water less oxygen will be dissolved	▪ Partly exchange water with colder water ▪ Add aquatic plants partially covering surface
No feeding, slow movement	Low water temperature	▪ Reduce feeding and closely observe because at colder weather fish will also feed less. Rate of infections might increase if colder weather continues.
Gasping for air, no feeding	Low dissolved oxygen (<3.5 ppm AM, <5 ppm PM) for other reasons than high temperature	▪ Increase water exchange with higher oxygen content ▪ "spray" or "splash" water into the pond to add oxygen ▪ Stop feeding until issue corrected ▪ Beating/stirring of water and/or moving water increases DO
Little feeding, apathetic	Low pH (<6)	▪ Add agricultural lime (CaCO3) 20-25g/m^3 ▪ Reduce feeding rate
	High ammonia (TAN >0.25mg/L) or pH higher than 9	▪ Exchange water ▪ Reduce feeding rate ▪ Lower pH ▪ Watch for symptoms of parasites/disease
	Transparency too low (<30cm)	▪ Exchange pond water with 20-30% clear water ▪ Reduce feeding rate and/or nutrient inputs

OBSERVATION OF FISH BEHAVIOR	POTENTIAL REASON	POTENTIAL ACTION
		▪ Provide shade to reduce sunlight, e.g., by adding floating plants
	Transparency too high	▪ If available, partly exchange water with well-fertilized water from another pond ▪ Increase fertilization
	Dark green or brown color	▪ Exchange water ▪ Reduce feeding rate or nutrient inputs ▪ Measure DO ▪ Reduce sunlight for photosynthesis

6.3 FISH HEALTH: DISEASE PREVENTION AND MANAGEMENT

Outbreaks of disease pose a great risk to fish farming operations and can cause heavy losses to aquaculture operators by high mortalities and negatively impacting growth rates. Efforts need to be taken to prevent diseases by following good and appropriate aquaculture practices, such as those on water quality management and biosecurity outlined above in previous modules. It is important to be able to detect symptoms and indicators of disease such as unusual behavior of fish. Changes in behavior may be the first sign that fish are being stressed. Physical changes may become apparent, such as abnormal growth, lesions or discoloration on the body surface, loss of some scales, cloudiness of eyes, eroded fins, clogged gills, etc.

Fish health management includes practices that are designed to prevent fish diseases. Prevention is key and focus of management, rather than treatment. The foundation of preventing and controlling possible outbreaks of diseases is to create a pond environment that provides good living conditions for fish through good water quality management, feeding, and nutrition – as described in the previous Modules and sections. Poor water quality and poor nutrition can stress fish which suppresses their immune systems and can increase the risk of diseases. Stressful conditions allow pathogens to cause disease because fish immune systems cannot effectively fight pathogens. In previous Modules, we stressed the importance of re-creating natural ecosystem processes in the pond for production of natural feed. In an extensive farming system with low stocking densities, the risk of spreading disease is lower than in systems with higher stocking densities.

In case a disease does occur, a quick and effective response is necessary. The pond in which the disease is observed should be quarantined, and management should be adjusted. Chemicals or veterinary drugs may be used for disease treatment. Medications used to treat these diseases are costly and are no substitute for proper pond management practices.

FISH DISEASES CAN BE DIFFERENTIATED INTO TWO BROAD CATEGORIES

1) **Infectious diseases**, which are caused by pathogenic organisms such as bacteria and viruses, fungi and parasites.

   Bacterial diseases are either internal infections or infections resulting from injuries to the fish, e.g., during sampling, grading or from harvesting gear. Bacterial infections require treatment with medicated feeds containing approved antibiotics. Typical symptoms include hemorrhagic spots or ulcers along the body wall and around the eyes and mouth. Fish may also have an enlarged, fluid-filled abdomens and protruding eyes. Bacterial diseases can also be external resulting in erosion of skin and ulcerations.

Viral diseases cannot be distinguished from bacterial diseases without special laboratory tests. They are difficult to diagnose and there are no specific medications available to cure viral infections of fish. Consultation with an aquaculture or fish health specialist at the local FiAC office is recommended if you suspect a bacterial or viral disease is killing your fish.

Parasitic diseases of fish are usually caused by small microscopic organisms called protozoa that live in the aquatic environment. There are a variety of protozoans that infest the gills and skin of fish causing irritation, weight loss, and eventually death. Most protozoan infections are relatively easy to control using standard aquaculture chemicals such as copper sulfate, formalin, or potassium permanganate.

Fungal diseases are caused by fungal spores, which are very common in aquatic environments. They do not usually cause disease in healthy fish. When fish are infected with an external parasite, bacterial infection, or injured by handling, the fungi can colonize damaged tissue on the exterior of the fish. These areas appear to have a cottony growth or may appear as brown matted areas when the fish are removed from the water. Formalin or potassium permanganate are effective against most fungal infections. Since fungi usually are a secondary problem, it is important to diagnose the original problem and correct it as well.

Sources of infection

99% of all diseases have their cause in poor living conditions for the fish. Poor living conditions such as high temperature and bad water quality and imbalanced diet impact the immune system of the fish. A good environment is important to maintain a well-functioning immune system, which is needed to fight bacteria and viruses.

Infected fish are the primary source of infectious disease. Wild fish and aquatic animals getting into the pond because of poor water management or protective fencing around the pond during flooding can introduce an infectious disease into the pond.

Infectious water supply. Water supplied from rivers, streams and lakes can carry pathogens that cause disease. In systems that are connected through common water management systems, water from one infected pond can infect the fish in other ponds. Measures to allow strict separation of water flow between several ponds need to be in place.

Improper feed can introduce parasitic diseases such as Mycobacterium spp. in water fleas or nematodes can transmit diseases through ingestion by carnivorous fish.

2) **Non-infectious diseases are caused by environmental problems** – such as low oxygen levels, wrong pH levels, high temperatures, nutritional deficiencies, or genetic anomalies.

Nutritional diseases are difficult to diagnose. They are caused by nutritional deficiencies such as vitamin deficiency, e.g., lack of dietary vitamin C contributes to improper bone development resulting in deformation of the spinal column.

Genetic abnormalities include conformational oddities such as lack of a tail or presence of an extra tail. These are not of great significance, however, in farming systems with multi-sex Tilapia, in which the fish are reproducing at high rates, it is important to minimize inbreeding, e.g., by bringing in unrelated fish for use as brood stock.

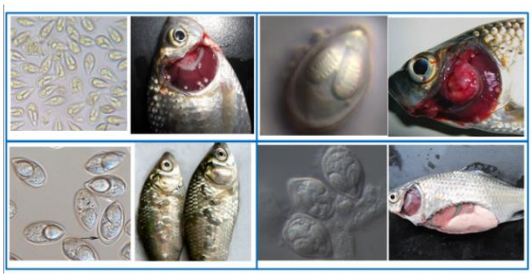
IDENTIFICATION, CAUSES, CONTROL, PREVENTION OF FISH DISEASES IN AQUACULTURE

Daily observation of fish and their behavior is a critical first step to know whether the fish are healthy. The farmer can recognize health problems in their fish by observing the appearance of fish, changes in their body structure and their behavior.

The most obvious sign of sick fish is the presence of dead or dying animals. However, the careful observer can usually tell that fish are sick before they start dying because sick fish often stop feeding and may appear lethargic. Healthy fish should eat aggressively if fed at regularly scheduled times. Pond fish should not be visible except at feeding time. Fish hanging listlessly in shallow water, gasping at the surface, or rubbing against objects indicate something may be wrong. These behavioral abnormalities indicate that the fish are not feeling well or that something is irritating them.

In addition to behavioral changes, there are physical signs that should alert producers to potential disease problems in their fish. These include the presence of sores (ulcers or hemorrhages), ragged fins, or abnormal body formation (e.g., a distended abdomen or "dropsy" and exophthalmia or "popeye"). When these abnormalities are observed, the fish should be evaluated for parasitic or bacterial infections.

Table 30: Observation of disease symptoms, potential causes and responses

OBSERVATION	INDICATIVE OF /POTENTIAL CAUSE	CONTROL METHODS
 **Figure 93: Fish with spots indicating infection** Photo credit: Bing-Wen/FFRC-CAFS	Parasitic infestation: Carp *myxosporean* disease **Clinical signs:** transparent spots appear on the body and gills, lethargic, reduced feeding, abnormal swimming (flashing) Causative agent: *Myxosporean* **Modes of transmission:** direct contact with infected tissues/contaminated systems	▪ **Improve environmental conditions, avoid overcrowding** ▪ Remove infected fish ▪ Bath treatment: use Potassium Permanganate (KMnO4) 20ppm, formalin 20-40ppm, routine salt solution 10-20ppt for 30-60 min. ▪ Alternative medicine (herbs): Garlic juice (50 ppm, bath treatment) for 3 days
 **Figure 94: Fish with red spots** Photo credit: Pelle Gaetke, SAFR Project  **Figure 95: Fish with body ulcers** Photo credit: Nget Touch/GFA, SAFR Project	**Bacterial disease:** Carp hemorrhage disease **Clinical signs:** Red boils on the skin, fin rot, lethargic, swimming near the water surface, hemorrhagic body ulcer, abnormal swimming behavior, some mortality. **Modes of transmission:** direct contact with infected tissues/contaminated systems; damaged areas (parasitic infestation/mechanical injuries during transport & grading).	▪ **Avoid rough handling (stocking/sampling/grading)** ▪ **Avoid overcrowding** ▪ Saltwater bath (10-15 min.) ▪ Alternative medicine (herbs): garlic, piper betel leaves – 50-100ppm in dietary feed for 3-7 days.

OBSERVATION	INDICATIVE OF /POTENTIAL CAUSE	CONTROL METHODS
 **Figure 96: Fish with bulging eyes** Photo credit: Bing-Wen Xi/FFR-CAFS	Bacterial Diseases: *Streptococcosis* **Clinical signs:** uni- or bilateral pop eye, cloudy eyes, lethargy, anorexia, reddening of skin at the base of the fins/ventral abdomen, mortality (50-70%) **Causative agent:** Streptococcosis sp. **Modes of transmission:** direct contact with infected tissues/contaminated systems	▪ Reduction in stocking densities, stock disease free fish ▪ Remove infected fish immediately when observing signs of infection ▪ Use medicine or alternative medicine (herbs): garlic, piper betel – 50-100ppm in dietary feed for 3-7 days

Table 31: Sample session plan for fish health and water quality management

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
20 min	Session objectives and expected outcome	Interactive plenary with brainstorming of participant expectations	Marker pen, flip-chart and color paper
180-200 min	**THE IMPORTANCE OF GOOD WATER QUALITY AND APPROPRIATE FEEDING**		
	How to read your fish: Observing fish behavior and responses	▪ Interactive brainstorming on what is needed for creating a healthy environment for fish ▪ Guide question about what key parameters the famers know about good water quality ▪ Collect answer on flip chart ▪ Presentation of key parameters (oxygen, sufficient feed) ▪ Presentation of other parameters ▪ Presenting pictures asking participants what they see, explaining what it means and recommended measures ▪ How do you know whether your fish are in good condition? ▪ How do you know if your fish are overfed or underfed? ▪ Do you think your fish is growing as expected? ▪ How do you regularly check your fish? ▪ Introduction to fish sampling (how to use cast net, handling fish with care, how to weigh fish and calculate the average weight.	Flip chart and marker Flip chart and marker Flip chart and marker Slides, posters, flip chart and marker Poster, paper tape Photos/Poster Flip chart and marker
120 min	**FIELD PRACTICE**		

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
	Fish observation and looking at samples	▪ Take participants to a fishpond and ask what should they regularly check and observe when checking fishponds? ▪ Let everybody look around the fishpond about 10 minutes, then ask them: ▪ What did you observe about the pond and the fish? ▪ Would you now feed the fish? ▪ Guide the participants to catch fish for sampling by using a cast net to assess whether the fish are growing well and checking for symptoms of disease. ▪ Let participants practice sampling and catch fish and to be careful to reduce stress and avoid injuries to the fish. ▪ How do we know fish are growing fast or not.? Sampling calculations (need to know date of stock, fingerling size, and the currently sampling weight) ▪ Did you observe any fish with symptom of diseases? ▪ If yes, refer to Table 30 for potential solutions and treatments	▪
20 min	Training evaluation	Distributing questionnaires and pens to each client HH	Questionnaire forms, pen
20 min	Conclusion and summary of the learned	Invite one participant to summarize the learned key points	Speech

MODULE 7

7 MODULE 7: FISH HARVESTING, HANDLING, AND TRANSPORTATION

The approach and techniques of harvesting vary depend on various factors such as extent and purpose of fish farming. Many small-scale, household-based fish farms have a dual purpose of providing fish for consumption as well as selling fish for additional income. Depending on these varying reasons for fish farming, farmers may choose to harvest just a portion of their fish (partial harvest) for their own consumption or for selling in nearby markets. Farmers with a greater commercial purpose and access to traders who are interested in larger quantities of fish may opt to harvest all of their fish at one time to sell their entire production to traders.

In all these cases, care during harvesting needs to be taken not to injure or damage the fish as cuts and bruises can speed up spoilage. Depending on the purpose for fish farming and market requirements, the farmer may use size-selective equipment and specific harvest methods to ensure that the harvested fish have a specific size and quantity.

This module familiarizes farmers with basic principles, technologies and techniques of fish harvesting, handling and transportation. Knowing these, the farmer will be able to select a harvesting method appropriate for their farms.

7.1 PREPARING AND PLANNING THE HARVEST

Fish harvesting needs to be prepared and planned based on the purpose for raising fish. Does the farmer want to sell all the fish or only some of the fish? The farmer needs to explore the market for the fish to be harvested and sold, considering questions such as the following:

- Where is demand for the fish being produced?
- Are there fish traders who are interested in buying the fish?
- How much are the traders interested to buy?
- At what price are they willing to buy?
- Do they expect me to harvest and transport the harvested fish or will the trader be responsible for the transport?
- Does the trader expect/want to buy live fish or dead fish?

Answering these questions, identifying the buyers, agreeing on a price, and setting a date for the harvest will help the farmer plan the harvest activities and schedule. Agreeing on a date with the trader will enable the farmer to ensure that transportation (vehicle and containers) is ready and, if necessary, ice is available on the day. If additional help and labor is required, planning ahead is important to ensure that the required support for operating a seine net are ready and on time for harvesting.

7.2 NETS AND TRAPS – EQUIPMENT FOR HARVESTING FISH

Depending on the purpose and the plan for fish harvesting, decisions must be made about the equipment needed. These decisions are determined by several factors, namely:

- Is it a full or partial harvest?
- Will the harvest require draining the pond?
- Will fish need to be graded by size?

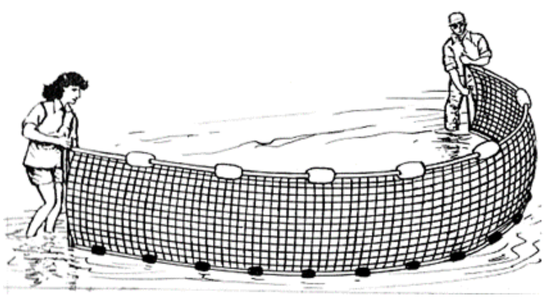
Before harvest, the farmer needs to make sure that harvest and sorting equipment is soft, cleaned and prepared before the harvest. If the fish are sold in nearby markets, harvesting during morning hours is preferred as the water temperatures are lower. However, as oxygen levels are usually at their lowest in the mornings, late evening is often better. This allows for longer transport during the cooler night and arrival at the fish market in the early morning if the markets are further away.

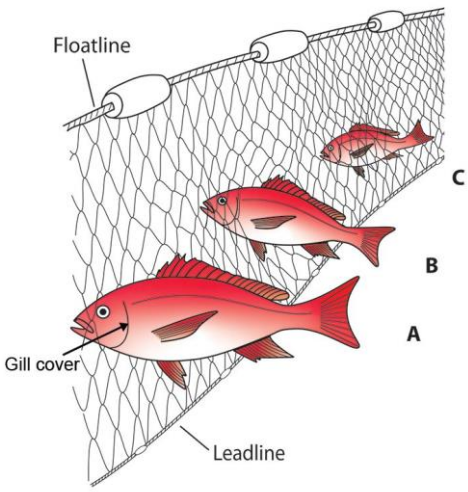
For full harvests, fish should not be fed for 1-2 days before harvesting to give fish time to digest any consumed food and release waste, as the fish can disgorge undigested food during transportation and spoil the water.

For daily or partial harvests, part of fish biomass could be seined and contained by net at one side of the pond without feeding. The remaining fish outside the net can be fed normally.

The following is a brief overview of common harvesting equipment, their uses, advantages, and disadvantages.

Table 32: Overview and description of various harvesting tools and their advantages and disadvantages

Type of net or equipment	Description and uses	Advantages and Disadvantages
Seine Nets  **Figure 97: Seine net with rubber floats and lead sinkers** Source Nets and More  **Figure 98: Harvesting fish by seine net** Photo credit: Theo Ebbers, SAFR Project	Seine nets are the most common types of net to harvest fish on fish farms. They are used to herd and haul the fish from a pond. A seine net is a long net, set from the pond dykes and manually pulled by two ropes attached to its ends along the sides of the pond. A seine net is made up of a longish piece of net that is around 1.5 to 2 times the width of the pond. Its height should match the water depth or be one meter higher. To keep the net vertical (like a rounded wall) top floats are mounted along the surface end of the net; along the bottom weights or sinkers are hung. If the pond has a sloping bottom, i.e., one side is deeper than the other, the net should be pulled from the deeper end towards the shallow end.	Seine nets are good for both full and partial harvest. With an appropriately designed and sized seine net, the farmer can drive the fish in the pond to one side, where fish can be harvested out of the water without fish escaping. Seine nets can be difficult to handle, depending on the size of the pond and net. They usually require at least two people to be operated – one person on each end to evenly pull the net. In larger ponds and with higher fish production, the weight of caught fish might be too great for lifting the net and captured fish out of the water. Seine nets are easier to handle if the pond

Type of net or equipment	Description and uses	Advantages and Disadvantages
 **Figure 99: Sorting for market-sized fish during harvest** Photo credit: Theo Ebbers, SAFR Project		is partially drained before using the net. (See below section on harvesting fish by fully or partially draining the pond). It is worth noting that partially draining the pond to harvest can stress the fish that will remain in the pond.
Gill nets  **Figure 100: Gill net with float and sinkers** Source: Oceana.org	Unlike seine nets, gill nets are stationary. Ideally, they are set in a right angle to a pond side across the pond. They usually consist of a finer thread than seine nets and have a very size selective mesh size. The mesh size will be determined by the size of the fish the farmer wants to harvest. The mesh size should be about 75% of the circumference/body thickness of the fish. Fish of the right size will thus be able to pass partly through the net but not further than their gills. When they try to get out of the net, they will get caught by their gill covers. Smaller fish will be able to pass through the net, while bigger fish cannot pass through the net far	Gill nets are good for regular partial harvest in ponds that have fish of different sizes and/or several species. They can be set at different depths and thus can be used to target bottom dwelling species or pelagic species in a polyculture pond. The method of harvest will not stress the unwanted fish that will remain in the pond. Gill nets are not suitable for a full harvest. As fish caught in the net will eventually die, the farmer should check the net at least once a day.

Type of net or equipment	Description and uses	Advantages and Disadvantages
	enough for their gill covers to be caught. Gill nets work best at night when less visible, and should be checked frequently because fish caught usually die.	
Cast nets  **Figure 101: Cast net** Source: www.shopcalypse.com  **Figure 102: Using a cast net** Photo credit: Theo Ebbers, SAFR Project	Like gill nets, cast nets are suitable for partial harvesting of fish. They are most effective when fish density is high. Their mesh size is usually smaller and thus not size selective. They are made from a round piece of net that is weighted along its outer border with sinkers. Cords attached to the outer border are lead through a center ring and joined into a one rope, by which the net will be pulled. When thrown, the net spreads in a circle and rapidly sinks to the bottom of the pond. By pulling the rope it is closed and entraps the fish	Good for partial harvest and sampling. They are inexpensive and useful for sampling Fish with spines entangle easily. Require practice and skills to throw correctly. Stress the fish easily Since cast nets are not size selective, they can be used to catch various sizes of fish together in one pull, thus causing stress to other unwanted fish. It takes more time and effort to move fish out of the net.
Traps	Traps are generally used in lakes and rivers, but some types can be used for regular and partial harvesting of fish from ponds. Traps can be made from wood, plastic pipes, bamboo or wire frames, with	Traps are useful for size selective, regular harvest. They allow only fish of a specific size range to be trapped, as fish smaller than the mesh size can escape and fish too large for the entrance cannot enter.

Type of net or equipment	Description and uses	Advantages and Dis-advantages
 **Figure 103: Umbrella trap with wire frame and netting** Source: www.pinterest.com  **Figure 104: Drum trap with bamboo frame and netting** Photo credit: Theo Ebbers, SAFR Project  **Figure 105: Bamboo trap** Source: www.tr.pinterest.com	netting, bamboo slats or wire mesh surfaces. If baited traps are used, they should be checked regularly to remove the trapped fish and re-bait the trap.	Unlike Gill nets, they are good for capturing live fish and can keep fish alive in the trap until sale. There is generally less stress to fish than other meth-ods. Sometimes, fish can-not be caught in suffi-cient quantity for sell-ing, but it is a good tool for harvesting fish for HH consumption.

Type of net or equipment	Description and uses	Advantages and Dis-advantages
Lift and scoop nets  **Figure 106: Hand-held scoop basket** Photo credit: Nget Touch, SAFR Project  **Figure 107: Lift net with wire frame and netting** Source: Walmart.com	Like traps, lift nets can be used for regular and partial harvesting of fish to capture small numbers of fish. These nets are made of soft, small mesh that minimizes injury. Fish are lured with feed into the area above the net and the net is lifted quickly. Lift nets can be made from bamboo or wire frames with four cross sides and with netting. The main pole is connected with the joint section in the center, which is used to manually lift the net up out of water for collecting the fish.	Good for partial harvest and sampling. They are suitable for collecting live fish and to quickly sort the desired fish size. The unwanted fish can be released back to the pond, thus minimizing stress to fish. Like traps, sometimes, fish cannot be caught in a sufficient quantity for sale.
Hand-held dip nets for sampling and fish handling  **Figure 108: Dip scoop net** Source: pngimg.com	Hand scoop nets are usually used to move fish from the seine net into baskets to transport for selling or sampling. Hand scoop nets can be made from bamboo or wire frames with dip netting in order to collect more fish.	Are easy to handle and move fish around quickly during harvest. Since they are relatively small, scoop nets can easily stress fish when kept out of the water for long periods. Fish should be moved quickly into buckets or tubs filled with clean water; and should not be overloaded.

7.3 HARVESTING WITH AND WITHOUT DRAINING THE POND

Fully or partially draining the water from a pond makes harvesting easier but is most useful for a full harvest. Often, small ponds used in small-scale, household-based aquaculture, do not have an inlet or outlet. For draining such ponds, a pump is be needed, which causes additional costs to the farmer.

Seine nets are the most effective nets for a full harvest, without fully or partially draining the water. Lift nets and cast nets and traps are effective tools for partial and regular harvesting without draining the water.

7.3.1 WITHOUT DRAINING WATER

Some fish producers prefer to re-stock their ponds continuously by partially harvesting larger market-sized fish in a population of mixed fish sizes. This method works best with seine nets in ponds that require no draining or cannot be drained. The same pond may have fish harvested three or more times yearly. Fish should be harvested when sufficient numbers reach market size. Harvesting efficiency with seine nets can be about 70-90% of the harvestable-sized fish, depending on species, size, experience of harvesters, and the condition of the pond and harvesting equipment. Some farmers conduct only a partial harvest for to capture a small number of fish for sale by using cast nets, lift nets and traps without draining the pond at all.

7.3.2 DRAINING THE WATER PARTIALLY

Partially draining is usually practiced when the pond is big and full of water and it is more difficult for a complete or partial harvest by seine net. To facilitate the harvest and make catching fish easier, 20-30% of the water in the pond can be drained before using a seine net to capture some of the fish. To complete a full harvest, a follow-up catch can be undertaken when the pond is almost completely drained.

7.3.3 DRAINING THE WATER FULLY

The only reliable way to harvest all fish from a pond is to drain it completely. This involves a combination of draining and seining. Avoid using a seine in very shallow water with high density of fish in the pond because it stirs up the mud and causes low dissolved oxygen and high toxic gas conditions, which can be extremely stressful to fish. Shallow water can also warm quickly in hot weather so harvesting in a hot time of the day should be avoided.

If the pond has an outlet, the fish can be caught at the outlet as pond is drained. A net is set either in front of the outlet, i.e., inside the pond or, alternatively, outside the pond at the other end of the outlet to catch the fish while the water is flowing out.

7.4 HANDLING AND TRANSPORT

Fish can easily spoil if not handled properly after harvest. Handling provides many opportunities for fish to get stress and contaminated which can cause a negative odor and flavor. Fish need to be handled carefully to avoid damage that can foster spoilage through the spread of bacteria. Avoid bending the body when placing the fish in a container. Fish sellers or processors accept live or dead fish on arrival but do not want damaged or spoiled products. Ensure that people processing fish wash their hands, wear clean clothes, and cover their hair. They must not cough or spit and should thoroughly clean their work tools. Fish should be protected from bacteria and other contaminants by using enclosed transport vehicles or closed containers.

Equipment and transportation vessels and containers need to be clean and safe. Use plastic buckets, baskets or containers with a smooth surface to prevent damage to the fish. Transport containers and equipment should be designed to minimize physical damage and allow for rapid handing of fish. Containers should allow melted ice water to drain.

Transportation storage time should be minimized as fish start decomposing rapidly. Temperature control is essential for maintaining the quality of fish. Fish should be kept as cold as possible right from the time of harvest and exposure to sun and wind should be minimized. Fish should be kept in clean areas at low temperature and humidity, where they are protected from contamination and by pests. Thus, it is important to plan the harvest and transport to prevent loss of fish and quality.

Make sure that harvest and sorting equipment is soft, clean and prepared before the harvest. If the fish are sold in nearby markets, harvesting during morning hours is preferred as water temperatures are lower. However, oxygen levels are also very low in the mornings so evenings can be preferred. For more distant markets, this allows for longer transport during cooler nights and arrival at fish markets early in the morning.

In the case of full harvests, fish should not be fed for 1-2 days before harvesting to give fish time to digest their food and release any wastes as the fish can disgorge undigested food during transportation and spoil the water. In case of daily partial harvests, part of fish biomass could be seined and contained by nets at one end of the pond without feeding. The remaining fish outside the net can be fed normally.

Ensure that fish that have been given medications are properly weaned prior to harvest so that no residue remains in the fish during sale and consumption. Follow instructions that come with any medicine.

7.4.1 TRANSPORTATION OF LIVE FISH

Cambodian consumers usually prefer to purchase live fish; and in live markets, fish need to be alive for selling. To get a better price, farmers can keep their fish alive during harvest and transportation. The methods of live transportation for market size fish depend on the species of fish and the transporting equipment. Some air-breathing fish such as Striped Catfish, Walking Catfish, Snakehead, Climbing Perch, and Snake-skin Gourami can be transported live in open containers without the addition of any aeration. Other fish like Tilapia, Silver Barb and Silver Carp can be transported in open containers with the addition of aeration or can be packed in oxygenated polybags at very low densities. Some fish such as Snakehead, Walking Catfish and Climbing Perch can be transported with less water and without aeration. For small-scale farmers, small containers or buckets can be used for transporting live fish at low densities without aeration to sell in nearby local markets. For long distance markets, the addition of small-scale aeration systems should be used such as portable battery or solar air pumps and/or with regular water exchange during transportation.

Small-scale farmers can use transport methods according to the equipment they can afford for short or long distances. For live fish transport, fish need to be in water or contact with water to survive. The ratio of water content to fish weight should be 2.5 - 3:1 and 1:1 for fish transported with full water. During transport, salt should be added to the water used to transport fish at 1kg per 1000 L of water. Water temperature should be kept low between 18 to 25ºC during transportation. To lower water temperature by 1ºC, use 10kg of ice per $1m^3$ of water. Lowering the water temperature can keep fish quiet and lower their metabolic rates.

Figure 109: Transporting live fish in a metal container for a short distance
Photo credit: Nen Phanna, SAFR Project

Figure 110: Transporting individual food fish in poly bags or with low densities for long distances
Sources: www.wikiHow.com (left) and www.discusguy.com (right)

Figure 111: Small tank equipped with a small engine-run aeration system for transporting live fish for longer distances
Photo credit: Nen Phanna, SAFR Project

7.4.2 TRANSPORTATION OF DEAD FISH

The purpose of transporting dead fish is to keep the fish as fresh as possible after harvesting and transporting to the target market. Temperatures should be kept low during transport to maintain freshness of fish. After harvest, fish should be moved by dip nets into buckets with shaved ice and salt as soon as possible to keep the freshness. In the buckets or containers, fish should be properly organized in between the layers of ice. Fish should be kept and transported at temperatures below 4°C. If shaved ice is used, the fish to ice ratio should be 1:1 for long distances of more than 200km and 1:1/2 for shorter distances of less than 200km. Get ice (flake, tube, or crushed) from an approved supplier, who produces ice from clean de-chlorinated potable water. Salt should be mixed with ice at the ratio 1:1000 (1g of salt for every 1000g of ice).

Farmers can use plastic, wood, bamboo and metal buckets vertically arranging one on top of another to save space for transportation. To prolong the freshness, internal organs can be removed before transport.

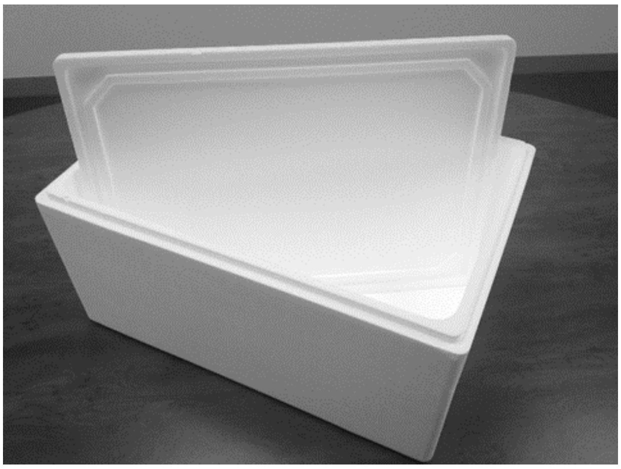


Figure 112: Styrofoam box for transporting fish with ice for long distances
Source: www.onegapackaging.som.au

Figure 113: The correct use of ice for cooling fish during transport or temporary storage
Source: https://nkunimfishenterprise.com/how-to-store-fish/

The choice of transportation methods and containers depends largely on the time required to get the fish to the market. The most important factor is the temperature. It is important to keep temperature as low as possible while also ensuring that the fish are not damaged and kept clean during transportation.

Table 33: Sample session plan for module 7

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
20 min	Session objectives and expected outcome	Interactive plenary with brainstorming of participants expectations	Marker pen, flip chart, and color paper.
120 min	**PREPARING HARVESTING**		
	Introduction of various harvesting gear	Brainstorming with participants: ▪ Who has harvested fish for selling? ▪ What do you need to do and what do you need to know before harvesting fish: Purpose (selling, own consumption) ▪ Contacting buyer ▪ Amount (partial or full harvest) ▪ Transportation (Vehicle, containers and packaging, cooling such as ice and salt). ▪ Conclude and feedback to the answers and questions of participants for more clarity and understanding good harvest preparation practices. ▪ Demonstrate various harvesting equipment (traps, nets) and discuss with the farmers their respective advantages and disadvantages. Slide or poster presentation and/or presentation of actual harvesting equipment with discussion of advantages and disadvantages of each	Flip chart and marker Flip chart, posters and marker Model traps and nets
120 min	**FIELD PRACTICE**		
	If training is in the field near some fish ponds, several harvesting gear and net types can be tested: e.g., a gill net and/or traps can be set in the morning before the input session and observed. In the afternoon farmers can practice using cast nets	▪ If training location and facilities allow, set a gill net and a trap in the morning before the "classroom" training starts. ▪ Take participants to visit the pond of a farmer/participant who wants to harvest fish. ▪ Demonstrate and let participants practice using a cast and a seine net. Explain and demonstrate to all participants how to harvest and handle fish safely to ensure fish will not be injured or killed. ▪ Demonstrate and practice packaging and transport of live and dead fish (for dead fish prepare ice and salt, demonstrate packing with ice in box).	Various harvesting gear, such as gill net, traps, cast net, seine net Scales, book, pen, buckets, plastic containers, salt and ice,
20 min	Training evaluation	Distributing questionnaires and pens to each client HH	Questionnaires form Pen
20 min	Conclusion and summary of the learned material	Invite one participant to summarize the learned key points	Speech

MODULE 8

8 MODULE 8: MONITORING AND ECONOMIC ANALYSIS OF PRODUCTION

Farmers engaging in small-scale, household-based aquaculture are farming fish for two key reasons:

- To supplement their diet with home-grown fish
- To supplement their farm income by selling farmed fish

Often small-scale farmers do not monitor the economics of their fish farming activities. In a typically low-income household economy, the fishpond is a kind of "piggybank" or savings account where setting up and stocking the pond are the initial deposit and smaller irregular deposits consist of feeding the fish. Once the fish are big enough, the farmer can choose to either sell some or all of the crop to get a cash return or they can eat some of the fish thereby saving cash by not spending it on buying fish.

Even if these farmers are not primarily concerned about "making a profit", some form of monitoring the economic performance of their fish farming activities will help them to better understand whether the revenue (cash, fish) they are getting out of their fish farming activities exceeds the cost of inputs (equipment, feed, etc.) that they are putting into the system. In other words, whether their fish farming is creating a net profit or a net loss for their household economy.

By monitoring input costs, production, and outputs, of their fish pond systems, the farmers are able to identify specific areas or actions that can increase the potential value of their "piggybank", e.g., by reducing input costs or increasing productivity by changing the feeding regime or species.

Monitoring expenses and income should be accompanied by monitoring production through the use of accurate, up-to-date record keeping on fish feeding, fish growth and mortality. This will help farmers adjust their management if production targets are not met and to identify issues and problems that need to be addressed.

For both production monitoring and economic assessment of the production, farmers may want to keep a farm logbook or record-keeping book where production related data are recorded regularly.

8.1 MONITORING AND RECORD KEEPING

Maintaining and monitoring production-related records is important for day-to-day management of fish farming. If production targets are not met, accurate information captured in records or log books can help to identify issues and problems that need to be addressed when adapting or improving management.

The type of records and recording intervals will depend on several factors, such as the:

- Level and purpose of production, i.e., own consumption/subsistence vs. selling fish as a small business.
- Educational level of farmers. Many small-scale farmers in rural Cambodia lack the literacy and numeracy skills required to keep records, e.g., feed amounts and calculate feeding requirements.

However, even farmers whose interest is mainly subsistence production and who may have lower literacy and numeracy skills, simple monitoring and record keeping activities are useful and valuable. There is usually a family member who is able to read and write and can support record keeping to benefit the fish farming enterprise.

8.2 DAILY MONITORING AND OBSERVATIONS

Farmers should visit their ponds at least once every day and observe fish behavior and presence of natural feed in the pond. On a daily basis farmers should observe:

- Fish behavior
- Plankton turbidity
- Water color

The farmer should assess the water quality and if necessary, take corrective action such as adjusting feeding, provide fertilization, aeration, etc., as explained in the previous Module.

Other things that should be checked daily include:

- Water levels in the pond – if ponds have an external water supply, farmers should ensure the desired water level;
- Fish mortality – if the farmers see dead fish floating in the pond, these should be removed immediately;
- Integrity of the dykes and fences.

8.3 DAILY RECORD KEEPING AND ACCOUNTING

A simple logbook for recording pond management activities, money spent on these activities and benefits gained through consumption or sale of fish will supplement the daily monitoring activities. Such a logbook will allow the farmer to keep track of management issues, the costs of management and to assess the economic performance of farming operations. Typical financial records include summaries of farm inputs purchases, personnel costs, maintenance and investment costs, sales records, etc.

For small-scale farmer HH who primarily farm for subsistence and/or as a micro enterprise it is important to record the fish consumed as income (indirect benefit) and fish lost to mortality or fish given away to neighbors as expenditure to get a more realistic picture of the income and expenditures of their farming operations.

A simple table can be made to record the following:

- Amount of money spent on fish farming.
- Total number of fish harvested.
- Number or weight of fish harvested for family consumption or given away to neighbors.
- Number or weight of fish sold for cash.

Table 34: Example daily record keeping

DATE	DESCRIPTION / ACTIVITY	EXPENDITURE			INCOME	
		COST/MONEY SPENT (KHR)	DEAD FISH / MORTALITY (KG = KHR)	FISH GIVEN AWAY (KG = KHR)	FISH CONSUMED BY FAMILY (KG = KHR)	FISH SOLD (KG = KHR)
02	Add fertilizer to the pond	-	-	-	-	-
03	Buy ingredients for making fish feed; catch fish for neighbor	20,000	-	0,8kg = 4,000KHR	-	-
05	Repair fence; eat fish	6,000	-	-	1,2kg = 6,000KHR	-
06	Catch fish for selling	1,000	-	-	-	4kg = 20,000KHR
….						
08	Some dead fish early in the morning		0,6kg = 3,000KHR			
08	Pump fresh, clear water					
09	Buy fuel for water pump	8,000				
10	Catch fish for selling					3,5kg = 17,500KHR
16	Catch fish for eating				1kg = 5,000KHR	
Total		35,000KHR	3,000KHR	4, 000KHR	11,000KHR	37,500KHR
Total expenditure		42,000KHR				
Total income					48,500KHR	
Balance		6,500KHR				

These daily records can then be compiled into a monthly overview which will show the:

- Total value of the fish sold or consumed per month.
- Total expenditure on management per month.
- Amount gained (net profit) or lost (net loss) through fish farming.

Table 35: Monthly summary expenditure and income year 2022

MONTH	EXPENDITURE (៛)	INCOME (៛)			BALANCE (៛)
		FISH SOLD	FISH CONSUMED	TOTAL	
January	42,000KHR	37,500KHR	11,000KHR	48,500KHR	6,500KHR
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Total					

By recording the expenses of various management measures and inputs, the farmer can identify the greatest cost factors in his farming system and take action to reduce some of the costs by adjusting management to reduce losses and/or increase profitability.

For example, the farmer realizes that a lot of money is spent on pumping water to maintain water quality. Measures such as reducing fertilization can be taken to improve water quality without exchanging water by pumping.

Table 36: Sample session plan for module 8

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
20 min	Session objectives and expected outcome	Interactive plenary with brainstorming of participants expectations	Marker pen, flip chart, and color paper.
45 min	Daily pond management activities; pond and fish observation	**Plenary brainstorming with participants** Guiding questions: ▪ Why is daily pond observation important? ▪ What do you look for when observing fish? Expected sample answers: – Fish behavior: fish active or sluggish – On surface gasping for air – Dead fish ▪ How do the fish feed? ▪ How is the water quality? (turbidity and water color) – How do you measure turbidity and what is good turbidity? – What is a good water color? Why is this good? **Collect/note down the answers** on flip charts and ask what management measures to take for each observation. **Brainstorming** with participants **on how they can record the observation** for monitoring. Note responses on flip charts.	Flip chart and marker
120 min	Economic analysis of production	**Brainstorming in plenary** Guiding question: ▪ What do you need to know (what information do you need) whether your production is profitable? Collect/note down answers on flip chart. Answers should cover various expenditure categories and income. Sort answers accordingly into two main columns (expenditure and income). The resulting table on a flip chart should look something like Table 34. **Call a participant to assist with a sample calculation of income and expenditure** based on the flip chart. **Distribute printouts of** Table 34 to participants and let them fill this in with information and data from their respective ponds.	Flip charts, markers, color paper and calculator

TIME ALLOCATION	ACTIVITIES/ TOPICS	METHODOLOGIES	MATERIALS
		Discuss the results with the farmers using guiding questions such as ▪ Did you make any profit from your farming? If not, why not? On what do you spend most of the money for farming? ▪ How can you reduce the input costs? Participants may have difficulties in filling in the table based on their own farming experiences as they do not have any records and this exercise relies on memory/recall. **Use this insight to:** ▪ Ask and explain to the participants which information should be recorded daily and how they would be able to record it (record keeping booklet or what would they suggest? ▪ Ask each participant to list down the parameters he/she can record daily as a basis for a daily record keeping template. **At the end of the session each participant has developed their own template/way of collecting production data to assess profitability**	
20 min	Training evaluation	Distributing questionnaires and pens to each client HH	Questionnaires/forms, pens
20 min	Conclusion and summary of the lessons learned	Invite one participant to summarize the learned key points	Speech