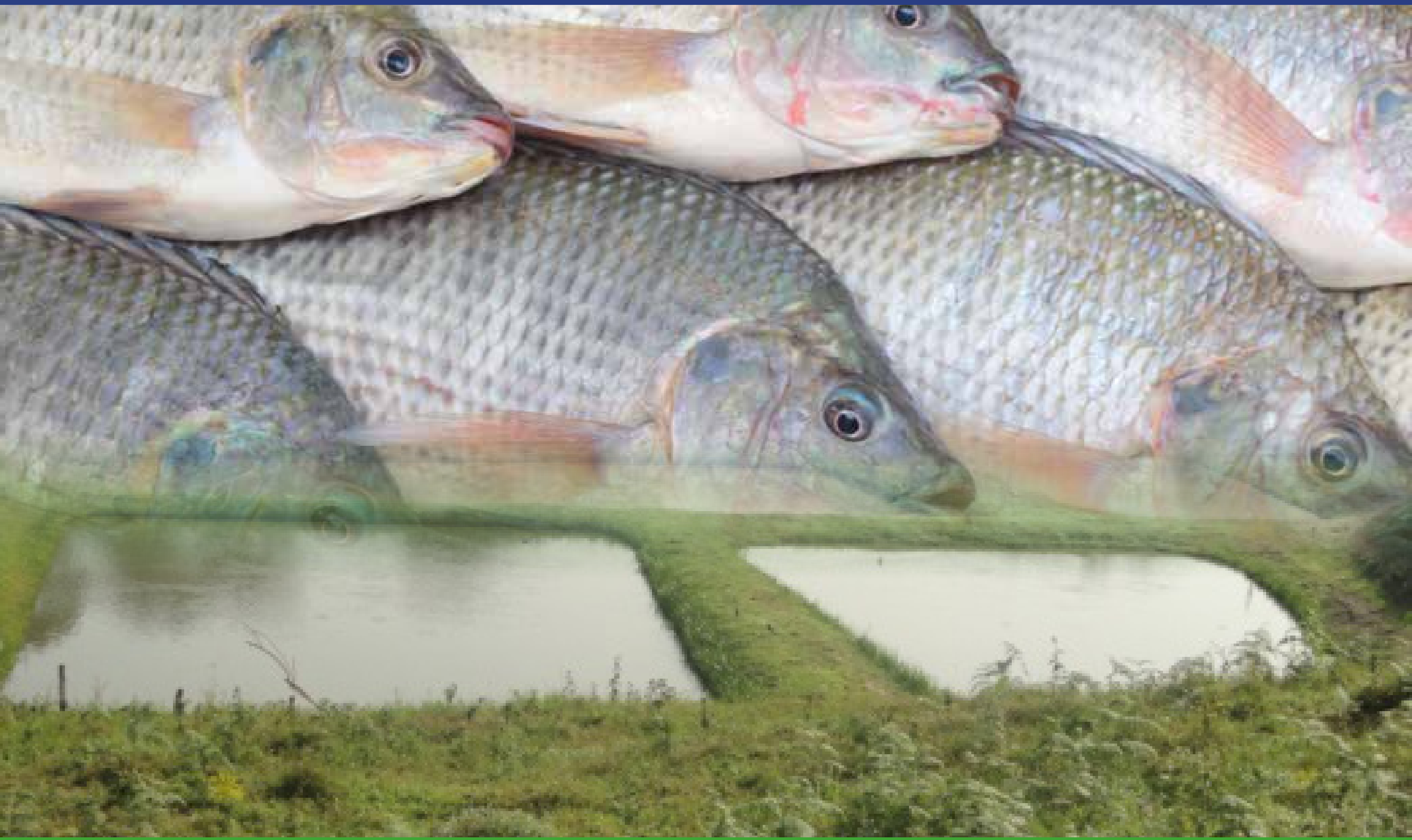
The Republic of Uganda

MINISTRY OF AGRICULTURE ANIMAL INDUSTRY AND FISHERIES

AQUACULTURE TRAINING MANUAL FOR EXTENSION AGENTS IN UGANDA

Improved livelihoods through profitable, competitive and sustainable aquaculture



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FOREWORD

The potential of aquaculture to contribute significantly to national food security, livelihoods and economic growth is recognised by Government of Uganda. With stagnating production from capture fisheries against rising demand for fish in domestic, regional and international markets, aquaculture presents a great opportunity to provide the much needed fish supplies. However, aquaculture has had a number of challenges in accessing adequate quality seed and feeds and extension services.

This training manual for aquaculture extension workers comes at a time when the aquaculture sub-sector in Uganda is at a critical stage of development. Over the last ten years, there has been tremendous change in the sub-sector associated with adoption of new more intensive technologies, a jump in national yield by about 300% and an expansion of market opportunities for producers within local and regional markets. At the same time, there have emerged challenges of environmental degradation, climate change and fish disease. Furthermore, rapid population growth and the limited ability of the fisheries to expand beyond their natural capacity place an enormous challenge on aquaculture sector to increase production to meet fish food and nutrition security needs, generate employment and create wealth in order to sustain its contribution to national development.

These dynamics have placed demands on service provision, particularly with respect to extension services. Ensuring that extension agents, producers and other stakeholders in the value chain remain up to date with the congruent knowledge and skill required to enable them make informed decisions based on validated evidence and industry best practices in such a dynamic and rapidly changing environment is no easy feat.

The Ministry of Agriculture, Animal Industry and Fisheries subsequently has laid down guiding principles for sustainable commercial aquaculture development in the Aquaculture Development Strategy. The strategy encompasses the development needs of the aquaculture value-chain for which a critical gap in access to validated and harmonised information, knowledge and skills is highlighted. This manual therefore is one among the instrumental anchors for validated standardised reference material providing extension agents and producers with reliable and harmonised guidance on recommended technological and sector best practices.

It is my strong desire and trust that the use of this manual shall result into improved enterprise performance for Uganda's fish farmers and increased national aquaculture production.

Hon. Vincent Bamulangaki Sempijja (MP)

MINISTER OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES.

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Acronyms

AMR	Anti-Microbial resistance
DO	Dissolved Oxygen
GAP	Good Aquaculture Practices
FAO	Food and Agriculture Organization of the United Nations
DFR	Directorate of Fisheries Resources
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MSY	Maximum Sustainable Yield
NAGRC-DB	National Animal Genetic Resource Center and Databank
NGO	Non-Governmental Organizations
WHO	World Health Organization of the United Nations
TDS	Total Dissolved Solids
UNBS	Uganda National Bureau of Standards
UBoS	Uganda Bureau of Statistics
POPs	Persistent Organic Pollutants
ras	Recirculating Aquaculture Systems
TW	Top Width
NARO	National Agricultural Research Organization
NEMA	National Environment Management Authority
MDA's	Ministries, Departments and Agencies
eia	Environment Impact Assessment
Dwrm	Directorate of Water Resources Management
Dfr	Directorate of Fisheries Resources
Uncst	Uganda National Council of Science and Technology
fcr	Feed Conversion Ratio
naads	National Agricultural Advisory Services
cod	Chemical Oxygen Demand
bod	Biological Oxygen Demand
TSS	Total Suspended Solid
lvhd	Low Volume High Density
hvld	High Volume Low Density
MPA	Marine Protected Areas
EU	European Union

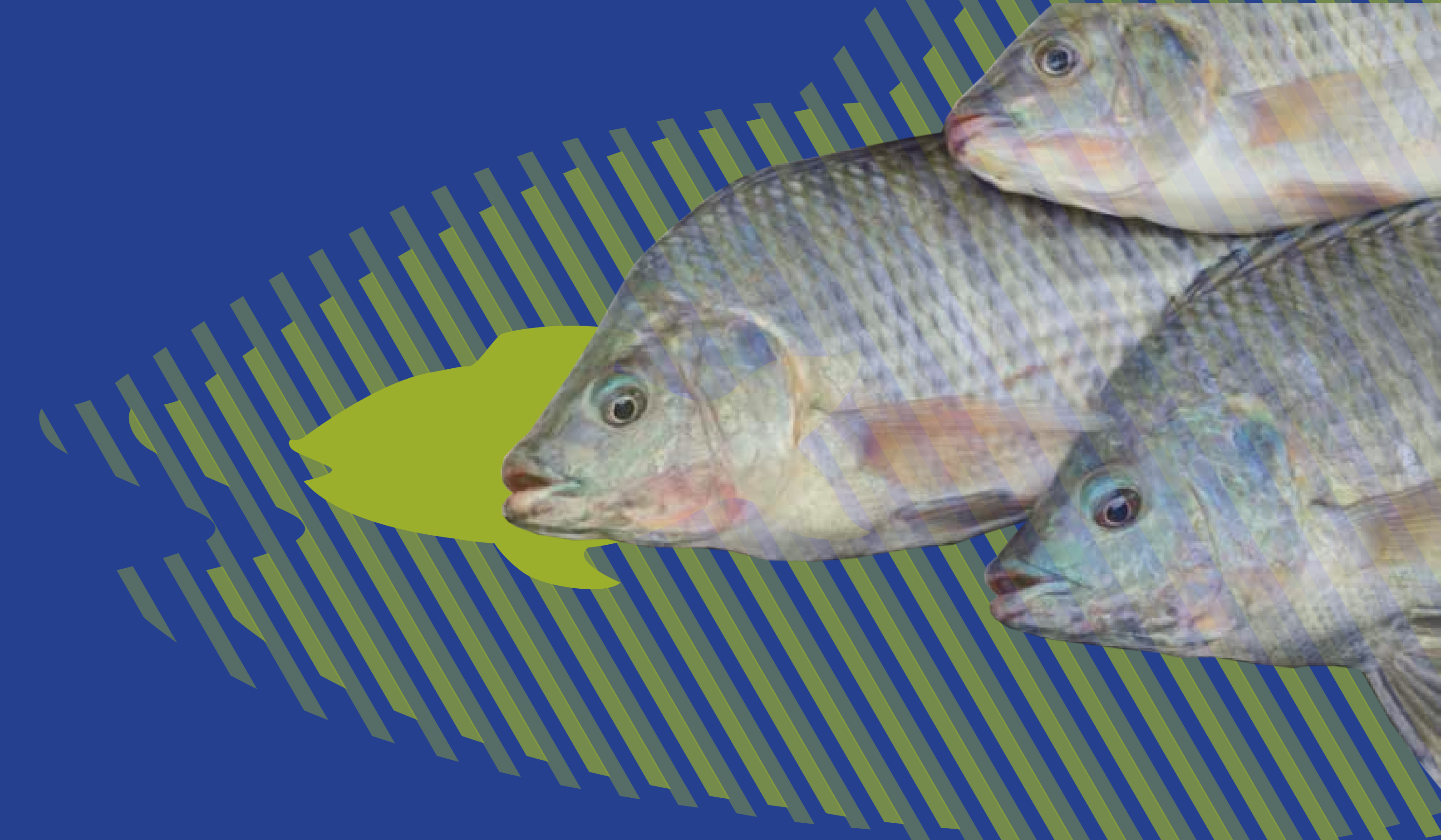
hdpe	High-Density Polyethylene
pvc	Polyvinyl chloride
LSA	Lateral Surface Area
NO_2	Nitrate
CO_2	Carbon dioxide
TDS	Total Dissolved Solid
(N_2)	Nitrogen
tan	Total Ammonium Nitrogen
d.a.p	Di-ammonium Phosphate fertilizer
t.s.p	Triple Super Phosphate fertilizer
M.a.p	Mono-ammonium phosphate fertilizer
n.p.k	Nitrogen Phosphorous Potassium fertilizer
usaid	
nda	National Drug Authority
SOPs	Standard Operating Procedures
fab	Features Advantages and Benefits

List of Definitions

Acclimate	Allowing the animal to slowly adjust to new environmental conditions.
Ad lib	Fish have the liberty to eat when and how much they would like to until they are satisfied
Aeration	Mechanically adding air into water with the objective of increasing the levels of dissolved oxygen in the water.
Alkalinity	Total alkalinity is the measurement of all bases in the water and can be thought of as the buffering capacity of water, or its ability to resist change in pH. The most common and important base is carbonate. Total alkalinity is expressed as milligrams per litre (mg/L) or parts per million (ppm) of calcium carbonate (CaCO3).
Anaerobic	This refers to life forms or processes that occur in environments with limited or no oxygen.
Anoxia (Anoxic)	A situation whereby the dissolved oxygen levels are zero in water.
Assimilation	Organic matter is broken down into smaller less complex particles that are less toxic through biological processes that involve bacteria.
Best Management Practices	This term is used to describe a practice considered to be the most practical means of solving a resource management problem or reducing pollution levels to those compatible with water quality goals.
Buffering Capacity	This is the water's or a chemicals ability to control the level of change in pH and in the process maintaining the pH of the water at around 7, the neutral value. When the pH drops below 7, the water becomes increasingly acidic. When the pH increases above 7, the water becomes more alkaline.
Carrying capacity	The maximum biomass that can be held within the production unit or water body without resulting into water quality problems
Communicable diseases	One that is capable of being transferred directly from one person to another upon contact.
Climate change vulnerability	The combination of extrinsic and intrinsic factors associated with individual or ecological systems to a hazard (in this case climate change) and their ability to absorb and recover from losses arising to the hazard as well as exploit new opportunities from the hazard. Climate change adaptation is the system's ability to accommodate these changes.
Conditioning fish	Holding fish without feed for a minimum of 48 hours in good quality water at the hatchery or nursery prior to their collection and transportation to the grow-out farm. The major objective of doing so it to allow the fish empty their guts in order to reduce stress to the fish and maintain water quality during transit.
Dam wall, dyke	These all refer to the earthen wall of the pond. Pond walls sometimes also double as levees.
Disease	This is the manifestation of something gone wrong. Body functions become impaired because of stress, inherent weakness or infection.
Disease causing agents	The term **disease causative agent** usually refers to the ***biological pathogens*** (a ***virus, parasite, fungus*** and **bacterium**) and ***toxins*** or ***toxic*** chemical that cause illness/disease.
Feed Conversion Ratio (FCR)	The Feed Conversion Ratio (FCR) is the amount of feed it takes to produce a unit weight of fish. It is a measure of the efficiency of feed utilization. It is a critical parameter to monitor as it determines the viability of the enterprise in feed-based production systems.

Feeding Frequency	This is the number of times in a day fish in are pond are given food.
Fingerlings	Tilapia juveniles that range between 5-20 g. Fingerlings from 10 g and above are suitable to stock into grow-out ponds directly. Fingerlings of 5 g to less than 10 g should be stocked into a nursery pond first until they are above 10g.
Flocculation	Flocculation is a way of controlling clay turbidity by adding substances to water that facilitate the formation of bridges between particles, allowing them to combine into groups of small particles called "flocs". As these particles begin to settle, they ensnare other particles, become progressively heavier, and settle much more readily from suspension.
Flushing	Replacing a half or more of the water in the pond within a day or less. The objective of flushing a pond is to get rid of excess suspended as well as soluble wastes and to dilute wastes. Think of flushing a toilet.
Green-Water	This is when phytoplankton density in the pond is maintained at an optimum level as a means of managing water quality for tilapia production. Because of phytoplankton, the pond water consequently looks always looks greenish. This refers to the preferred colour of pond water for tilapia production. The green colour is an indication of the natural productivity of the pond i.e. amount of plankton in the water.
Gutting	Removal of the intestines and other viscera from the abdomen of the fish.
Hardness	Total hardness is the measurement of divalent cations (+2 ions) in the water and, like total alkalinity, is expressed as milligrams per litre (mg/L) or parts per million (ppm) of calcium carbonate ($CaCO_3$). The two most common elements that contribute to hardness are calcium and magnesium.
Health	Is the standard or typical condition of the fish, whereby its bodily functions are normal. A healthy fish functions optimally and is free of abnormalities of stress and disease.
Live Weight Equivalent	The weight of a whole live fish before it has been processed. Processing fish includes gutting it. Therefore, the term refers to the weight of the fish before gutting.
Nursery Pond	This is a pond in which young juveniles are reared to the stage when they become fingerlings or stockers. Fish at this stage are extremely fragile and susceptible to predation. Extra attention is consequently given to water quality management and predation control in nursery pond management.
Infectivity	The ability of a pathogen to cause infection.
Obligate pathogen	A pathogen whose presence in or on the fish inadvertently results into disease. An obligate pathogen cannot survive outside the host and must cause infection in order to survive.
Opportunistic pathogen	A pathogen that is found and lives naturally in the environment. It will only infection the fish and cause disease if the fish's immune status is compromised, for example when fish are is stressed.
Optimum Ration	The fish feed that gives the best growth and Food Conversion Ratio (FCR). There is minimum wastage and minimum deterioration of water quality when fish are fed optimum amounts of feed.
Oxidation (oxidize)	This is a chemical reaction where oxygen binds to a substance that often results into changes in the physical and chemical attributes of the substance. Such a substance is said to have become oxidized. For example, oxidized substances become less acidic. Iron rusts when exposed to the oxygen in air.

Palatability	The appeal and acceptability of the feed to the fish. It is affected by the feed's odour, texture, moisture, physical form and temperature. A good quality feed should be highly palatable because quality includes intake and palatability is required for high levels of intake.
Phytoplankton	Microscopic plants that live within water.
Piping	This is when the tilapia come out to the water surface during moments when there is low dissolved oxygen in the water to gasp in air.
Pond Productivity	This refers to the ability of the pond to generate phytoplankton. A pond with good productivity looks green as a result of high levels of phytoplankton production.
Production Cycle	This is the period between stocking and draining when fish are being raised in the pond.
Ration	The amount of feed or food each fish should be given for consumption per day or at each meal.
Respiration	The process by which living organisms take up oxygen to combust food into energy and release carbondioxide
Satiation	When the fish is satisfied and will not desire to eat any more food.
Sampling	This is the removal of fish from the pond to assess their growth and health status. After the observations fish are returned to the pond.
Shooters	These are fish of the same age-group within the same population that grow much faster and larger than the rest. Such fish frequently cannibalise and bully the smaller ones preventing the latter's access to feed and causing them stress.
Spawning Pond	Pond's designed or kept for purpose reproduction. Eggs, larvae or fry may be harvested from such ponds.
Standing Crop	The total weight (mass) of fish in the pond at any one time.
Static Water Pond Management	This is a system of pond management whereby no 'continuous fresh' water is allowed into the pond during production except to top up water lost by evaporation and to exchange water if the water quality deteriorates such as when the pond is at carrying capacity.
Stock	Refers to the fish (animals) being reared on farms.
Susceptible	Likelihood of a fish contracting an infection or disease.
Transpiration	The process whereby plants absorb water through their roots and give off water through their leaves.
Turbidity	The degree to which light penetration through the water column is blocked. Turbidity in ponds is often caused by small particles of either clay or phytoplankton that are suspended within the water column.
Virulence	The ability of a pathogen to infect or damage the host.
Whole Fish	This refers to the fish before it has been gutted i.e. before any of it body parts have been removed for whatever reason.
Zoonotic disease	A disease that affects and can be transmitted between animals (fish) and man
Zooplankton	Microscopic animals that grow within the water, the smallest of which feed off phytoplankton.



MODULE ONE:

AN OVERVIEW OF AQUACULTURE IN UGANDA

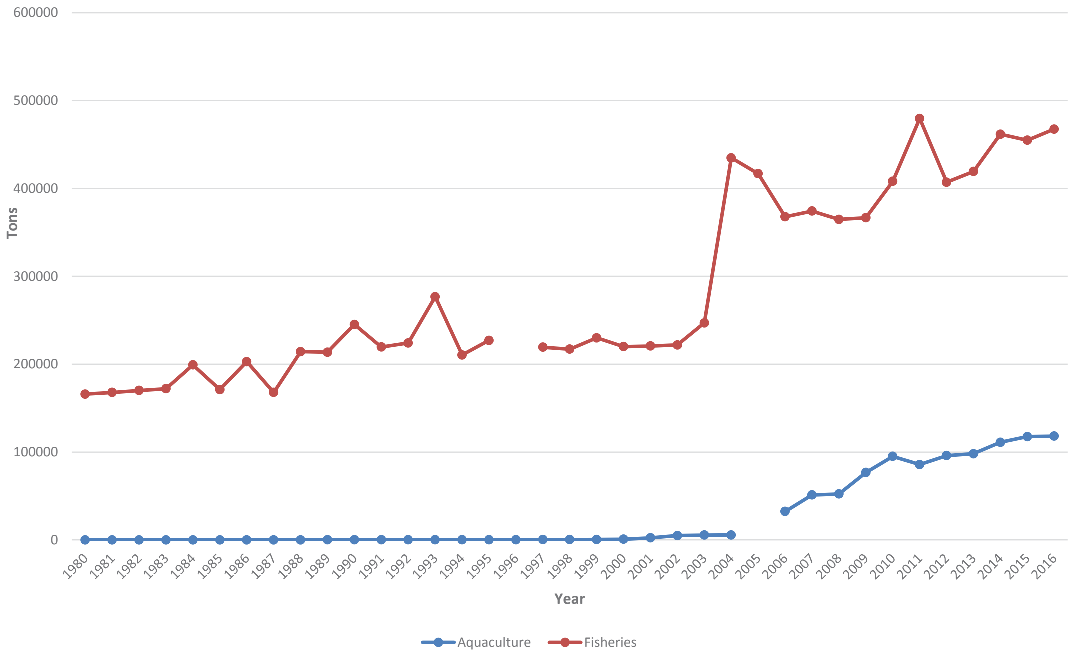
This module gives a brief background to aquaculture in Uganda, lists the key stakeholders in the sub-sector, highlights the opportunities and benefits of aquaculture and provides an overview of the manual.

1.1 Background

Commercial aquaculture is the rearing of aquatic animals (like fish) and plants under controlled or semi-controlled conditions profitably for food and other uses.

Fish farming was first introduced to Uganda in the 1940s as a subsistence activity to provide cheap animal protein for rural households. Fish farming has since become an important source of fish supply that is supplementing that from the fisheries. The transition to commercial aquaculture gained momentum between 2005 and 2006. Uganda is now among Africa's top five aquaculture producers. Average annual aquaculture growth rate since are about 15% per annum. National aquaculture production capacity comprises about 20,000 aquaculture farmers producing a total of 120,000 tons of fish from 25,000 ponds and over 3,000 cages. Most farmers are small holder farmers practicing extensive and semi-intensive pond and cage culture. The large-scale farmers run intensive systems and cage culture. By 2016, aquaculture contributed 20% to Uganda's total fish production (figure 1).

Figure 1: Trends in Aquaculture versus Fisheries Production (tons).



Adapted from FAO Fisheries and Aquaculture Statistics and UBOS Statistics.

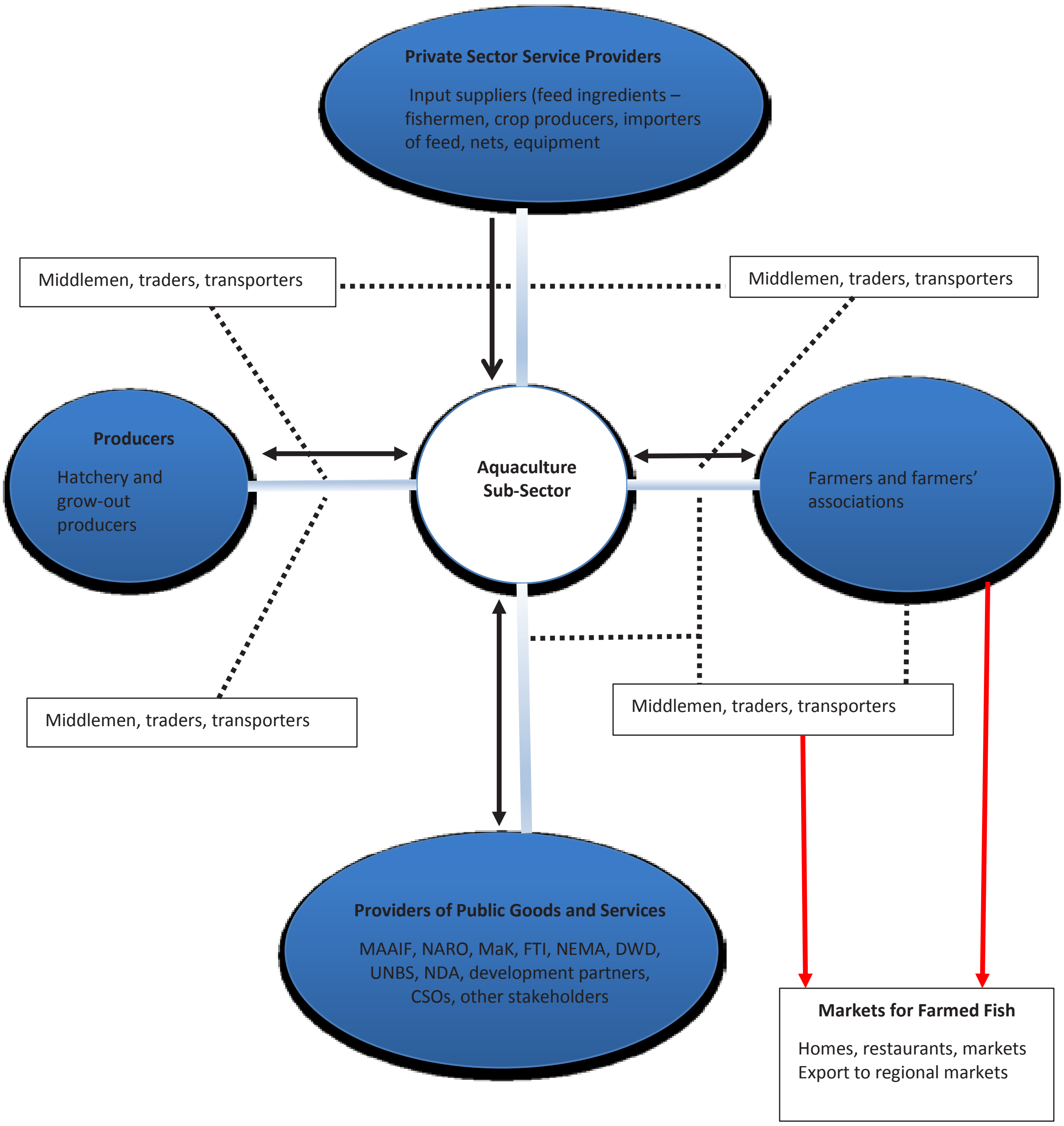
The steady growth and increased private-sector investment into aquaculture are attributed to the growing local demand and expanding regional markets for fish. Rapid population growth, limited supply from the fisheries, increased urbanisation, rising incomes, health awareness, favourable fish farming conditions and supportive government policies have created a conducive environment for commercial aquaculture.

Despite the positive trends however, the full production potential and contribution of Uganda's aquaculture to incomes and food security is yet to be realized. More than 50% of Ugandans consume fish as a major source of animal protein and essential micro-nutrients. It is estimated that about 72% of the fish produced in Uganda is consumed locally and about 28% is exported. The total sustainable fisheries yield from Uganda's lakes and rivers is estimated to be 500,000 metric tons of fish. This leaves a deficit one million tons of fish that can only be sustainably produced through aquaculture, if the recommended national nutritional requirements for Uganda's population of 40 million are to be met (MAAIF, 2017). The long-term prospects for sustainable commercial aquaculture in the country are therefore promising.

1.2 Key Stakeholders

The major stakeholders in Uganda's farmed-fish value chain include private sector service providers, producers, providers of public goods and services, traders, transporters and middlemen (figure 2).

Figure 2: Key Actors in the Aquaculture Value Chain



The Department of Aquaculture Management and Development, under the Directorate of Fisheries Resources (DiFR) of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) is directly responsible for aquaculture development in the country. It provides guidance on all matters pertaining to aquaculture in collaboration with other Ministries, Departments and Agencies (MDAs) as illustrated in the figure above.

1.3 Opportunities in aquaculture

The following factors favour aquaculture in Uganda and make it highly competitive:

- **Favourable climate.** Uganda is located across the equator at an average altitude of 1,000 m above sea level. It has a stable climate comprising two rainy and dry seasons each year. Average temperatures range between 25oC to 29oC and rainfall between 1,000 to 1,500 mm per year. It is warm and sunny during both the rainy and dry seasons. This favourable climate makes it possible for farmers to farm fish throughout the year. Farmers can have several crops in a year.
- **Availability of water resources.** Abundant supply of surface water. Eighteen percent of the country is covered by water in the form of rivers, lakes, streams and swamps.
- **Inputs for fish farming** such as feed, seed and equipment are readily available and accessible.
- Presence of industrial processing plants/factories.
- **There is a high demand for fish** and subsequently good farm-gate prices which creates a good opportunity for farming fish as a business.
- **Existence of institutional and human capacity** to provide technical advice. MAAIF and several private sector institutions have the required expertise to provide the necessary technical support to the sub-sector.
- Willingness of development partners to support the subsector.

1.4 Challenges

- The investment required to establish a fish farm is high.
- Weak aquaculture associations.
- Lack of organized market. There is no synchronization in production and hence limited bulk marketing and diversification of value-chain opportunities.
- Limited value addition in aquaculture products.
- Limited data and information on aquaculture activities to guide investments.
- Availability and access to quality feed and seed
- Increasing the interest and capacity of youth, women and other vulnerable groups to skillfully engage in sustainable commercial aquaculture

1.5 Benefits of farming fish

- **Fish is nutritious.** Fish is an animal food that is easy to digest, rich in non-saturated fatty acids, palatable and is acceptable among Uganda's diverse religious and cultural norms. It is also rich in minerals and essential micronutrients such as calcium, phosphorus, zinc, iodine, fluorine, and selenium. It is among the recommended essential foods for infants, invalids, expecting mothers and the aged.
- **Good utilization of resources.** Fish can be grown on non-arable land and in water which provides an opportunity for transforming non-agrarian resources into productive agricultural zones.

- **It is climate smart.** As opposed to crops and livestock, aquaculture does not extract water but rather, is a medium for production. Water from fish production is rich in nutrients and is good for irrigating crops. Furthermore, there are wide range of species and production systems that can be used for aquaculture creating vast opportunities. Farming fish also produces the least amount of carbon dioxide emissions per kilo meat produced compared to livestock.
- **Good income generating enterprise.** It can be done, the market is available and when done as a business, it generates reasonable profits.
- **Greater ability to tailor production to meet market requirements.** Unlike the fisheries where it is difficult to determine the exact species, size and quantity of fish one will catch above the allowable sizes; in aquaculture one can plan and produce the exact size, quantity and quality the market requires. One can also supply markets with live fish.
- **It is socially acceptable** that both women and men can engage in fish farming.

1.6 Purpose and Overview of the Manual

Although there are numerous opportunities, several challenges exist that limit the realisation of the aquaculture sub-sector's full potential. Key among these, is the lack of nationally harmonised training materials to guide extension workers in providing technical support to the sectors' value-chain actors. This manual is designed to guide extension workers train value-chain actors on recommended practices for successful commercial aquaculture.

It comprises the following modules:

Module One	Gives an overview of aquaculture in Uganda, the key stakeholders and highlights the opportunities and benefits of aquaculture.
Module Two	Provides guidance on factors to consider before making a decision to invest in aquaculture.
Module Three	Describes the different aquaculture production systems in Uganda.
Module Four	Gives guidance on site selection, farm planning construction and maintenance of production facilities.
Module Five	Provides guidance on water quality management in aquaculture.
Module Six	Explains the recommended nutritional and feeding practices for optimal production.
Module Seven	Discusses the recommended management practices for the different production systems.
Module Eight	Discusses fish health management and biosecurity.
Module Nine	Gives recommendations for post-harvest handling and processing of farmed fish.
Module Ten	Provides guidance on improving the marketing of farmed fish.
Module Eleven	Provides guidelines on how to improve the profitability of aquaculture by managing it as a business.

MODULE TWO:

BASIC REQUIREMENTS FOR COMMERCIAL FISH FARMING IN UGANDA

A fish farm or any other aquaculture related business is more likely to be successful if established upon a well-informed decision. This module explains the preliminary assessments and basic steps for establishing successful commercial aquaculture.

2.1 Why should I do a preliminary assessment?

Aquaculture is a major investment. Before making the decision to set up a fish farm, carry out an assessment to identify the most appropriate production system that meets one's business objectives.

Consideration should be given to:

- the potential market for your fish,
- the suitability of the proposed site,

- access to inputs and services,
- legal requirements for establishing and operating the enterprise, and
- feasibility and potential viability of the enterprise.

The outcome of this assessment will guide you on:

- whether it makes business sense to establish a fish farm at the given site,
- the species to farm,
- the size and type of farm,
- the most appropriate farm layout and production facilities to establish,
- production objectives and management options,
- market and business options, and
- potential risks and mitigation measures.

2.2 Background Research

Those already involved in aquaculture, often have useful information that would guide new investors. Visit and interact with key stakeholders like farmers and extension service providers on the available fish farming options, requirements, benefits and challenges of farming fish as a business. In addition, obtain information on the sources and availability of inputs, water supply to the proposed farm site and market opportunities. Their experience will provide valuable insight on viability and on key issues that should not be overlooked for successful fish farming.

2.3 Market

The availability of a market that offers a good price is a key determinant for a successful aquaculture enterprise. The following should be considered when assessing the market (Table 1).

Table 1: Market issues to consider before investing in aquaculture.

Issue	Implication
Location of possible markets	• Distant markets imply higher transport, marketing and storage costs
Customer preferences	• Price to sell • Production system to use (hatchery or grow-out farm) • Species, size, form (live, whole or processed fish) to produce • Packaging to use • Choice of feeds
Market price	• High prices contribute to making the enterprise profitable
Profitable volumes	• High profitable volumes require more financial and technical resources

For more details on markets and marketing, see **Module Ten**.

2.4 Deciding where best to locate the farm

Fish farms can be located within a water body or on land. In either case, the selected site will affect construction costs, ability to implement farm activities, operational costs and levels of production and productivity. A guaranteed year-round supply of water is among the pre-requisites for successful fish farming. The site should be located where access to inputs, markets and other services are good. The likelihood for conflict with the community over the use of common resources such as land and water should be low. Activities in the neighbourhood should have minimal negative impacts on water quality and supply as to ensure the production of safe fish. The likelihood of negative environmental impacts from the fish farm to the surroundings should be minimal. See **Module Four** for more details**.**

2.5 Guidelines and Regulations for Commercial Aquaculture

In order to undertake commercial fish farming successfully, it is important to conform to the Government guidelines and regulations, and to obtain the required permits for the benefit of the farm (Table 2). These have been developed to protect aquaculture establishments, safeguard other common resource users and avoid negative environmental impacts. They additionally ensure that aquaculture products are safe for human consumption thus improving access to markets for farmed fish produce and products.

Table 2: Guidelines and Regulations for Commercial Aquaculture

Permit/ Certificate	When it applies	Reference	Source
SOCIAL AND ENVIROMENTAL ASPECTS			
Certificate of Approval of Environment Impact Assessment (EIA)	Before developing proposed sites for large commercial farms	Third schedule of the National Environment Act, Cap 153 in accordance with the EIA Regulations 1998 and EIA Guidelines 1997	National Environment Management Authority
Waste Discharge Permit	Discharge large amounts of effluent into the environment water bodies As a rule, all cage culture operations require one	The Water Act (Cap. 152). The Water ***(Waste Discharge)*** Regulations, 1998	Ministry of Water and Environment, Directorate of Water Resources Management (DWRM)
SETTING UP FISH FARMS			
Aquaculture Establishment Certificate	All semi-intensive and intensive commercial fish farms after obtaining EIA certificate	The Fish ***(Aquaculture)*** Rules, 2003	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)
Fish Seed Production Certificate	Fish hatcheries and fish breeders after obtaining EIA certificate	The Fish ***(Aquaculture)*** Rules, 2003	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)

Permit/ Certificate	When it applies	Reference	Source
Cage Culture Permit	Cage culture farms after obtaining EIA certificate	The Fish ***(Aquaculture)*** Rules, 2003	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)
HARNESSING WATER FOR USE ON FARM			
Construction Permit	Construction of water harnessing infrastructure such as impoundments across water ways, boreholes, valley dams, etc.	The Water Act (Cap. 152). The Water ***(Waste Discharge)*** Regulations, 1998	Ministry of Water and Environment, Directorate of Water Resources Management (DWRM)
Drilling Permit	Prior to drilling a borehole on the farm	The Water Act (Cap. 152). The Water ***(Waste Discharge)*** Regulations, 1998	Ministry of Water and Environment, Directorate of Water Resources Management (DWRM)
Ground Water Permit	When a motorized pump shall be used to pump water from a borehole temporarily or permanently	The Water Act (Cap. 152). The Water ***(Waste Discharge)*** Regulations, 1998	Ministry of Water and Environment, Directorate of Water Resources Management (DWRM)
Surface Water Permit	If 270 litres of water per minute or more shall be extracted from a water way in a 24-hour period If a motorised pump shall be used to pump water either temporarily or permanently from a waterway (river, lake, swamp, dam or other surface-water body)	The Water Act (Cap. 152). The Water ***(Waste Discharge)*** Regulations, 1998	Ministry of Water and Environment, Directorate of Water Resources Management (DWRM)
MOVEMENT FISH STOCK AND FISH TRADE			
Fish Transfer Permit	Movement of live farmed fish from off the farm to any location within Uganda	The Fish ***(Aquaculture)*** Rules, 2003	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)
Fish Movement Permit	Movement of fish and fish products from one part of Uganda to another	Fish ***(Fishing)*** Rules, 2010 Department of Fisheries Resources Fish Movement Permit	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)
Fish Import/ Export Permit	Import or export farmed live fish or processed farmed fish products to and from Uganda	Fish Act, Cap 197 Fish ***(Fishing)*** Rules, 2010 Uganda Public Finance Management Act 2015 Section 30) Uganda Revenue Authority Act	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)

Permit/ Certificate	When it applies	Reference	Source
Fish Sanitary Certificate	All consignments of fish for human consumption to be sold within Uganda's markets whether they are locally produced or imported; All consignments of fish for human consumption for export	Fish ***(Quality Assurance)*** Rules, 2008	Ministry of Agriculture, Animal Industry and Fisheries, Directorate of Fisheries Resources (DiFR)
BIO-SAFETY			
Uganda National Council of Science and Technology (UNCST) Permits	Use of genetic material in aquaculture	The National Environment ***(Access to Genetic Resources and Benefit Sharing)*** Regulations, 2005 The Uganda National Council for Science and Technology (UNCST)	Ministry of Lands, Water and Environment

MODULE THREE:

AQUACULTURE PRODUCTION SYSTEMS IN UGANDA

This module describes the aquaculture production systems practiced in Uganda.

3.1 Classification of aquaculture production systems

Aquaculture production systems are classified based upon:

- Water quality characteristics
- Fish cultured
- Intensity of production
- Scale of production
- Level of control over water temperature, dissolved oxygen levels and waste

3.1.1 Water quality characteristics

Aquaculture production systems are described as being fresh-water, brackish or marine depending on the salt content of the water. Fresh waters have little or no dissolved salts and are typically found inland. Brackish and marine waters have a higher salt content. Brackish waters are found in coastal zones and marine waters in open seas and oceans. Hence, Uganda's aquaculture is characterised by warm fresh-water fish production systems.

3.1.2 Fish cultured

Production systems are also classified based on the type and number of species farmed within the rearing unit as follows:

- ***Monoculture:*** a single species is farmed in a production unit at a time
- ***Polyculture:*** two or more fish species with complementary habitat niches and feeding characteristics are raised in an earthen pond to increase productivity.

Table 3: Comparing the Advantages and Disadvantages of Mono and Polyculture Production Systems

	Advantages	Disadvantages
Monoculture	• It is easier to manage one species • Ideal for intensive systems	• In the event of a disease, all fish may be affected • By-products from monoculture are wasted • Miss out on the ecosystem and economic benefits of different species
Polyculture	• More than one type of fish to sale • Stocking complementary species improves water quality • More fish can be stocked at a lower operational cost • Environmentally friendly • In the event of a disease, some species can survive	• Difficult to equally monitor all the species during production depending on their behaviour. • Restricted to ponds

3.1.3 Intensity of production

Describes the level to which production resources are utilised in order to maximise production and returns per unit area or volume. The following three systems are practiced in Uganda:

- **Extensive system –** This is a low-input low-output system. Fish are stocked at low density in earthen ponds and are not given feeds. Some ponds are fertilised others are not.
- **Semi-intensive system –** Medium fish stocking densities which combined with the use of natural and/or artificial feeds in earthen ponds.
- **Intensive system –** the stocking of fish using high stocking densities, water quality enhancement and nutritionally complete diets.

See **Module Six** for more details on types of feeds.

Table 4: Advantages and Disadvantages of the Extensive, Semi-Intensive and Intensive Fish Production Systems

	Advantages	Disadvantages
Extensive	• Low investment and operation costs • Easy to operate • Low negative impacts on the environment • Stock enhancement programs in natural waterbodies • Promotes biodiversity within rearing units	• Low production per unit area which results in low income • Health risks to farm workers from waterborne diseases
Semi-intensive	• Higher productivity than extensive • A wider array of species can be raised in production units • Can use farm-by products as feed and fertiliser	• Variation in yields and quality of produce caused by challenges associated with fluctuations in on-farm feeds and fertilizer quality and availability. • Health risks to farm workers from waterborne diseases
Intensive	• Higher productivity than semi-intensive • High quality products due to greater control over growing conditions	• Requires more capital • Requires constant source of energy • Requires high technology and skilled labour • Greater risk for fish disease spreads in the event of an occurrence • When not well designed and managed, greater likelihood for negative environmental impacts

3.1.4 Scale of Production

Aquaculture production systems may be small, medium or large scale depending on the total farm surface area, total water volume used for production or tonnage produced per year.

Tables 5 and 6 describe the different scales in relation to Ugandan aquaculture.

Table 5: Scales of Production

Scale of Production	Tonnage Produced per Year (metric tons/year)
Small scale	> 10
Medium scale	10 to 50
Large scale	<50

Table 6: Advantages and Disadvantages of the Small, Medium and Large-Scale Fish Production Systems

	Advantages	Disadvantages
Small-scale	• Usually low-input low-output • Household waste and farm by-products can be used as feed and fertiliser in the fishponds • Easily integrated into rural household farming systems	• Low yield per unit area which results in low income • Quantity and quality of inputs, yield and produce are not consistent • Difficult to sustain good markets
Medium scale	• Medium input high output • More control over production practices better consistency of yields • High quality yields and better markets.	• Require more capital • Require skilled labour • Greater losses when accidents or negligence occurs
Large-Scale	• High input, high output • Better economies of scale • More control over production practices resulting in better consistency of yields • Better control over quality of fish produced and accessibility to markets	• Requires more capital • Requires skilled labour • Greater losses when accidents or negligence occurs

3.1.5 Level of control over water temperature, dissolved oxygen and waste

Production systems can be described based on the degree to which fish farming practices deviate from nature and enable biosecurity control, namely:

- **Open Systems –** characterised by low stocking densities. The system relies on natural ecosystems processes for water quality, feed supply and waste control as follows:
  a. Oxygen is supplied by diffusion from air, algal photosynthesis by natural algal communities.
  b. Water temperature depends on ambient temperature.
  c. Water exchange and waste removal determined by water currents, wind action and biological processes.
  d. The producer hardly has any control over environmental conditions that affect production.

  The production methods in Uganda under this category include cage culture, integrated rice-cum-fish systems and stock enhancement in reservoirs and lakes.

- **Semi-Closed System** – Typically man-made facilities that allow the producer to add and remove water from the production unit. Levels of dissolved oxygen, temperature and waste removal depend on nature but can be controlled to a limited degree by management. Site selection is important.

  Production methods under this category include ponds, raceways and tanks. Ponds constructed in rice paddies or irrigation schemes fall within this category.

- **Closed System** - All water quality variables are fully under human control. Examples include recirculatory aquaculture system (RAS) with biofilters. These can be established anywhere.
- **Hybrid Systems** – These are closed systems that incorporate other production systems such as crop production to maximize benefits. Example are aquaponics systems.

Table 7: Comparing the Advantages and Disadvantages of Open, Semi-Open, Closed and Hybrid Systems

System	Advantages	Disadvantages
Open Systems	• Low negative impacts on the environment	• Limited control over key production variables • Conflicts arising from rights of access to natural resources, theft, etc. • Predation • Limited capacity for biosecurity control • More prone to environmental risks such as pollution. • More susceptible to climate change risks
Semi-Closed Systems	• Little thermal stratification • Aeration can be done • Easier and more efficient use of prepared feeds • Control over water depth and replacement • Detection and rectification of water quality deterioration • More effective disease control • Clearer ownership and less conflict with community • Can do temperature control • Elimination of competitors and predators	• Higher construction and equipment costs • Higher energy requirements • Higher feed costs • More management demands on monitoring interventions • Greater likelihood for poor water quality and disease incidences
Closed Systems	• Water is re-used • Greater ability to control pathogen entry • Predators and poachers eliminated • Near industrial process • Feeding and FCR closely monitored	• Operator has complete responsibility for animals' production environment • Higher operational costs • More sensitive to system errors
Hybrid Systems	• Maximizes water use for fish and crop production in limited space	• Crops raised affect choice technology and equipment • Higher level of technology required • Sensitive to system errors

3.2 Fish Species Farmed

The following fish species are farmed in Uganda.

3.2.1 Commonly farmed commercial fish species

a) Nile Tilapia *(Oreochromis niloticus)*

Key features

- Most widely farmed species in Uganda.
- Large size (11-40 cm) and deep body, hence more flesh.
- Easy to cultivate.
- Easy to reproduce and mature in ponds between 5-6 months.
- Highly marketable within the country and region.
- Suited to all fish farming systems.
- Grown in ponds, tanks and cages.

b) African Catfish *(Clarias gariepinus)*

Key features

- Second most important species farmed in the country
- Easy to cultivate.
- Performs better in ponds and tanks
- Consumes all foods
- Fast growers

c) The Mirror Carp *(Cyrpinus carpio)*

Key features

- Imported into Uganda for aquaculture in the 1950's
- Temperate fish and can grow at cooler temperatures
- Grown mainly in Uganda's highlands
- Largely grown in ponds
- Bottom dwellers

d) Singida tilapia *(Oreochromis esculentus)*

Key Features

- Indigenous to Uganda
- Readily accepts and easily converts low protein diets
- Good growth rates achieved fertilized ponds without artificial feeding
- Not a prolific breeder
- Can be raised completely on algal material in the first 3 to 5 months
- Marketable

3.2.2 Commonly farmed ornamental fish species

- Ornamental species are high value niche species
- Major clients are hobbyists who keep them for aquaria to beautify places
- Require small area to farm.

a) Non-indigenous Ornamental Fishes

Goldfish *(Carassius auratus)*

Koi Carp (*Cyprinus carpio*)

b. Indigenous Ornamental Fishes - Haplochromines

3.2.3 High value indigenous species currently under development for aquaculture

a. Ningu *(Labeo victorianus)*

Key features

- Highly valued in Uganda
- Among Uganda's endangered species
- Potential for pond, cage and tank culture
- Bottom dwellers

b. Angara, Pebble Fish *(Alestes baramoze)*

Key features

- Maximum length about 43 cm
- Optimum water temperature 15-35 oC
- Highly valued in Northern Uganda and Democratic Republic of Congo around Lake Albert
- Potential for pond and tank culture

c. Mamba, Marbled Lungfish *(Protopterus aethiopicus)*

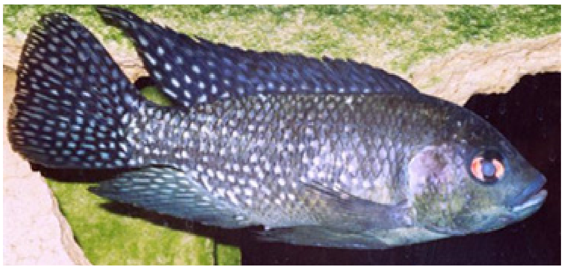
Key features

- Highly marketable and increasingly replacing Nile Perch on local market among low-income households
- Large, fully fleshed fish with few bones

Appendix 1 provides more details on the species mentioned above.

3.3 Distinguishing characteristics between major commercial aquaculture species and their close relatives

3.3.1 The Tilapia's

RECOMMENDED AQUACULTURE TILAPIA SPECIES	CLOSE TILAPIA RELATIVES <u>NOT</u> RECOMMENDED FOR COMMERCIAL AQUACULTURE
	
Female (above) and Male (below) Nile Tilapia *(O. niloiticus)*	***Blue-spotted tilapia*** *(O. leucosticus)*
Advantages • Larger size and deep body, hence more flesh • Can withstand high stocking densities in grow-out units due to protection of scales and schooling behaviour • Performs well, faster growth • sexual maturity in ponds reach only at age of 5-6 months • suitable for culture in wide range of extensive and intensive fish farming systems in ponds, tanks, cages, integrated and aquaponics systems. • high consumer and producer acceptance • Accept a wide array of diets and can be raised using different production strategies **Disadvantages** • least tolerant to cold water	**Disadvantages** • Mature at small sizes in ponds, a trait undesirable for commercial aquaculture, because ponds quickly filled up with numerous small fish of low market value. • Easily hybridises with other native *Oreochromis* species, resulting in hybrids with reduced growth potential, which is a great disadvantage of farming this species

RECOMMENDED AQUACULTURE TILAPIA SPECIES

Singida Tilapia *(Oreochromis esculentus)*

Advantages

- Readily accepts and easily converts low protein diets
- Good growth rates achieved fertilized ponds without artificial feeding
- Can be raised completely on algal material in the first 3 to 5 months
- Not as prolific breeder

CLOSE TILAPIA RELATIVES NOT RECOMM-ENDED FOR COMMERCIAL AQUACULTURE

Red Belly Tilapia
(Coptodon zillii formerly Tilapia zillii)

Advantages

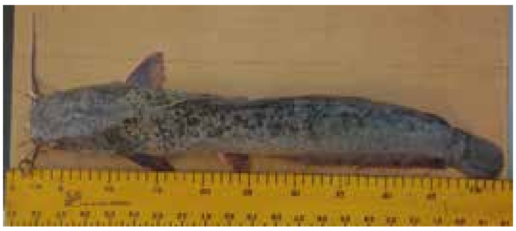
- Grows well in full strength seawater
- Utilise on-farm fresh leafy forage (e.g. yam leaves, straw, etc.) better than the Nile tilapia and blue spotted tilapia.

Disadvantages

- considered a serious threat to native aquatic plants and to fish that rely on plants for cover, foraging, or spawning sites

3.3.2 The Catfishes

RECOMMENDED AQUACULTURE CATFISH SPECIES



African Catfish *(Clarias gariepinus)*

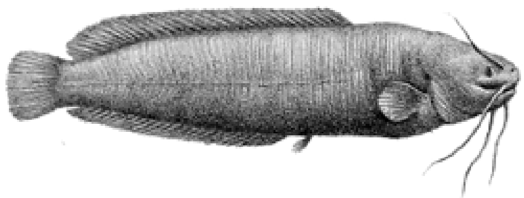
Advantages

- Hardy adaptable fish
- Consumes all foods
- Marketable in Uganda
- Perform better in fish ponds and tanks.
- In ponds monoculture and polyculture with tilapia
- Challenges administering feed uniformly and obtaining uniform growth in cages

Disadvantages

- Burrow into pond walls making harvesting by seining more challenging.
- Where pond walls not well compacted, can burrow through walls resulting into leaking and loss of fish.

CLOSE CATFISH RELATIVES NOT RECOMM-ENDED FOR COMMERCIAL AQUACULTURE



Nsonzi *(Clarias liocephalus)*

Disadvantages

- Naturally small body size, maximum length 32 cm in wild and less than a kilo each.
- Relatively large head compared to body length
- Normally mistaken for ***C. gariepinus fry*** and fingerlings

MODULE FOUR:

ESTABLISHING A FISH FARM

A fish farm is a commercial facility for raising fish for human food and other purposes. There are various units within which fish can be grown such as tanks, ponds, cages and pens. No single type of rearing unit meets all the fishes growing needs. Consequently, farms will often have more than one type of rearing unit. This module describes the tasks to establish a fish farm facility notably: site selection, farm planning, construction and maintenance of fish production units.

4.1 Suitable Sites for Fish Farming

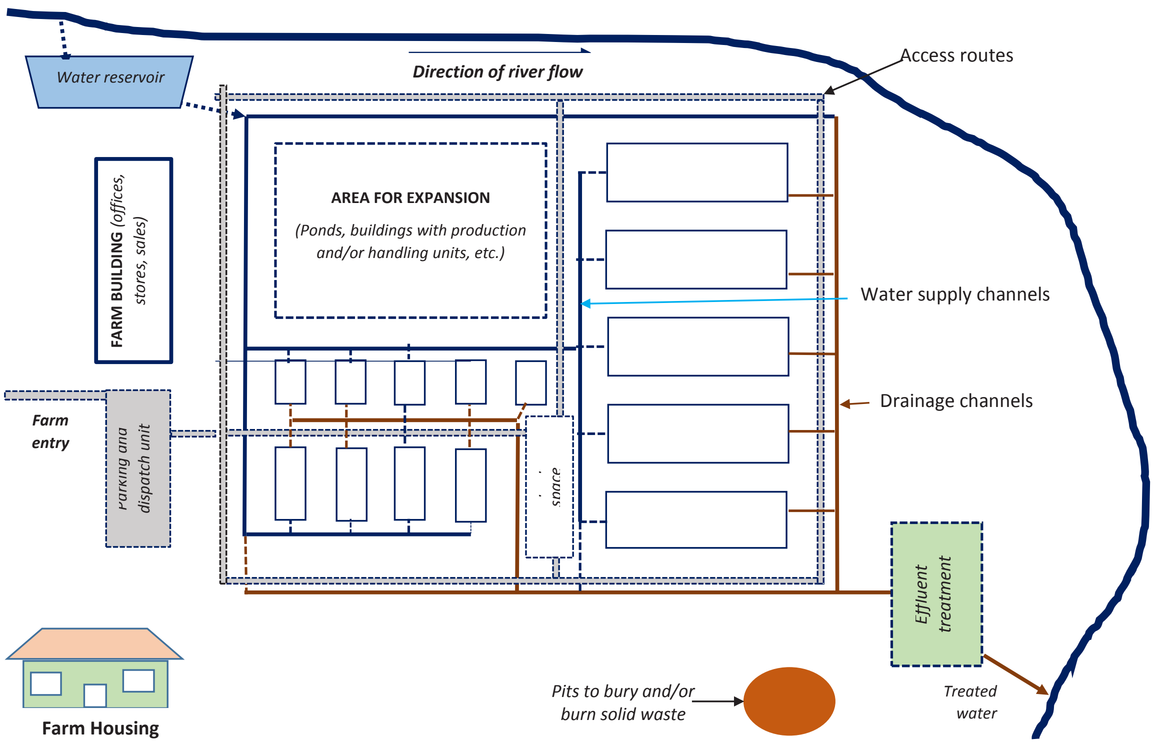
The factors listed table 8 will help guide you select a suitable site.

Table 8: General Factors for Consideration when Selecting a Site for Fish Farming

Factor	Aspects
1. Production objectives	Based on business plan, notably: • Species targeted • Planned production volumes • Capital constraints (e.g. ability to afford different types of feeds, infrastructure) • sequencing of operations in relation to market requirements (e.g. how much and how often to supply, storage requirements, etc) • number of personnel required

Factor	Aspects
2. Environment and socio-Economic Factors	• Land and other water uses in the vicinity • Factors that might affect water supply and drainage • Future development plans for the area e.g. if it is an industrial area the likelihood of supply water becoming polluted is high, urban developments may negatively affect water supply • Access to land (leased land, ownership, etc.) • Gazetted areas such as wetlands, national parks • Public health concerns • Likely negative environment impacts such as pollution, fish escapes - NB: The above considerations also comprise the mandatory Environmental Impact Assessment (EIA) done before establishing medium and large commercial developments.
3. Topography	• Gentle slopes that can allow for effective drainage under gravity. • Avoid areas that are: - Flat as they are more prone to flooding and may need pumping to drain facilities. - Too steep because costs of construction and subsequently maintenance are higher. It is also more challenging to undertake day-to-day tasks on such farms.
4. Hydrology and weather patterns	• Adequate year-round from water-source. • For land-based farms water may be harnessed from: (i) Rain –surface rainwater catchment dams, roof water (ii) open water sources - rivers, streams, lakes, swamps, dams (iii) underground sources – wells, springs, boreholes • Preferably water should flow under gravity to the farm. Where underground sources are used, pumping may be necessary. • Cages farms are located within water bodies.
5. Soil characteristics	• Soils that allow for the construction of: (i) Buildings and access routes. (ii) Production units(e.g. ponds)
6. Water quality	• Good water quality for production (see **Module 5** for more details).

Figure 3: **Impacts of Land Use for Fish Farming.** *Rapid urban development in vicinity of the farm is likely to result in reduced water supply, increased pollution and higher incidences of theft.*



	Earthen Structure	Description
	Off-take channel from natural water source	
	Dams, pond and dykes	• Dykes are the earthen walls that form the pond or dam • The top width of the dyke (pond bank) is a utility area. • Recommendations on the dyke top width, slope and degree of compaction vary depending on the intended size and use of wall and/or pond (e.g. vehicle access, farm building, walk-way, perimeter flood barrier, etc.). • In all cases, the width between the top of two dykes should not be less than two meters.
	Inlet canal	• Transfer water from the source or farm reservoir to the ponds. • May be made open channels or pipes. • The inlet canal or pipe should big enough to allow ponds on the farm fill within the required time. And to enable all ponds on the farm fill up within less than 50 days. • A flow of 0.9 m3/m is adequate for 4,000 m2 pond surface area. • Set at least 10 cm higher than the normal water level in inlets to individual ponds. • Seepage control is important. • Open inlet canals should be trapezoid in shape. • Mitigate against water source risks - wild fish, pesticides and industrial chemicals, seasonal variations (floods and droughts)

	Earthen Structure	Description
	Internal pond inlet channels	• Set to relay water at a minimum height of 20 cm above the expected normal water level. • Water flow in inlet should be adequate to fill the pond within 10 days
	Drainage canal	• Conveys water from ponds on the farm back to stream and/or treatment pond. • Also drains seepage from ponds, rain water run-off, and extra water from the inlet channels. • Set at least 30 cm below the terrain level • Do not allow water over-flow from drainage canal. • Usually placed at perimeter or edge of farm. • Distance between the outer dyke toe and the major drain should be not less than 2.0 m. • Construct the drainage canal first before the ponds so that if it rains during construction, water can drain and the site will not flood.
	Internal pond drainage channels	• The bottom of this channel should be at least 20 cm deeper than the lowest level at which water drains from the pond or external harvest basin. • When sizing take into consideration required draining times for the individual and other ponds drained by the channel.
	Effluent treatment pond	• Pond effluent (drainage water) cleaned before release into natural water body. • Size to ensure adequate time for settling of suspended solids in water and other soluble waste. • Set at least 60 cm lower (at lowest end) than lowest point of drainage channel.
	Channel to natural water source	• Convey water from the effluent treatment pond to natural water body.
	Access routes	• Construct on top of dyke • All ponds on the farm should independently be easily accessible to allow for adding inputs and transporting harvested fish from the pond with relative ease and safety.
	Waste-disposal	• Pits and other structures for the safe disposal of farm waste, including dead fish.

Figure 4: Example of a Well-Planned

4.2 Fish Ponds

Earthen ponds are impoundments made to contain water for rearing aquatic organisms like fish. The costs of pond construction, maintenance, production and lifespan of ponds depend on the site characteristics and quality of construction.

A well-constructed pond should:

- Fill and drain within about a week to avoid water plants and predators establishing before fish are stocked.
- Hold water at an average depth of 1 meter during the entire production cycle.
- Enable water quality management during production.
- Be protected from erosion and flooding.
- Easy and safe for personnel to undertake their daily management tasks and access
- Guard against entry of predators and loss of fish.

In order to achieve the above-mentioned optimum pond growing conditions, the following are the recommended guidelines for site selection and pond construction.

4.2.1 Site Selection

An ideal site for fish ponds should:

- Have a gentle slope of about 2% to allow ponds to fill and drain by gravity
- Soils that are impervious to water
- Be situated above the water table and not within wetlands
- Be free of rock outcrops, large trees and roots.
- Be accessible
- Ownership of the land should be assured.
- Activities in the area should not affect water supply and quality and fish farming negatively.

4.2.1.1 Determining the slope and type of ponds to construct

Determine the contours of the land by taking levels after every meter to determine the slope or gradient of the land. Surveying tools and equipment are required for this (see figure 8.)

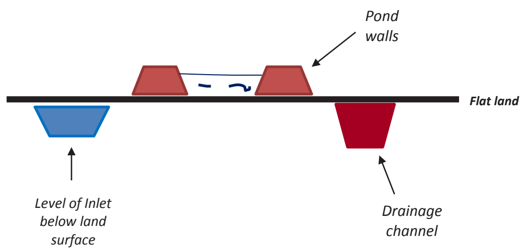
Types of fish ponds

The slope of the land determines what type of pond can be constructed.

a. Diversion Ponds

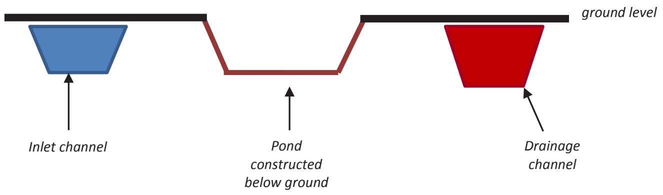
Water is drawn from a natural surface water source into the pond(s). See figure 4 above.

b. Embarkment Ponds



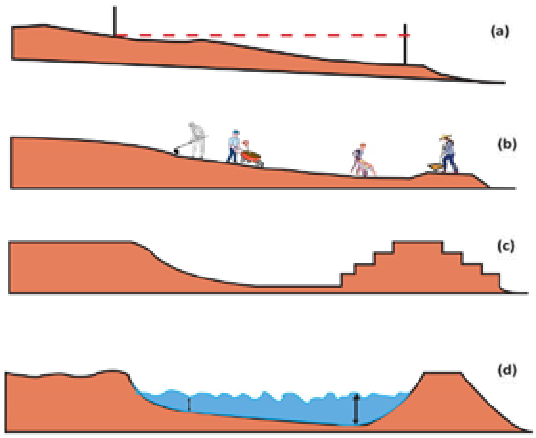
- Constructed on flat land with no slope
- Pond is built above the water level.
- Water must be pumped in to fill pond
- Help control flooding

c. Excavated Ponds



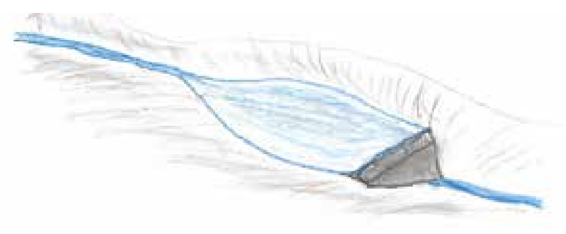
- Dug into the ground
- Easy to fill
- Difficult to drain
- Prone to flooding
- Characteristic of ponds constructed in wetlands

d. Partially excavated ponds with low dykes



- Also known as cut and fill ponds
- Commonest type of pond
- Constructed against a gentle slope
- Soil from upper level of the slope is used to build up the dyke from the lower level.

e. Barrage ponds



- A wall is built across a natural surface stream or river in a steep valley to dam water flowing downstream
- Dam/barrage pond is created behind the dam wall.
- Easy to construct
- Difficult to manage as production ponds

4.2.1.2 Assessing Suitability of Soils for Pond Construction

Soils that can maintain their form, have a relatively high 'plasticity' and can retain water after compaction are best for fish ponds.

The following soil types **are recommended** for pond construction:

- Clay
- Clay loam soils with a clay content of above 30%. Loam soils are a mixture of clay, sand and silt

The following soil types are **not recommended** for construction of earthen ponds:

- Sand
- Silt
- Humus

- Black cotton soils - Black cotton soils mould but develop large cracks when dry. They are common in cotton, groundnut and tobacco growing areas, notably East and Northern parts of Uganda. Use a lot of organic matter to seal cracks that develop.

Before constructing ponds do a soil survey to test the ability of the soils to retain water (figure 5) and mould under compaction. These tests can be done on-site. Soil samples can also be taken to soil laboratories.

Figure 5: **Water Retention Test.** *(a) Dig a hole of about 1 x 1 meter into dry ground at the site and fill with water. (b) The water may be absorbed into the ground if its dry. (c) On the second day, add more water. If water remains in the hole for some days after this, then the soil at the site is suitable for pond construction. If the hole is empty, the soil is not suitable.*

(a) *(b)* *(c)*

How to test ability of soil to Mould

- Press and mould moistened soil obtained from different parts of the proposed site in your hand into balls of 5 to 10 cm diameter. Let the dry slowly in the shade until completely dry
- If the ball crumbles soon after or later, develops cracks then it's not suitable for building ponds walls.
- If it remains firm and maintains its shape even when thrown down a height of 60 cm to 100 cm, its suitable for building pond walls.

Table 9 provides guidelines on how preliminary and site assessment findings affect pond design.

Table 9: Implications of site characteristics and production objectives on pond design

General Considerations	Specific Issues	Implications for layout and Pond Design*
Production objectives and management requirements	• Species to be produced • Stages of production • Production methods to be used • Production quantities envisaged • Methods of nutrient supply • Feed distribution to ponds	• Hatchery and nursery ponds often smaller and have harvest basins within rather than outside ponds • Static water or flow through methods • Aeration required then stand for equipment and power supply • Large volumes of fish expected at harvest sizing of harvest basins for temporary holding, supply and aeration within basins
General technical data	Data affecting water supply and drainage	• Additional drainage and erosion control requirements e.g. gabions, liners, etc.

General Considerations	Specific Issues	Implications for layout and Pond Design*
Topographical surveys	Topographic surveys maps at a scale of 1:500 to 1:50000 Take levels every meter	• Ensure correct slope within channels and ponds in sequence for water reticulation under gravity. • Avoid heaping soil in wrong places and too high dykes to reduce construction costs, management costs and avoid their negative impacts on production
Hydrological and meteorological data	• Seasonality of flow and flow rates in stream • Likelihood of flooding • Peak periods of monthly evaporation and rainfall to assess water demand • Monthly average and maximum temperatures • Likely seasonal variation in sediment levels in inflow channels • In windy areas, direction and highest speed of prevailing winds • Depth of water table	• Reinforcement around perimeter dykes • Estimate water budgets and sizing of reservoirs for dry season use • Management requirements and storage space for inputs such as feeds, estimate duration of production cycles therefore no of ponds and depth, likely sedimentation rates within inflow channels, • Reinforcement of dykes (particularly large ponds) against wave action • Orientation of ponds
Soil Characteristics	• Soil characteristics across the farm	• Additional inputs to improve soil structure and chemistry for construction and pond management

* For more details see **Module 7**

4.2.2 Constructing Ponds

4.2.2.1 Recommended Pond Standards

Figure 6 illustrates the basic features of a fish pond. The following are the basic requirements for fish ponds:

a. Size of pond

- The size of fish pond varies depending on production function of the pond, market requirements, marketing frequency
- Maximum length a pond is limited by the slope of the land. The gentler the gradient, the longer the pond can be made.

b. Shape of Pond

- Rectangular ponds are recommended because they are easier to seine, feed and manage.
- When several ponds on the farm are to be constructed, make each of them of similar widths so that the same seine net can be used in all ponds.
- The width of the pond determines the length of the seine.

c. Soil use for construction

- Clay or clay loam soils with a minimum of 30% clay.
- Avoid other soils such as gravel, rocky, sand which are porous.
- Where there is no alternative, porous soils have to be lined with an impervious material (e.g. dam-lining)

d. Slope of pond wall (dyke/levee/embankment)
   - Pond walls should have a gentle wall. The larger the pond, the larger the slope (see figure 6).
   - For a pond of:
     - 5,000 – 20,000 m2, the recommended slope is 4:1 to 7:1
     - 1,500 – 5,000 m2, the recommended slope is 2:1 to 4:1
     - 1,500 – 5,000 m2, the recommended slope is 2:1 ?
     - 1,500 – 5,000 m^2, the recommended slope is 1.5:1 to 1:1?

e. Slope of pond bottom
   - A slope of about 2% is recommended.
   - If it is greater, it won't be possible to maintain recommended average pond depth and optimum maximum depths at inlet (80 cm) and outlet (120 cm). In such a case the outlet ends up being too deep for safe seining and favourable fish production.

f. Outlet pipe
   - The outlet should be placed 60 cm above the intended water level to avoid fish swimming out of the pond.
   - Pipes are recommended because:
     - They can be completely screened against predator entry
     - Provide better control for water flow into pond.
   - For ponds larger than 1,000 m2 6 inch PVC pipe and for ponds less than 1,000 m2 a 4 inch pipe.
   - Fit and anchor pipe at a slope within pond wall from inlet channel or pipe.
   - Anti-seep collar to pipe.
   - Screen pipes (see figure 7)

g. Inlet pipe
   - Water flow in inlet should be adequate to fill the pond within 10 days
   - Use 2" pipe for ponds less than 1,000m2 or ponds with limited water supply
   - Where there is abundant supply of water use 4" pipe
   - Dress pipe with filter sock
   - Protect dyke from erosion stone laying or concrete casting or any other suitable means

h. Top-width
   - The minimum top width of a dyke (distance between ponds on the pond bank) should be 1 meter.
   - Make the top width of the main dyke at the deep end greater than the divider dykes to facilitate transport

i. Free board

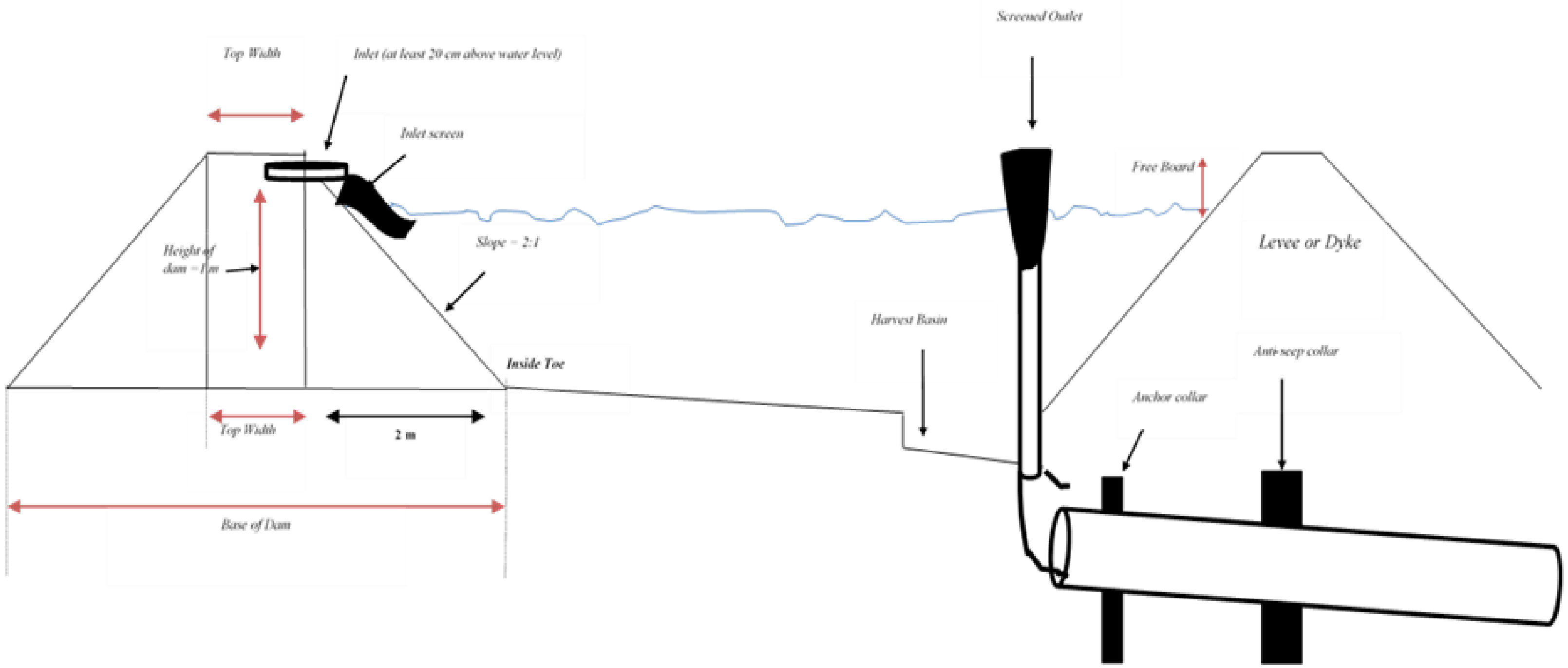
   A height difference of 20 to 30 cm between the water level and top of dyke is recommended because:
   - It allows for more free movement of air currents above the pond water surface which improves mixing and oxygenation of the water.
   - It becomes easy to undertake routine tasks such as feeding, seining, checking water quality and removing dead fish.
   - It is cheaper to construct and maintain.
   - There is less surface area for erosion into the pond.

j. Core Trench (optional)

k. Anchor and Collar

l. Harvest Basin (optional)

Figure 6. Basic Features of a Fish Pond.



4.2.2.2 *Tools and Equipment for Pond Construction*

Taking Measurements and demarcation


Tape measure

String

Sticks cut out as pegs for demarcating

Tools and equipment for taking levels

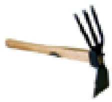
Elevation (height), distance (length) and slope are critical measurements taken continuously during construction

Line level

Surveying equipment

Site clearing, excavation and earth movement tools and equipment





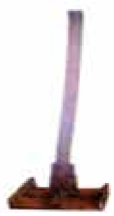
Old gunny bags or sacks





Earth moving machinery

Compaction equipment



Manual hand compactor

Motorised compactors

Sheep-foots packer

rollers

Tools for maintaining suitable moisture content of soil during compaction

Containers, small impoundments, jerry cans, hoses and/or sprinklers for holding and conveying water to moisten pond walls during compaction.

4.2.2.3 Steps in Pond Construction

The major steps in pond construction after determining the site are:

- Prepare the area to construct the pond
- Mark out the pond, its inlet and drainage
- Construct the core trench ***(optional)***
- Construct the dam wall or dyke
- Construct the harvest basin ***(optional)***
- Construct the outlet
- Construct the inlet
- Level the pond floor
- Plant grass on top of dyke

Step 1: Preparing the area to construct the pond

- Clear the site of all bush, tree stumps, debris.
- Remove the stop soil and put it aside
- Ascertain the different soil types across the proposed pond surface area in case one point may require more suitable soil from another end.

Step 2: Mark out the pond, its inlet and drainage

- Use pegs to mark out the pond perimeter (figure 7).
- Take more detailed measurements at the pegs to determine the levels and slope around the pond.
- Based on these measurements, determine and peg out location of inner and outer toes, outlet, and if a harvest basin is desired, the location of the harvest basin.
- Take additional measurements of levels from inner toes across to the drainage to ensure the pond floor slopes towards the outlet and what the lowest point should be at the outlet.

Figure 7: **Pegging the pond. (a)** *The outer line is the perimeter. The central line shows where the inlet pipe and outlet shall be placed. The central line pegs are points at which levels are measured to guide sloping of pond floor towards drainage. The pond floor slope from each corner towards the drainage should be not more than 2%. Note the top soil has been removed and put to the side. It will be used to cover and plant grass on the dyke after construction. (b)The inside toe also needs to be pegged. The outer line (perimeter) forms the centre of the dam wall (more details below)*

Step 3: Construct the core trench

- The core trench is an impermeable layer in between the pond wall (dyke) to prevent seepage and sliding of dam walls.
- It is often constructed with clay (figure 8)
- Seepage across pond walls can also be stopped using an HDPE plastic.

Figure 8: **Constructing the Core Trench**

(a) Dig a trench around perimeter pegs. Even a shallow core trench allows root zone to be cut.

(b) Compact trench with good clay soils. Do not allow the core trench to dry and crack before covering.

Step 4: Construct the pond walls (dykes)

- Build up the dyke from the base upwards layer-by-layer; over the core-trench where a core trench has been built.
- Place layer by layer 20 cm of soil. If it is too dry, moisten it, then compact the layer down to about 50% of 20 cm (figure 9)

Figure 9: Constructing the Pond Wall. *(a) spread and compact one layer at a time (b) layered steps (c) trimmed walls (d) series of completed ponds and new ones coming up.*


(a) ***(b)***

(c) ***(d)***

Advantages of a gentler slope:

- A gentle slope helps break up thus reducing the impact of waves as they hit the pond wall. The likelihood of the pond wall collapsing, pond siltation and leakages are greatly reduced. The benefits are increased pond lifespan, reduced pond maintenance costs and higher yields.
- It is easier and safer for personnel to enter and come out of the pond during seining. One should be able to walk into and out of a pond and not have to 'jump in and climb out'.

Step 5: Construct the harvest basin

a. Having a harvest basin set in the pond or between ponds is optional.
b. A harvest basin can either be set within or outside the pond. If it is to be set within the pond, excavate it before the outlet as it should drain completely into the outlet (see figures 10 and 11). Obtaining the right levels for this is important.
c. Harvest basins:
   - Make it possible to hold and handle fish alive without causing them much stress while draining ponds.

- Reduce the amount of labour required during complete pond harvests
- Recommended in frequently drained hatchery/nursery ponds.
- Useful in ponds that are difficult to drain

d. Can be constructed inside or outside the pond.

Things consider when deciding to construct the harvest basin inside or outside the ponds:

a. Cost
b. Access to the fish
c. Access to fresh water for exchanging within the harvest basin
d. Elevations
e. Pipe placement

Factors that determine the size of the harvest basin:

a. Scoop net size,
b. Estimated standard crop in pond
c. Access to fresh water

HARVEST BASIN INSIDE THE POND

Figure 10: Harvest Basin Inside Pond. *When draining pond, standpipe is turned down (b). Harvest basin soon after draining pond (c)*

(a) *(b)* *(c)*

HARVEST BASIN SET OUTSIDE THE POND

The locations of the inlet and outlet pipes should give a minimum water depth of 0.6m at shallow end and 1.0 m at the deep end (figure 13).

Figure 11: Harvest Basin Outside Pond. *(a) View from pond wall showing outlet within harvest basin (b) View showing water inflow points into harvest basin*

(a) *(b)*

Step 6: Install the Outlet Pipe

- The components comprise the stand-pipe, outlet pipe, bend, anti-seep collar and anchor collar (figure 6).
- Install the outlet before the inlet
- Ideally the pond inlet and outlet should be opposite each other to facilitate flushing. However, this is not all that important if you flush the recommended way.
- Outlets may be made of concrete or PVC pipes. Concrete tends to leak

CONSTRUCTING THE OUTLET AND INSTALLING THE PIPE

- Cut into the dyke wall at the point where the outlet is to be and excavate pipe trench with the desired slope (figure 12 ***a***).
- The size of pipe to use depends on the acceptable draining time and size of pond. For the average Ugandan pond size of not more than 2,000 m^2 a 6" PVC drain-pipe placed to the slope is adequate. Use 4" pipe for ponds less than 1,000 m^2.
- Construct the anchor collar around the pipe by excavating and moulding concrete around the pipe. The anchor collar provides anchorage to the drain pipe and bend when they are empty during production. When not in use, the drain pipe is full of air and this causes the pipe to dislodge at the bend and float as a result of the upward thrust from the pond water (figure 12 ***c***). Leaks can also develop due to loss or realignment as the pipe floats up slightly.
- Place the anti-seep collar after the anchor collar by tying closely strips of old tyre tubing (magalo) around the pipe to a height about 1 to 2" and width of about 10 to 15 cm (figure 12 ***b***). The anti-seep collar prevents water seepage along the outlet pipe as plastic and clay do not bond.
- Fit the bend. This should be a flexible joint to enable the stand-pipe be moved up and down
- Back fill the trench and compact over the pipe to rebuild wall as described above.
- Fit in the standpipe. When the pond is empty, the standpipe can be removed (figure 12 ***c***).
- Screen the outlet when pond is in use to prevent fish escaping during heavy down pours or when there's too much water in the pond (figure 12 ***e*** and ***f***).

Figure 12: The Outlet.

(a) *(b)* *(c)* *(d)* *(e)* *(f)*

Step 8: Install the Inlet Pipe

- Cut within and excavate a trench to the desired slope in the pond wall at the shallow end to lay down the inlet pipe.
- The diameter of the inlet pipe should be less than that of the outlet pipe in order to prevent overflow from the pond if someone accidentally leaves the inlet open.
- Use 2" pipe for ponds less than 1,000 m2 or ponds with limited water supply. Where there is abundant supply of water use 4" pipe.
- The inlet pipe should be set at least 20 cm above the intended water surface to prevent fish from escaping. If the inlet is set at or near the level of the water, fish will swim against the current of the inflowing water and escape from the pond.
- Avoid open earthen channels as inlets to commercial ponds. Such channels are difficult to screen effectively and often erode. Consequently, they come closer to the pond water level each year.
- Place pipe to slope, backfill and compact soil removed over the pipe (figure 13).
- Protect dyke from erosion stone laying or concrete casting or any other suitable means.
- Dress pipe with filter sock. When the inlet is above the water level and properly screened, fish are unable to jump into the pipe and escape through the inlet pipe. The screen also prevents fish outside from the pond entering it.

Step 7: Smoothen and compact the pond bottom

- The pond bottom should be smooth and firm.
- Remove all 'pot holes' by filling and bumps by levelling. Pot holes:
  - (i) Provide shelter for fish to hide after ponds have been drained. Such fish predate upon the new stock.
  - (ii) Pose a danger to persons seining the pond who may trip and injure themselves.
- Compact the pond bottom to make it firm to avoid:
  - (i) Muddy pond bottom during production which results into poor pond productivity.
  - (ii) Muddy bottoms provide refuge for fish to hide and are difficult to seine.
  - (iii) Fish getting trapped in mud when the pond is being drained.
- As you level and compact the bottom, pour water to ensure it flows to and out the outlet

Figure 13: Smoothening and levelling the Pond Bottom. *The pond bottom should be sloped towards the outlet. Remember to compact the floor again once done.*

Step 8: Strengthen the Dyke Tops and Free-Board Areas

- Compact the pond bank again to strengthen for the desired use.
- Place the top soil over the bank and down to the water line (figure 14 ***a***).
- Compact lightly.
- Plant grass over the top soil down to the water level. Water the grass to ensure it grows (figure 14 ***b***).

Figure 14: Finishing the Bank.

(a) ***(b)***

A free board less than 20 cm is dangerous in case of over flooding and fish like the African catfish can easily escape when the freeboard gets 'wet'.

It is undesirable to have a free-board higher than what is recommended because:

a. It is an unnecessary added construction cost - expensive to make.
b. It attracts predators and burrowing animals such as nutria and muskrats
c. High freeboards above the water favour the nesting of birds and anthills creating points for water leakage (figure 15).
d. It makes working on the pond difficult and dangerous.
e. Can collapse into pond.

Figure 15: Bird nests in a high Free-board

4.2.3 Maintenance and Rehabilitation of Pond and Channels

During production, siltation, erosion of the dykes, and leakages progressively occur due to wave action, fish behaviour and seining. Ponds therefore regularly need to be:

(i) De-silted

(ii) Walls reconstructed and strengthened against erosion

(iii) Leakages repaired

1. *De-silting*

- In old ponds, broken-down pond walls, accumulated silt and shallowness occur from using the pond (figure 16 ***a***).
- Scrap the silt from the bottom and it into mounds until semi-dry (figure 16 ***b***).
- Use this same soil to reconstruct the eroded parts of the dyke (figure 16 ***c***).
- Do not heap soil on the pond bank because when it rains, it will be washed back into the pond. Take excess silt and soil you don't need to repair the walls away from the pond area.

Figure 16: De-silting Ponds

(a) *(b)* *(c)*

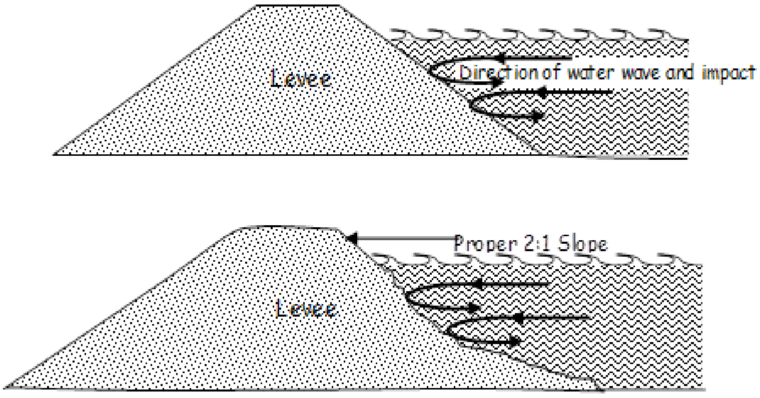
2. *Reconstructing the pond wall*

- During production, the slope of the wall progressively becomes eroded (Figures 17 and 18 ***a*** and ***b)***
- When the slope has become steeper than recommended, trim and rebuild the wall up layer by layer while ensuring the desired slope of the inside achieved (figure 19 ***c***).

Figure 17: Erosion of Pond Walls

(a) *(b)* *(c)*

Figure 18: Impact of wave action on pond walls.



4.3 Fish Tanks

Aquatic animals and plants can be raised in tanks. Fish tanks are described based on their:

- Shape (circular, rectangular or conical)
- Function (hatchery, grow-out, aquaria or holding tanks)
- Size (troughs, small, medium or large)
- Material they are made from (plastic, fibre glass, concrete, wood/metallic lined)
- Fixed or portable (figure 19)

Figure 19: Tanks


Fixed hacthery concrete tanks


Wooden lined tank ***Plastic tanks***

Collapsible portable tank made of tarpualin

Semi-permanent tank improvised for emergency use on-farm

Assorted plastic household basins and buckets improvised into hatchery tanks

NB:

- High pH is likely in concrete tanks where no sealant is used (e.g. tiles, water-proof paints, etc).
- Do not use toxic materials such galvanised iron metal sheets to construct fish tanks, especially in hatcheries

4.3.1 Basic Features of a Fish Tank

The fish tank should:

- Be able to hold water
- Be able to fill and drain rapidly
    - Have inflow and outflow valves to separately control filling and drainage
    - Permit the control of water volume, flows and quality.
    - Permit good circulation within and water exchange through the tank to enable the removal of wastes.
- Have smooth and easy to clean walls without protrusions so as not to cause injury to fish or personnel
- Choices of depth should be more than 'chest high' considering worker safety and ease handling fish within the tank.
- Add re-enforcement in the bottom of fixed tanks to provide support for the unit when filled with water.

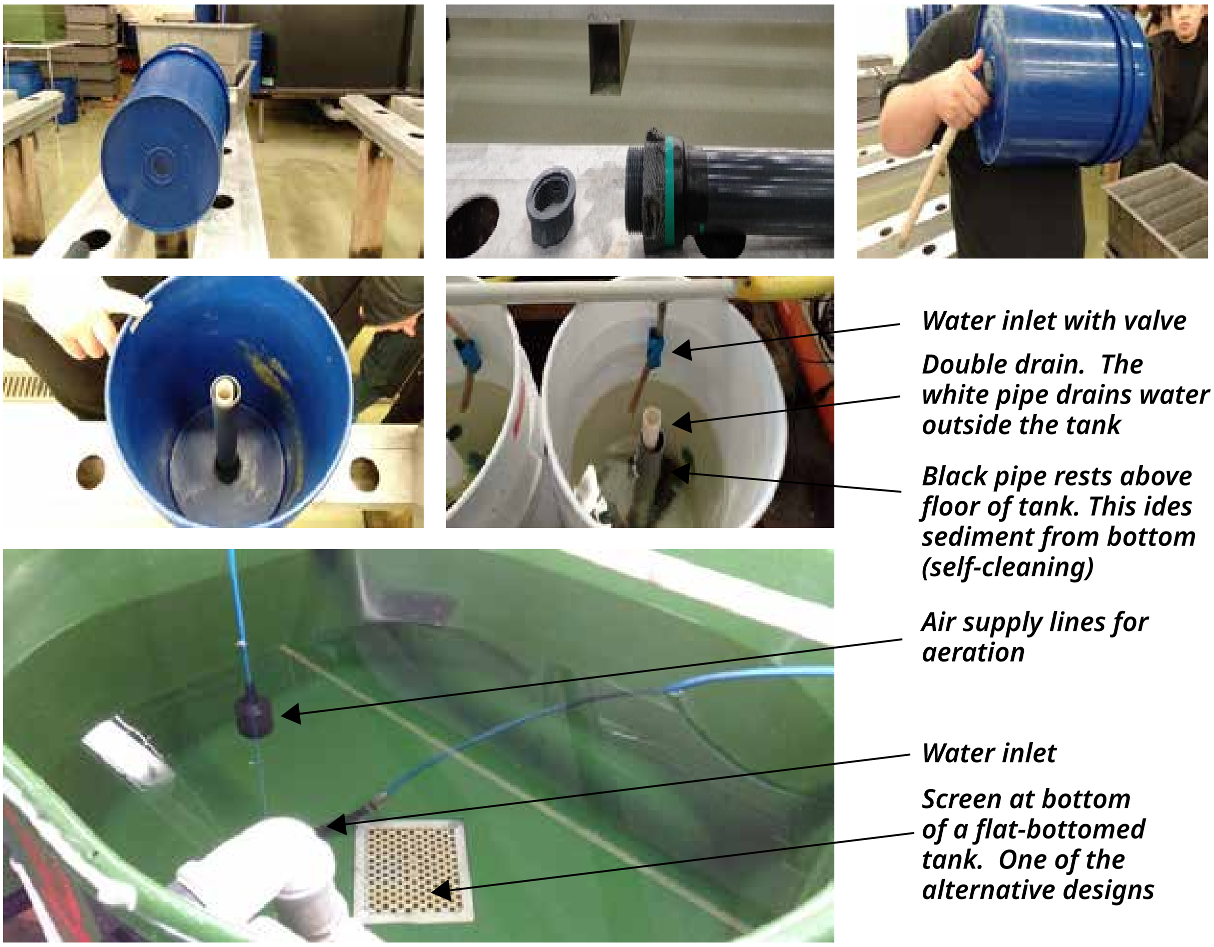
The tank design, valves, standpipes, buffers and aeration are used to do achieve this (see table 10 and figure 20 below).

Table 10. Standard Tank Features

	Circular Tank	Rectangular Tank	Raceways
General Features	• May have flat or V-shaped bottom	• Include troughs • Ensure there is no variation in width to prevent eddies, dead spots and accumulation of wastes.	• Raceways or running water ponds have brick or concrete sides and bottoms as they have relatively fast flowing water. • Ensure there is no variation in width to prevent eddies, dead spots and accumulation of wastes.
Inlet	• Water usually injected tangentially from side into tank	• Water flows from upper end to lower end at outlet	• Water flows from upper end to lower end at outlet
Direction of water flow **Water mixing**	• Rotating water flow and uniform water quality due to effective water mixing • Uniform flow patterns and high velocities	• Water flows from upper end to lower end at outlet can present unpredictable flow patterns	• Location of water inlet and outlet determine the flow pattern; and can be used to create rotating flow pattern
Outlet	• Water outlet placed centrally = central flow pattern that flushes solids down to center	• Minimum waste concentration at inlet, maximum at outlet. • Gradient in environmental conditions = heterogeneous fish distribution	• Cross-flow tanks = water inlet from top, to mimic hydraulics of raceway and circular tanks
	• Better optimization of water and space	• Conditions in tank non-uniform towards inlet which reduces efficiency of energy and treatment	• Mixed cell raceways.
Inlet designs	• Single point source produces less homogenous flow • Vertical pipe with nozzles along the water column – mixing depends on direction of nozzles	• Can install buffers or attachments to inlets for multiple entry for homogenous flows	• Can install buffers or attachments to inlets for multiple entry for homogenous flows
Length, diameter, width and depth ratios	• Recommended diameter:depth ratio range from 5:1 and 10:1 to allow for homogenous movement of water withing tank. • When sizing also consider floor space, feeding, stocking densities, water head and type of handling required	• Length: width: depth 6:<2:1 ratios for	• Length: width: depth ratio of 30:3:1

	Circular Tank	Rectangular Tank	Raceways
Drain types	• Outside standpipe and flat centre bottom screen to control depth of water. Emergency overflow screen in event the bottom effluent screen gets clogged • Cylindrical centre screens used in 1 - 2 meter diameter tanks provide better cleaning action if they are not perforated in the upper portion • Dual-drain systems are preferable as minimal water is required to remove solids	• Have at least 0.09m2 (30 cm2) of screen area at outflow for each 94 litres per minute water flow.	•

Figure 20: Basic components of a Fish Tank. *The figure also illustrates plumbing parts and how to fabricate a circular tank from a plastic container.*



4.3.2 Factors Affecting Choice of Tank

Tanks are designed in consideration of production cost, space utilization, water quality and fish management. In addition, for operational purposes:

1. Natural swimming and social behavior of the fish to be reared - This reduces stress, improves fish growth and fish welfare.
2. Provision of uniform water quality within the tank - To ensure entire tank volume provides optimal growing conditions.

3. Fast removal of solid wastes
4. Uniform distribution of fish throughout the tank
5. Velocities within the tank should not be stressful (table 11)

Table 11: Advantages and Disadvantages of Circular and Rectangular Tanks

	Circular	Rectangular
Advantages	• Labour required to manage a 1 to 100 m3 tank daily are the same. Hence a few large tanks cheaper to manage than several small ones. • Capital costs per unit volume decrease with increasing size of tank • Easy to maintain. • Provide uniform water quality hence uniform distribution of fish and better optimization of space. • Can be operated over a wider range of rotational velocities allowing one adjust to needs for different fish species and stage of fish growth. • Settle able solids can be rapidly flushed through the center drain making self-cleaning possible. • One can observe waste accumulation associated with feeding which makes feeding to satiation easier to determine. • Carrying capacity superior to troughs and rectangular tanks as there is sufficient pressure for aeration and re-aeration	• Rectangular tanks with length: breadth ratio of 5:1 or more. • Most popular because use space more efficiently, • Easier to manage, handle and sort fish, • Easier to construct, • Easier handle as units and adapt to water flows • When properly constructed have identical water conditions from side to side with gradual decline in water quality towards outlet. Consequently fish will be attracted towards inlet. In circular tanks fish cannot select areas of higher oxygen and lower ammonia.
Disadvantages	• Ability to distributing flow to obtain uniform mixing and rapid solid removal in single drainage systems and where water flows not permitting • Grading and harvesting fish more difficult. Requires crowders and scoop nets. • Removing mortalities • Higher risk of economic loss per tank when technical and biological failures occur. • Require more space • More labor intensive	• Higher water exchange rates are needed to produce self-cleaning. This entails more energy • Sedimentation tends to occur in areas of low velocity and low fish density • Water quality distribution gradient favors hierarchies and aggressive behavior among fish in the tank • Substantial water supply is needed, young fish especially accumulate at inlets hence space not efficiently utilised • Better suited from fingerling stage

4.3.3 Establishing Fish Tanks

a. Site Selection

Fish tanks can be established anywhere. The most important things to consider are:

- An adequate and constant water supply to maintain required water volumes, flows and exchange rates during production and for other uses.

- Firm foundation upon which tanks will be set
- Cost of establishing and operating the facility

b. Major Features of a Tank-Based Fish Farm

- **Size of the tanks based on the operational flow requirements** of the farm in account of production targets and additional water needed for draining and cleaning.
- **Water delivery and aeration:** Install the appropriate piping systems, pumps, periodic changes are required leakage

NOTE:

- Use **water-proof cement** only to constructing tanks to avoid seepage
- For further advice for designing and installing water system consult a mechanical or agricultural engineer and plumber.

4.3.4 Maintenance of Fish Tanks

- Keep clean
- Immediately water and air leakages are noticed, repair tank, water and air plumbing
- Ensure water and air pumps and valves are good working condition

4.4 Fish Cages

Essentially a cage is a container made of mesh for rearing or temporarily holding aquatic animals within a water body. The mesh allows water to flow into and out of the cage without obstruction or letting fish out of the cage. Cages vary in shape, size, are versatile and can be used in several ways.

4.4.1 Cage types

a. Fixed Cages

- Made of net bag supported by posts driven into the bottom of the lake, river, dam or pond
- Square and rectangular
- Limited in size
- Inexpensive and simple to build
- Use restricted to sheltered areas with slow currents that have non-rocky but firm bottom substrate to allow posts fix and hold
- Hapas are common example (figure 21 **a**).

b. Floating Cages

- Most widely used
- Bag is supported by a buoyant collar or frame
- Can be made in shapes and sizes depending on farmers needs
- Suited to wider variety of sites (figure 21 ***b***).

c. Submersible Cages

- Have a net collar but rely on a frame or rigging to maintain shape
- Suspended from buoys/floating frames on the water surface or can be designed to have variable buoyancy

- Can be positioned within the water column to take advantage of prevailing environmental conditions. For example, they may be brought up to the surface in good weather and sub-merged during toxic algal blooms or extreme weather (figure 21 ***c***).

d. Submerged Cages

- Wooden boxes with slats or net bags anchored to substrate by stones or posts
- Used in flowing waters or lakes (figure 21 ***d***).

Figure 21: Types of Fish Cages

(a) ***(b)***

(c) ***(d)***

4.4.2 Site Selection for Cage Farms

The suitability of a site for cage culture depends on:

(i) **Water quality** - whether the physical and chemical characteristics at the site are suitable rearing the intended species

(ii) **Environmental factors** associated with establishing the cage system

(iii) **Other factors** influencing farm establishment and operations such as legal requirements.

4.4.2.1 Water Quality

The water quality in a cage cannot be corrected during production as opposed to ponds and tanks. The only corrective measure in such instances is to relocate the cage to a different site. It is therefore important that cages are established in waters of optimum quality.

The recommended water quality criteria for selecting cage sites in Uganda are given below (see **Mod-ule 5** for more details).

k) ***Chemical Parameters***

Table 12 provides the guidelines for chemical water quality for cage sites

Table 12: LVFO Recommended Water Quality Characteristics for Cage Sites

Parameter	Value
Dissolved oxygen	>4 mg/l
Salinity	15 – 30ppt
Electrical Conductivity	90 – 110 μScm^{-1} expected range in Lake Victoria (except heavily polluted Murchison bay)
Ammonia-nitrogen (NH_3-N)	< 0.5 ppm
Hydrogen ion index (PH)	7.0 – 8.5
Nitrate (NO_3-N)	< 200 mg/l
Nitrite (NO_2-N)	<4 mg/l
phosphate	<70 mg/l
Chemical oxygen demand (COD)	<3 mg/l
Biological oxygen demand (BOD)	<5 mg/l
Biological criteria	
Bacteria count (E. coli)	<3000 cell/ml

Adapted from MAAIF, 2016.

l) ***Phytoplankton Blooms***

The nature, degree and frequency of phytoplankton blooms at the proposed site should be taken into consideration because:

(i) Heavy blooms cause drastic fluctuations in oxygen, pH and ammonia levels which is stressful to the fish and influences the onset of disease, mortality and poor growth (figure 23).

(ii) Some phytoplankton species produce toxic algal blooms. For example, toxic forming species of ***Microsystis, Anabena, Aphanizomenon*** and ***Osciallatoria***.

(iii) Some blooms can cause off-flavor in harvested fish. For example, ***Oscillatoria, Anabena*** and ***Microcystis*** sp.

(iv) Clog cage meshes which reduces water exchange and hence quality of water within cages.

Sites with frequent heavy blooms tend to be found in the listed areas and should be avoided:

(i) Higher than normal dissolved levels of nitrogen and phosphorus in the water column

(ii) Are close to sources of pollution

(iii) Zones with poor water exchange or currents to wash away blooms

Figure 22: **Heavy Algal Blooms.** *Picture courtesy of SoN and Ian Derry.*

m) ***Biological Information***

Biological data on phytoplankton, zooplankton, benthic invertebrates, fish and macrophytes gives and indication of the status of aquatic life at the site, notably:

- How much aquatic animal production can be supported at the site
- Natural habitat characteristics of the site (i.e. spawning and nursery grounds, fish migratory corridors, critical areas for fish food organisms, sensitive habitats for ecosystem health, endangered or threatened species).

This information forms part of the environmental monitoring plan.

Information on levels of faecal coliforms and total bacteria counts gives an indication on whether the site is exposed to contamination by faeces from man or terrestrial animals (table 12). Faecal coliforms are a public health and food-safety hazard issue.

n) ***Pollutants and contaminants***

The cage site must be free from pollutants such as heavy metals and Persistent Organic Pollutants (POPs) as these accumulate into the flesh of fish.

The minimum safe levels for cage sites are listed in tables 13 and 14 below. Sites with pollutants above permissible levels will not be licensed.

Table 13: Minimum concentrations at cage sites for heavy metal contaminants in water and sediments

Heavy metal	Sediments (µg/g)	Water (mg m^{-3})
Mercury	0.2	0.144
Lead	31	5
Nickel	16	13.4
Cadmium	0.6	10
Zinc	120	20
Iron	2	300
Copper	16	3
Chromium	26	50
Arsenic	6	5
Manganese	460	50
Selenium	-	10
Barium	60	1000
Silver	0.5	50
Thallium	-	13

Adapted from MAAIF, 2016.

Table 14: Minimum concentrations persistent organic pollutants (POP) and pesticides at cage sites and aquaculture parks.

Persistent organic pollutant/ pesticides	Sediments (µg/g)	Water (µg/l)
Aldrin	0.002	0.01
Chlordane	0.007	
DDT (total)	0.007	
Dieldrin	0.002	0.005
Endrin	0.003	0.005
Heptachlor	0.0003	
Toxaphene	-	0.002
Polychlorinated Biphenyls (total)	0.07	
Mirex	0.007	
Hexachlorobenzene	0.02	0.01
Endosulfan	-	0.1
Tributyltin	-	0.014
Pentachlorobenzene	-	1
Lindane	0.005	0.02
α-Hexachlorocyclohexane	-	10

Adapted from MAAIF, 2016.

o) Disease

The quality of water and health status of wild fish at a site influence the likelihood of diseases occurring at cage farms.

Avoid sites with:

- Poor water quality
- Polluted water is more likely to harbor disease causing agents
- A lot of bottom sediment as fish parasites are more likely to be found
- wild fish are infested with parasites or frequently fall sick.

For more details on disease control see **Module Eight.**

p) Water Exchange

The extent to which water currents at the site can flush water away from cage farms limits the accumulation of wastes in the area. The buildup of waste at the site progressively results in the deterioration of water quality within cages and the farm area.

The rate at which water is exchanged at a site depends on the current, water temperature, salinity and topography. There is likely to be less wind action in bay sheltered by steep slopes.

q) Fouling

Fouling is the build-up of phytoplankton on the mesh of cages during production. It results into the reduction of mesh-size and hence the level of water exchange through cages. Where current velocities are low it can become a major management problem.

4.4.2.2 Environmental Factors Associated with Cage Establishment

r) Weather

Avoid sites where violent stormy weather is frequent. Cages can get damaged in such environments. Submersible cages are more suited to such sites.

s) Shelter and waves

Wind speeds, wind duration and the distance of open unobstructed water across which wind blows influences wave height and length. Non-sheltered areas with more waves are more suited for large cages (table 15).

Obtain, meteorological and topographical data and the site history to ascertain the likelihood of frequent high waves.

Table 15: Summary of Physical criteria for cage aquaculture site selection showing the acceptable standards for cage fish farming

Parameter		Acceptable standard
Hydrological criteria		
Height of the wave	Stationary cage	<0.5m
	Floating cage	<1.0m
Wind velocity	Stationary cage	<5 knots
	Floating cage	<10 knots

Depth	Stationary cage	Min >4m, max <8m
	Floating cage	Min >5m, max <20m
Physical criteria		
Current velocity		Min >10cm/sec, max <100cm/sec
Total Suspended Solid (TSS)		<10mg/l
Water temperature		27 – 31^{0}C
Secchi Depth		> 0.5m

Adapted from MAAIF, 2016.

t) Currents

The rate and direction of flow of water at the site affect:

- Water exchange rates through the cage
- Fish behavior
- Suitability of cage type
- Mooring

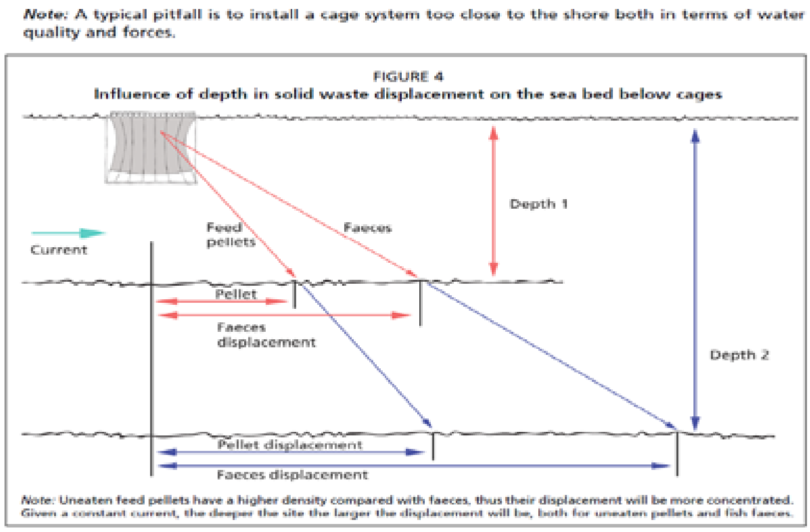
u) Water Depth

The minimum water depth is that which ensures cage is covered by water and at least 3 m above the bottom sediment for small cages to allow for unobstructed dispersal of waste away from the cage site (see table 16 and figure 23 below).

Table 16: Recommended minimum Distances above bottom sediment

Cage Type	**Depth Range**
Fixed cage	<8 m
LVHD	At least 3 m above sediment
HVLD	At least 4-5 m above sediment

Figure 23: Illustration of the effect of distance from pond sediment on water quality in fish cages. *Uneaten feed pellets have a higher density compared with faeces; thus their displacement will be more concentrated. Given a constant current, the deeper the site, the larger the displacement will be, both for uneaten pellets and fish faeces.*



v) ***Substrate***

Firm rocky substrate is more suitable for floating cages.

3.7.2.3 Other factors influencing farm establishment and operations

w) ***Legal Requirements and Planning***

Cage culture is not permissible in Government gazetted restricted areas. These are ***'no-go'*** areas.

Establishments that have a protective zone around them restricting access even though the site may be suitable for cage culture are referred to as ***'no-go-within'*** areas.

(i) No-Go Areas

Ugandan Government gazetted 'no-go' areas.

- Areas of military or security interest or activities;
- Published anchorages (where ships and boats anchor) and their defined berths;
- Established navigation channels for ships or ferries or any other form of water transport;
- Established harbors (where ships and boats seek shelter from stormy weather, or are stored for future use) and harbor approaches;
- Marinas or mooring areas with structures to which vessels may be secured such as piers;
- Fish sanctuaries and Marine Protected Areas (MPA);
- Cables, pipelines and drilling platforms;
- Parks, conservation and heritage or tourist sites;
- Gazetted fish breeding sites, fish spawning and nursery grounds;
- Existing domestic and industrial water intake and extraction points;
- Fish migration routes;
- Existing hydropower plants;
- Core Zones of Ramsar sites
- Areas gazetted under the Lacustrine Statutory Instrument
- Areas where water depth and quality fluctuation is high such as seasonal rivers;
- Known common and important fishing grounds;
- Effluent discharging gates of industrial and urban effluents; and
- River and stream mouths and sources

NOTE: The above list is subject to change. Therefore, always verify the actual legal status of with the local authorities and community whenever considering a potential site for cage culture.

(ii) No-Go-Within Areas

Table 17 lists distances of restricted zones around gazetted establishments.

Table 17: No go areas within proximity of some establishments around candidate sites

Establishment	Distance with not go within
• Shore line	200m
• Areas of military or security interest or activities;	2km
• Published anchorages (where ships and boats anchor) and their defined berths (sufficient space for a vessel to manoeuvre);	500m

Establishment	Distance with not go within
• Shore line	200m
• Marked navigation channels for ships or ferries or any other form of water transport;	100 m
• Established harbors (where ships and boats seek shelter from stormy weather, or are stored for future use) and harbor approaches;	5 km
• Marinas or mooring areas with structures to which vessels may be secured such as piers;	500m
• Fish sanctuaries and Marine Protected Areas (MPA);	2km
• Cables, pipelines and drilling platforms;	100m
• Parks, conservation and heritage or tourist sites;	100 m
• Gazetted fish breeding sites, fish spawning and nursery grounds;	200-300 m
• Existing domestic and industrial water intake and extraction points;	100 m
• Fish migration routes;	500m
• Existing cage culture areas;	2km
• Existing hydropower plants;	1km
• Core Zones of Ramsar sites	2km
• Areas gazetted under the Lacustrine Statutory Instrument	1km
• Areas where water depth and quality fluctuation is high such as seasonal rivers;	500m
• Known common and important fishing grounds;	1km
• Effluent discharging gates of industrial urban effluents and other waste disposal points	500m
• River and stream mouths and sources	1.5 or 3 km
• Landing sites	200 m
• Weed hotspots (e.g. water hyacinth)	100 m
• Recreational facilities	500m

NOTE: Always verify the legal status of with the local authorities and community whenever considering a potential site for cage culture.

x) ***Access to services and shore facilities***

Land along the shore is required for:

- Offices, stores and workshops, housing and utilities to run such facilities.
- Pier for docking boats
- Land for the farm should in an easily accessible area to cage site.

y) ***Security***

Security against theft and vandalism.

4.4.2.4 *Evaluating the Site*

The above data can be evaluated using:

(i) Simple scoring tools for small farms (figure 24)

(ii) remote decision support tools such as GIS for large farms further away from shore

Figure 24: Example of a Scoring Card for Evaluating Cage Sites

Factor	Possible Score	Actual Score	Criteria/Comments
Temperature			
Salinity			
Oxygen			
Plankton			
Currents			
Fouling and obstructive aquatic plants			
Gazette areas			
hydrology			
Depth (bathymetry)			
Substrate characteristics			
Wind and waves			
climate			
predators			
pollution			
Tidal debris			
Total Score			

4.4.3 Planning the Farm Cages on the Farm

4.4.3.1 *Estimating the number of cages per site*

The optimum number of cages that can be placed at a site depends on the sites carrying capacity (**Module 5** for more details).

To determine this, the following steps should be followed (appendix 2 for more details)

1. Assess site suitability
2. Estimate site carrying capacity
3. Proposed management for site
4. Estimated number of cages for the different management conditions per site category

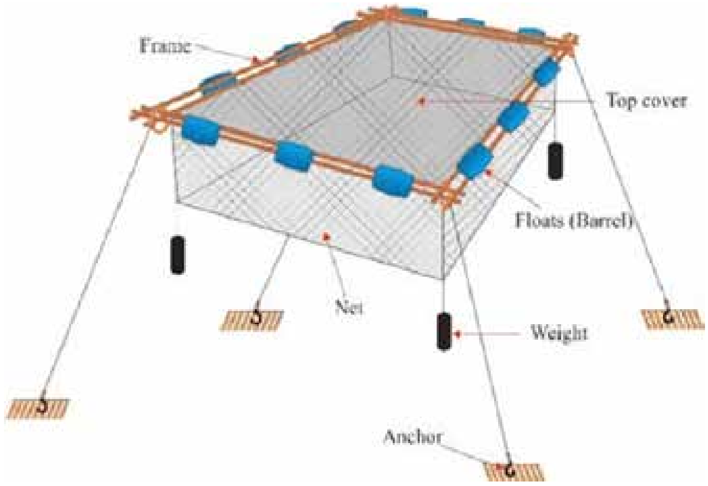
At sites that rank low, fewer cages should be stocked.

4.4.4 Cage Construction

4.4.4.1 Basic Components of Cage

The basic components of a cage are the frame, bag and mooring (figure 25)

Figure 25: Basic Components of a Floating Cage

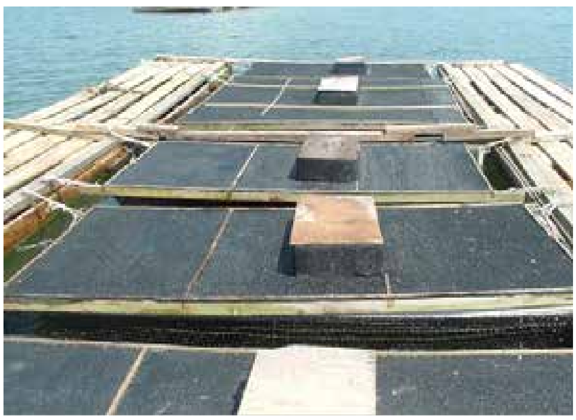


aa) ***1. The Frame***

- The frame holds the net in position and provides a point for attaching the floats, anchor-line and cover.
- Use water and weather resistant, strong, durable materials that remain semi-buoyant after the floats and weights attached to make the frame.
- Suitable materials include PVC, HDPE, metallic rods and bamboo.
- The wave movement and strength at the site determine the most appropriate frame to use:
  - (i) ***Rigid frames*** do not follow wave movement. May be made of poles, steel or plastic. More suited to sheltered inshore bays or small impoundments (e.g. ponds, dams).
  - (ii) ***Frames with joints*** follow wave force to some extent.
  - (iii) ***Flexible frames*** follow wave movements. Often made of plastic. More suited for open off-shore areas with greater wave movement (figure 26).

Figure 26: Types of Cage frames

Rigid frame

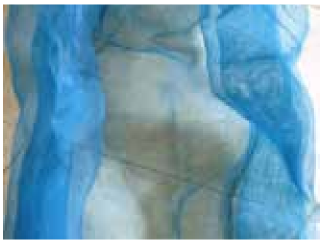


Rigid frame doubling as work platform

bb) ***2. The Bag***

- The mesh netting that holds the fish
- May be made of flexible or rigid material sewn.
- The size of mesh used must be big enough to permit optimum water exchange through and small enough to ensure the fish within the cage cannot escape as listed below (see figure 27)
  - (i) Hatchery cages
  - (ii) Nursery cages
  - (iii) Grow-out cages

Figure 27: Cage Netting Materials



Hatchery netting	***Nursery netting***	***Grow-out cage netting***

cc) ***3. Sinkers***

Sinkers are attached directly to the bag to maintain its shape.

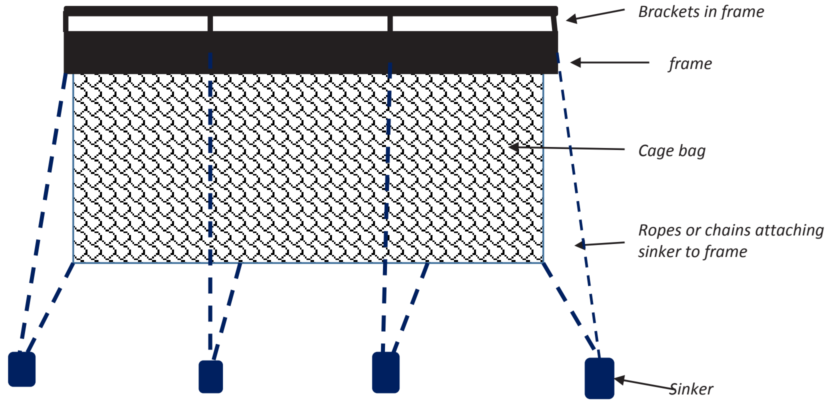
Sinkers should be:

- Water resistant
- The environmental characteristics (notably salinity, currents and waves), size of cage and bio-mass of fish. Faster currents and waves required heavier sinkers. Materials should withstand environmental conditions.
- The weight of the sinker(s) should not exceed that of the frame.
- Iron bar sinkers should be enclosed PVC pipes to prevent rusting
- Hapa sinkers can be made from mineral water bottles filled with sand or concrete seine net sinkers.

Sinkers may be fixed inside or outside the bag depending on:

- ***The size of cage***: For cages larger than 2 x 2 meters, attach the sinkers outside the cage be-cause it is difficult to remove sinker from a large cage (figure 28).

Figure 28: Attachment of external sinkers to a large cage.



- ***Wild fish and other aquatic animals outside cage:*** Large catfish living wild in man-made reservoirs can push up cages to knock out the feed. In such cases use a rigid cage, heavier sinkers or an additional internal or exterior cage frame with vertical reinforcements (figure 29).

Figure 29: Double LVHD nursery cage for offshore use in a lake or river. *Note the inner cage us finer mesh (white) into which juveniles are initially stocked. When they grow older, the inner cage is pulled out. For such small cages, the sinker in the inner cage is made of an air-tight sealed plastic frame filled with sand or an iron bar.*

4.4.4.2 Selecting the Appropriate Shape and Size of Cage for a Particular Site

a. Cage shape

Cages can be of any shape and size. Most cages are square, rectangular or circular. Table 18 explains the advantages and disadvantages of the different cage types

Table 18: Advantages and Disadvantages of Rectangular and Circular Cages

Cage Shape	Advantage	Disadvantage
Rectangular	• Ease of construction • Can produce large modular* structures • Have a higher surface area: volume ratio hence higher water exchange rate within the net so can stock higher densities per unit volume • Can use fixed or flexible netting • Preferable in sheltered bays, shallow waters and fairly eutrophic waters	• Bear more impact of wave forces at corners which can eventually result in breakage in sites where wave action is great ***(Polygonal collars have more corners than rectangular cages so can withstand wave stress better).*** • Not suited to open offshore sites
Circular	• Higher surface: perimeter ratio for any given volume hence less material is used. Hence lower cost per unit volume compared to rectangular cages • For some species, better utilisation of space as corners of rectangular cages are less utilised • Lighter in weight hence simpler mooring and floating systems • Bear wave forces equally sides hence withstand dynamic stress better hence can be used in less sheltered sites further offshore	• lower surface area: volume ratio => water exchange through cages is lower hence cannot be stocked at high densities per unit volume and not suited to eutrophic waters • Constructing collars requires more skill and technology •

*Can replace or add any one component (module) without affecting the rest of the cage

b. Cage Size

Choice of the size of cage depends on the site characteristics and expected dynamic stress on the cage arising from wave action (table 19).

Table 19: Advantages and Disadvantages of Small and Large Cages

Cage Size	Advantages	Disadvantages
Small cages	• easier to sort and grade, visually monitor health and feeding	• More costly to construct per unit
Large cages	• cheaper to construct per unit as save material (e.g. 100 m3 cage will cost less to construct than two 50 m3 cages) • easier to manage fewer large cages on a farm rather than several small ones	• more difficult and costly manage during operation (e.g. removal of mortalities, inspection of nets, monitoring health, etc) • lateral surface area: volume ratio reduces the larger the cage irrespective of whether its rectangular and circular => lower water exchange rate than smaller cages • greater risk of loss associated holding tens of tonnes in a single cage rather than several

c) Selecting the most suitable type of cage for the site

Guidelines for choosing the appropriate cage for a particular site are given in Table 20.

Table 20. Identifying appropriate cage for a site

Site Characteristics	Suitable Cage Type		
	Shape	**Size**	**Volume**
Sheltered waters	Square, rectangular	Large Can be modular	large
Open exposed waters	Circular, hexagonal	small	small
Good water quality *(high levels of dissolved oxygen)*	All shapes	large	large
Suboptimal water quality *(low levels of dissolved oxygen and fairly eutrophic water)*	Square, rectangular	Small Can be modular	small

4.4.4.3 Making the Cage

Materials used for cage construction should be:

- water and rot resistant
- light and strong
- weather resistant
- fouling resistant
- smooth; non-abrasive for fish
- draft free
- affordable

1. *Rigid Cages*

Rigid cages have a sturdy frame all around. The bag may be made of flexible or rigid mesh material (figure 30).

Figure 30: Rigid cages

*(a) **Rigid cage with flexble mesh. A collar with floats can be attached to such cages to make them float***

*(b) **Rigid cage with rigid mesh. Such cages are useful for temporily holding fish in ponds***

2. *Floating Cages*

Collars, floats and/or platforms keep floating cages buoyant. They help balance the total downward and upward static forces from gravity and the water column to keep the cage buoyant (figures 31 and 32).

Floating cages are kept in position once installed by the mooring (section 4.4.5)

Figure 31: Forces affecting design criteria and installation of floating cages.

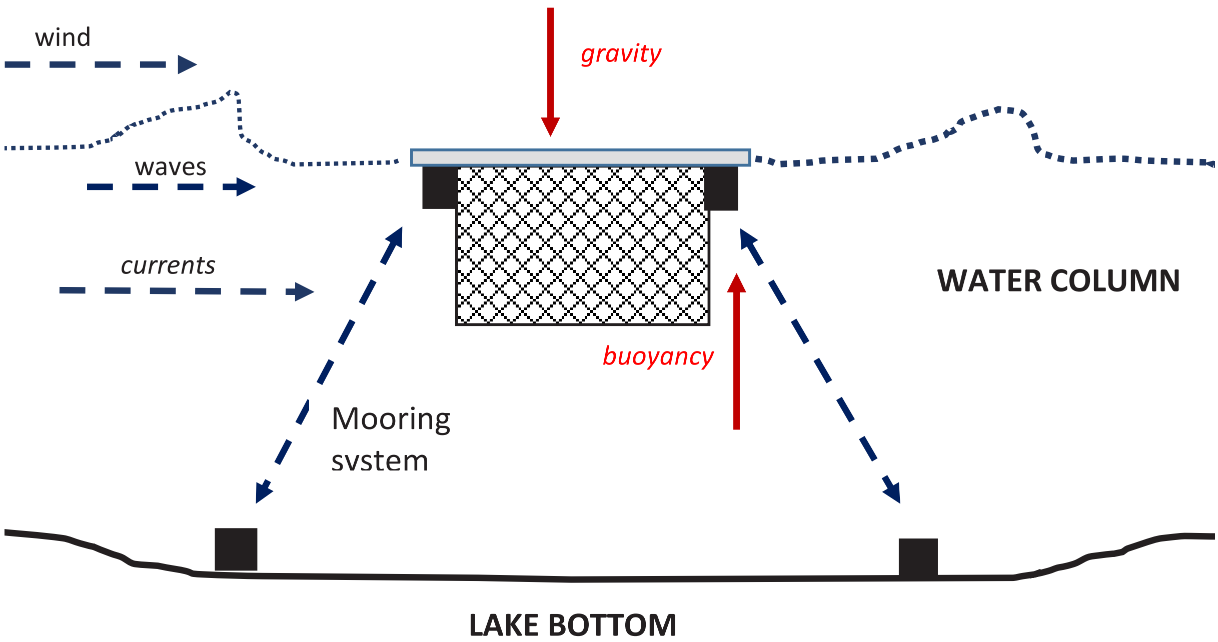


Figure 32: Collars, Floats and Platforms. *Note that the size of collar, float or platform varies with the size of cage and environmental conditions. Several cages can be attached to one platform.*

(a) ***Polystyrene blocks attached to the frame to make a collar. Cover them before installation in water.***

(b) ***Plastic drums filled with Polystyrene pieces then sealed to be water-tight.*** *the float will sink rather than float. Water is heavier than Styrofoam*

(c) ***Floating wooden platform***

3. Cage Cover

All cages should be covered with opaque netting to:

- Protect fish in the cage from predators (such as otters, birds and theft).
- Limit amount of sunlight entering the cage to restrict the fish vision of objects and movements above the cage that might stress them (e.g. birds).
- Use light weight and weather resistant material for the cover.

4. Feeding Attachments

Feeding enclosures, automatic or demand feeders can be attached to the cages for administering feeds.

- Feed enclosure for floating feeds is a ring or a box positioned in the top centre of the cage with an open bottom and removable top cover. It should extend 40 cm below and 10 cm above the water surface. Its purpose is to prevent loss of floating feed while allowing the fish free access to the feed. Water surface area inside the feed container should be 20 - 25% of the total cage surface area. Floating feed enclosures should be placed in the centre of cages (figure 33).

- Demand feeders may be used as trickle feeders.
- Solid or fine mesh tray (covering 20 % of the cage bottom) with 5 to 15 cm raised sides if sinking feeds are used

Figure 33: Attachment for feeding sinking pellets in cages

For feeding rings and demand feeders see **Module Six**

4.4.5 Installing Cages at the Farm

4.4.5.1 Positioning of Cages

When positioning cages on the farm:

- Set them perpendicular to current to optimise water exchange through the cage (figures 34 to 36).
- Ease access to the cages to harvest feed
- Allow natural movement routes of other aquatic animals (e.g. otters) and their habitats
- Maintain minimum distances between cages to minimise risks of poor water quality within cages and disease spread between cages.
  a. LHVD cages the minimum distance should be 2 m in between cages within the same row and 10 m in between rows
  b. HVLD – depends on the diameter of the cages. For 10 m diameter cage, not less than 30 m apart.

For feeding rings and demand feeders see **Module Six**

Figure 34: Positioning Cages. *Figure 8 illustrates the manner in which cages should be placed in a water body. Cages should be positioned in a single line perpendicular to the current. This is to ensure that wastes are washed out of the cages. If they are positioned improperly in a chequerboard fashion without spaces in between, the cages in the middle and end will receive the water with wastes from the cages on the inflow side.*

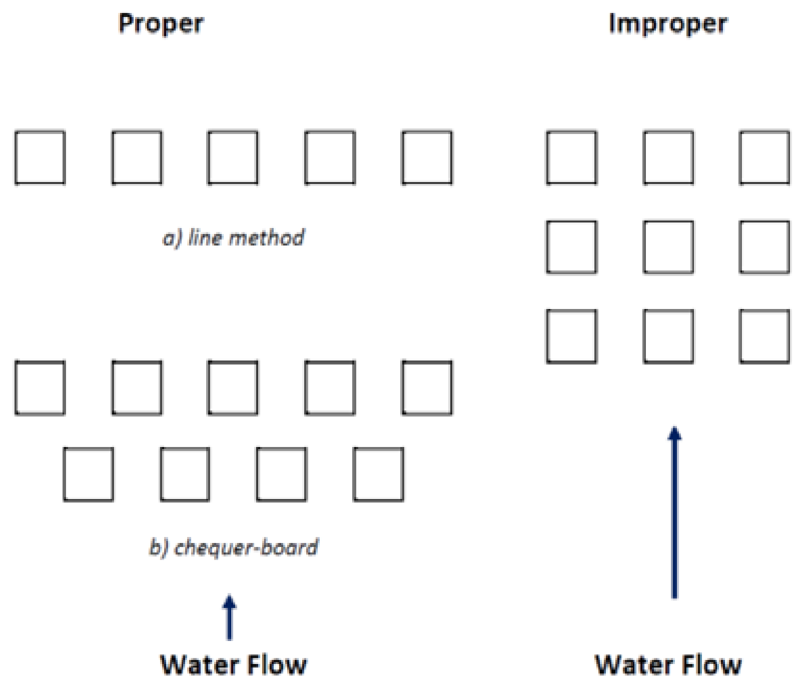


Figure 35: LVHD Cages Properly Aligned in a Single File with Adequate Spacing Between Cages and Rows.

Figure 36: Chequered Alignment Poorly Positioned with No Spacing.

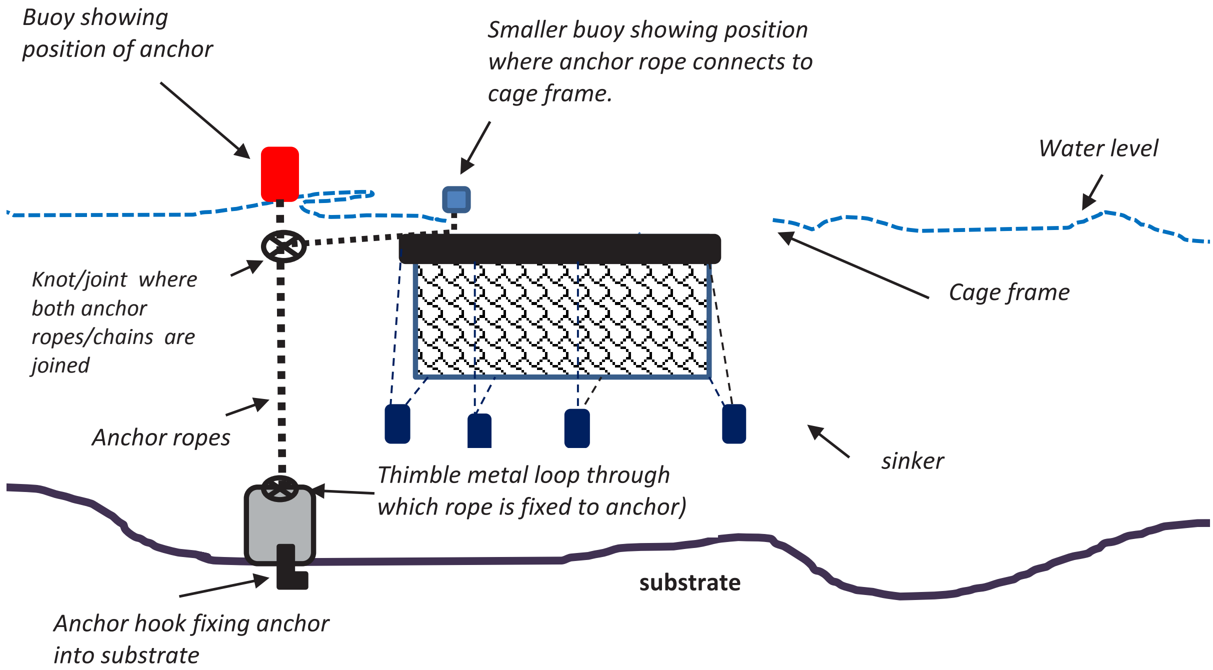
4.5.5.2. Fixing the Cages in Position

Cages are fixed into position with what's termed the **'mooring system'**. The mooring system has two components:

(i) The mooring comprising the anchors, ground chains, ropes and related shackles and buoys (figure 37).

(ii) The grid whose components are the frame ropes, mooring buoys, connector rings or plates, bridles, and related shackles. The grid system keeps a set of cages within the farming area.

Figure 37: Basic components of the Mooring



dd) ***Consideration for Making the Mooring***

The mooring depends on:

(i) The design, type and number of cages

(ii) Site characteristics (weather conditions, waves, currents, characteristics of the substrate). For example, where currents are strong, secure the cages in the position of least resistance to the prevailing winds and currents. In sheltered sites with poor water circulation, moor cages in the position that allows for the best water exchange.

Attention must be paid to mooring because it influences:

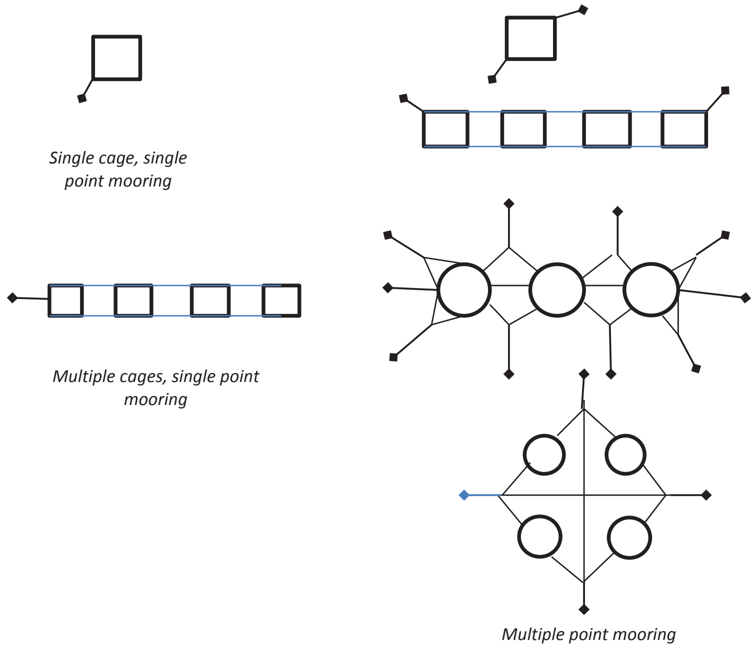
- the level of stress on the structural elements of the cage,
- behavior of cages in rough weather
- levels of production and profitability
- staff safety

Cages can be moored in two ways as described in table 21 and figure 38.

Table 21: Types of Mooring

Mooring system	Description	Comments
Single point	Cage(s) are secured from one point allowing them to move in a complete circle depending on position of least resistance to the prevailing wind, waves, current forces, inter-cage forces and torsional forces at linkages	• single LVHD • not recommended in exposed sites • distribute waste over larger surface area than the multiple point system • less site area is used for the farm compared to multiple point system because much less surface area is taken up by the mooring structures
Multiple point	Mooring are attached to more than one point of the cage(s).	• use up more farm space than the single point system

Figure 38: Examples of configuration of mooring system. *The number and rows of cages may be increased in multiple point mooring*



4.4.5 Maintenance of Cages

- Wash, dry immediately after use
- Mend any damage in net
- Store when hung in a net shed to avoid damage.

4.4.6 Other Requirements for Cage Farms

The following are essential tools necessary for cage farms:

- Water transport - a canoe/boat, outboard engine, life jackets and fuel to facilitate movements from the shore to the cages;
- Life jackets

4.5 Recirculating Aquaculture Systems

Recirculating aquaculture systems (RAS) were initially designed to maintain water temperature within the production unit.

The basic components of the RAS system are the:

(i) ***Biofilter*** to remove soluble waste, mainly ammonia

(ii) Production tank(s) for fish rearing

(iii) ***Filtration unit*** comprising a sedimentation tank and filter to remove non-soluble waste particles (figures 39 to 41).

Figure 39: Key Components of a RAS System

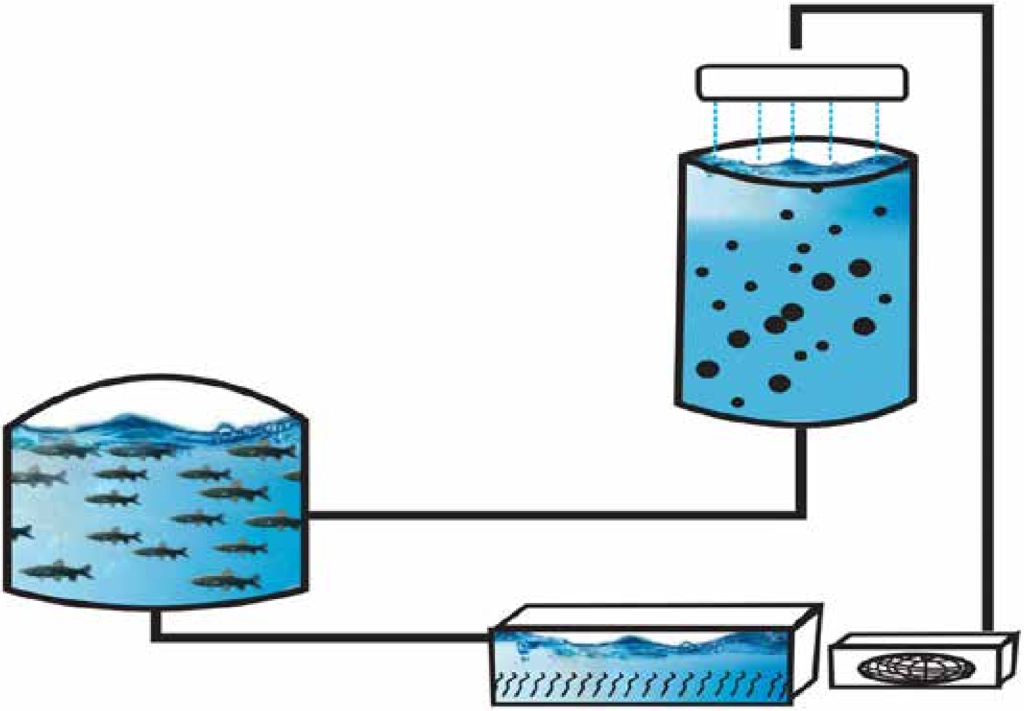


Figure 40: A Backyard RAS System with Four Production Tanks

Figure 41: Bio filter Substrate and Submersible Pump

(a) *Substrate used in biofilter.* *Plastic shaving or bottle tops*

(b) Submersible Pumps. *Normally placed inside unit with filtered water*

4.6 Integrated agriculture-aquaculture systems

The objective is to optimize nutrient cycling on the farm in order to increase overall farm production and productivity. Waste from one activity is converted into a resource for another activity.

4.6.1 Terrestrial Farm Integrated Aquaculture Systems

The following are the major integrated fish farming systems practiced on terrestrial farms:

a. Livestock/poultry cum fish farming
b. Crop cum livestock cum fish farming
c. Crop cum fish farming (figures 42 and 43).

Figure 42: Illustration of Integrated Fish Farm

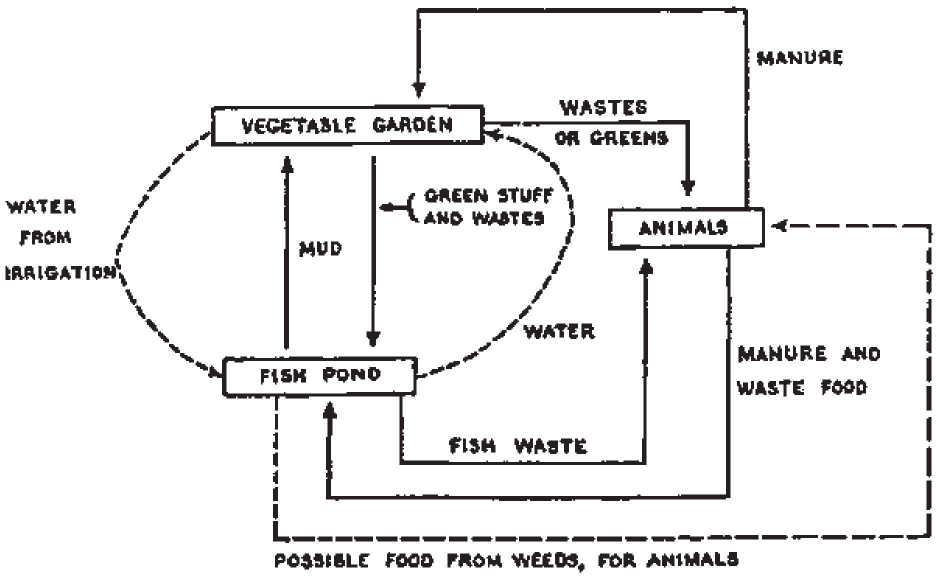


Figure 43: Integrated Fish Farms

Water from ponds can be used to irrigate fruits and vegetables

Simple poultry pen placed over a fish pond. The waste feed and poultry droppings go directly into pond

Channel at edge of rice-paddy for fish in integrated rice paddy-fish culture

Sampling fish in the paddy

4.6.2 Aquaponics

Aquaponics systems are integrating the RAS for growing both fish and plants. The plants are grown in nutrient rich water effluent from the fish tanks only without soil or any substrate (figure 44 and 45).

Figure 44: Adaptation of the RAS into an Aquaponics System

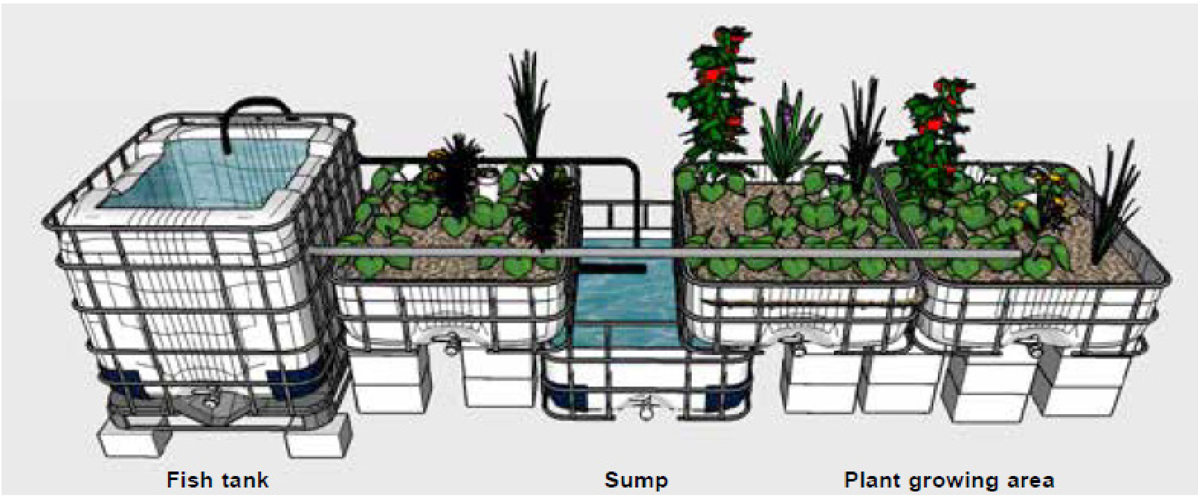
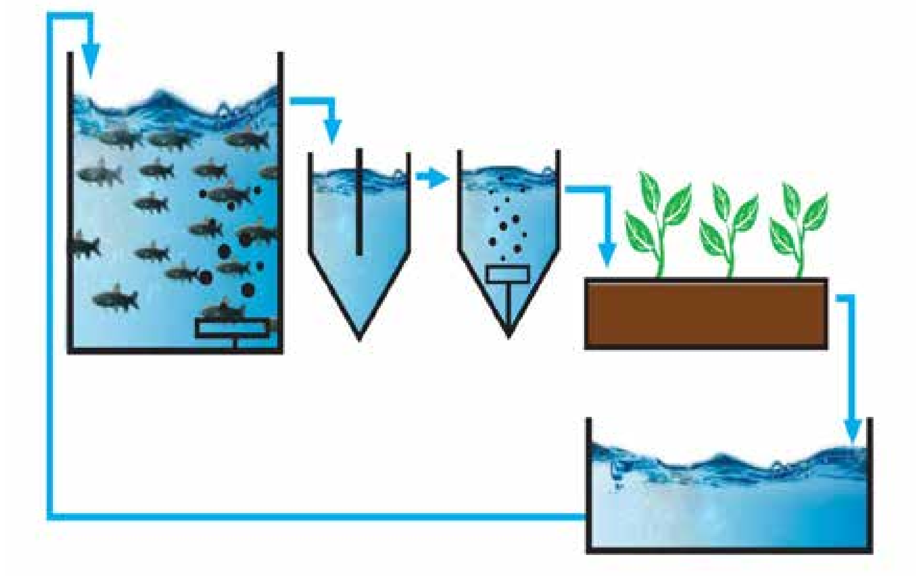


Figure 45: A simple Aquaponics System



Aquaponics units can be established anywhere. When constructing an aquaponics unit:

- Level and firm the ground to prevent sinking when the water tanks are full. Concrete slabs, cement or stone blocks and stone chippings can be used.
- Limit exposure to wind and rain. Simple roofing including green housing is recommended.
- Ensure adequate sunlight for plants
- There must be a source of energy to run pumps.

4.7 Farm Effluent

Land-based fish farms should have a sedimentation pond fed by the main drainage to remove excess silt and nutrients from the water before its released back into streams.

Reeds can be planted in such ponds. Alternatively, the water from farms can be channeled to crop farms for irrigation

MODULE FIVE:

WATER QUALITY MANAGMENT

The quality of water determines the success or failure for any aquaculture operation. This module explains why water quality is important for production, the most important water quality variables and how to manage them during production.

5.1 The Importance of Water Quality in Aquaculture

In aquaculture, water quality refers to all the physical, chemical and biological attributes of water that affect yields. The physical and chemical characteristics of water directly affect the fish's physiology and consequently, its production performance. When water quality is suboptimal, fish become stressed. This results into poor growth, ill health and mortality.

The physical and chemical characteristics such as suspended solids, temperature, dissolved gases; pH, mineral content and the presence of toxic metals in water are largely influenced by the water source. Site selection, weather conditions, facility design and production management all affect water quality during production. Hydrological aspects such as water flow rate and volume are important for water quality management.

Aquatic plants (phytoplankton) and animals (zooplankton) constitute the biological attributes of water quality. Like fish, they are living things and their presence in water depends on water having water quality being favourable for their survival. Some plankton are beneficial for fish farming because they are a source of food for fish and moderate water quality parameters. For example, nitrifying bacteria convert toxic ammonia into less toxic ammonium. When farming fish, the water quality requirements for useful aquatic organisms is also considered. Water quality also affects the quality and safety of fish produced for human consumption.

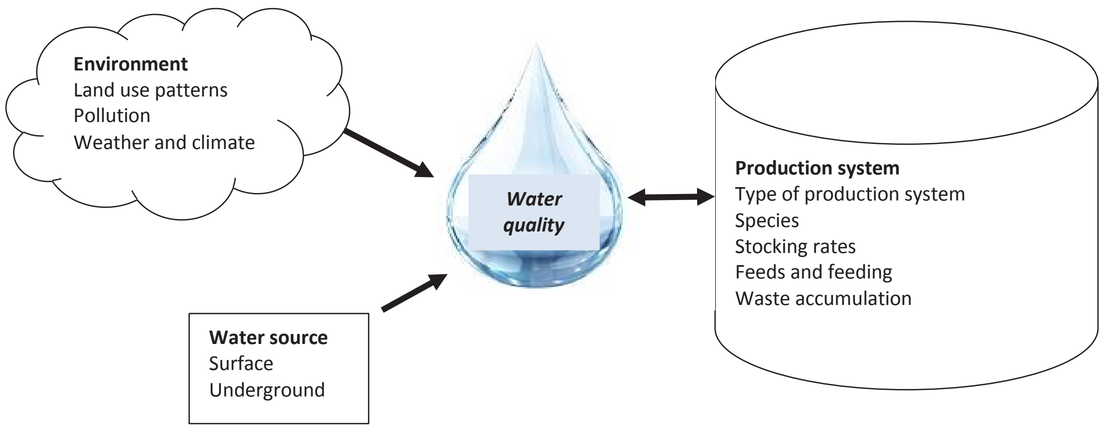
- The table below shows which water quality parameters must be controlled for production, fish health and food safety.

5.2 Water Quality and Fish Production.

The major factors that affect water quality during fish production are the environment, water source and production system. Weather patterns and climatic factors such as rainfall, ambient temperature, winds and cloud cover affect water temperature, phytoplankton growth and consequently the dissolved oxygen (DO) and pH levels of surface water. Minerals in soils dissipate into the water and determine hardness, alkalinity and pH of the water.

Surface waters that are exposed to ambient temperature and air tend to be warmer with higher levels of DO compared to water from underground sources. Similarly, surface waters tend to be more affected by environmental pollution, have wild fish and pathogens as opposed to underground water. Underground waters are colder with more pressurised with gases (figure 46).

Figure 46: Factors that Influence Water Quality in Fish Farming



The most critical water quality parameters for fish production are water temperature, DO, pH and ammonia. Their levels in water are influenced by the metabolism of fish and other aquatic organisms, the buffering capacity of water, production management (including of water volume and flow rates) and the water quality characteristics attributable to the water source. Failure to maintain these key parameters within the optimum ranges results into fish stress, reduced feeding, poor growth, disease and/or mortality. Therefore, these key water quality variables must be maintained within the recommended ranges during production (table 22)

Table 22: Recommended Water Quality Ranges

Parameter	Relevance to Production	Recommended Range	What happens when Consistently below recommended Value	What happens when consistently above recommended value
Dissolved Oxygen	• Fish breathe in oxygen for their metabolism. • Dissolved oxygen is needed to oxidise potentially toxic metabolic wastes into less toxic forms (e.g. ammonia (NH3) to nitrite (NO2-) and then nitrate (NO3-) and oxidation of anions into basic compounds which reduces formation of acids) • Bacteria that help transform wastes into less toxic products need oxygen for their metabolism.	From 4 mg/l to saturation	• 0 – 1.5 mg/l Lethal especially if exposed for several hours • 1.4 – 5 mg/l Fish survive, but reduced metabolism and feed intake. • Feed Conversion Ratio (FCR) s higher slow growth, stress, and increased susceptibility to disease results. • Build-up of toxic wastes because they are not broken down (oxidised)	• Above saturation, gas bubble trauma.
Temperature	• Fish are cold blooded animals. Their metabolic rate is directly influenced by water temperature. • Rate at which wastes are broken down and chemicals dissolve faster in warmer waters • Affects the solubility of oxygen. The warmer the water, the lower the solubility of oxygen.	25 °C to 30 °C	• 0 oC to 10 oC Lower lethal limits • 10 oC to 15 oC Poor growth, ability to reproduce greatly reduced if any at all. • 15 to 25 oC Reduced feed intake and growth rates. Higher (FCR). Fish more stressed at lower temperatures, therefore, more susceptible to disease. • Tilapia cannot withstand the stress of handling when water temperatures are 21o oC and below. • Organic matter and other waste broken down at slower rate. Higher risk of eutrophication.	• Lower solubility of oxygen, stress and death at extreme temperatures.

Parameter	Relevance to Production	Recommended Range	What happens when Consistently below recommended Value	What happens when consistently above recommended value
pH	• Affects the solubility and chemical forms of various compounds some of which can be toxic.	6.0 to 8	• Below pH 4, acid death point. • pH 5 Survive but stressed, slow growth, reduced feed intake, higher FEED CONVERSION RATIO (FCR)s. Lower limit for tilapia. • Higher proportion of Total Ammonium Nitrogen in the form of ionized ammonia, which fish can tolerate for short exposures	• 9 – 11 Stressful for fish, slow growth rate. • Above 11 alkaline death point. All life, including bacteria in pond will die at this point. • Higher proportion of Total Ammonium Nitrogen in the form of unionized ammonia in water, which is more toxic for the fish.
Alkalinity and Hardness	• In combination, influence the buff-ering capacity of the pond water. • Hardness is composed mostly of calcium and magnesium, which affect the physiological condition of the fish • Calcium found in hard waters is important for fish egg, bone and tissue development. * • Alkalinity also controls the amount and form of carbondioxide in water	Alkalinity > 20 ppm Hardness > 20 ppm Total alkalinity and hardness above 60 ppm is desirable	• Extreme fluctuations pH levels during the day which is stressful to the fish. • Fish are under physiological stress • In ponds and open water bodies low levels of primary production which results in lower natural sources of food.	• Water will be well buffered and diurnal fluctuations in pH will be less extreme • Fish will be less stressed physiologically • Young fish will have more natural food. • Hard waters in catfish hatcheries should be avoided.
Ammonia	• Ammonia occurs in two forms depending on the acidity of the water. The unionised form of ammonia (NH_3) is more dominant when the water is alkaline and the ionised form, ammonium (NH_4^+) when the water is acidic. Total Ammonium Nitrogen (TAN) is the combined measure of its two forms, unionised ammonia (NH_3) and ammonium ion (NH_4^+). The levels of either form also depend as water temperature. Table 5.2	Fish can tolerate 0.01 to 0.05 mg/l of ammonia without a significant negative effect on production as long as the levels of dissolved oxygen and water temperature are within the recommended range. catfish can withstand levels of ammonia of up to 0.6 mg/l to 2 mg/l for only short periods.	• Fish are happiest when there is little or no ammonia in water.	• The unionised form, ammonia, is toxic. High levels of dissolved ammonia in water negatively affect ammonia excretion, blood pH, enzyme systems, and the physical integrity of body tissues (especially the gills) of fish. Gill damage impairs oxygen uptake and osmoregulation becomes impaired. • Fish succumb more to attacks by trematodes and other parasites

*Some species may require soft water. Rivers in rainforest usually have soft waters (less than 20 mg/l) while waters from East Africa's great lakes are usually above 300 mg/l.

5.2.1 Dissolved oxygen (DO)

DO levels in a production unit are managed by:

(i) Controlling oxygen consumption rates in the production unit

(ii) Aeration

(iii) Oxygenation

(iv) Biologically

a. Controlling oxygen consumption rates in the production unit

DO utilisation within production units as a fish metabolism, bacteria and organic waste can be controlled by:

- Stocking within the limits of carrying capacity (see section 5.3)
- ***Minimise build-up of organic waste and other suspended solids in production units by flushing out waste and limiting levels of organic inputs to what is necessary***.

b. Aeration

Air is introduced into the water to increase the levels of DO. Aerators are used to do this.

- Types of Aerators
  1. **Submersible Aeration:** Air is extracted from the atmosphere using air pumps, blowers or compressors and is released under the water surface through diffusers. Diffusers may be high pressure or low pressure depending on the amount of air resistance built within the diffuser as the air passes through (figure 47).

Figure 47: Equipment for submersible aerators and diffusers

Air pump

Aquarium air pump

Air blower

Tyre tube air blower

Air stones

Low pressure diffuser tubing

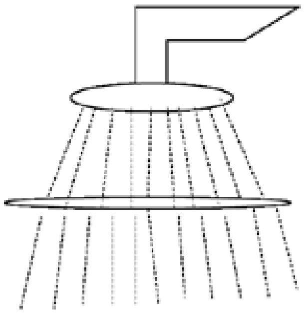
Micro-pore diffusers (high pressure)

2. **Surface Aeration:** Surface aeration is done mechanically by throwing water from the water surface up into the air. Air is incorporated into the water as the water falls. The higher the water is thrown up and the smaller the water particles, the more air gets incorporated into the water. Surface aeration is more commonly done in ponds (figure 48).

Figure 48: Surface aerators

Paddle wheel aerator

Dual-prop aerator



Trickle aeration with cascades.
Picture on the right shows illustrates how this can be done simply on-farm to degas water from a borehole into main hatchery supply water tank

- Factors to consider when selecting aeration equipment
  - For tanks, the total water volume and for ponds, the total surface area to be aerated.
  - Total fish biomass in the unit
  - Source, reliability and cost of power
  - Type of power on the farm, i.e. access to power lines, single-phase, three-phase, solar, generator, etc.
  - Will aeration be used full-time or part-time?
  - Maintenance and running costs of the equipment proposed
  - Access to technical support for installation and maintenance.
  - Whether it makes economic sense for the business.

c. ***Oxygenation***

Oxygenation is the addition of pure oxygen into water. It is used for live fish transportation, in temporary live fish holding facilities, emergency situations when oxygen levels drop too low and in super-intensive grow-out systems. Pure oxygen gas is available on the local market in pressurized cylinders.

It is necessary to have oxygen cylinders with the associated accessories in hatcheries or on intensive tank-based facilities for packaging live fish and emergency situations.

d. ***Biological Processes***

Dissolved oxygen in non-aerated fish ponds is generated during photosynthesis by phytoplankton and from air, when wind blows over the water surface and mixes into the water (see section 5.4).

5.2.2 Temperature

Temperature is a pacesetter. The warmer the temperature, the faster the decomposition of organic matter and fish metabolism implying a higher demand for oxygen. However, the solubility of oxygen in water falls with increasing temperature. In tropical fresh-waters, pay greater attention to the impacts of decomposition of organic matter.

Water temperature in ponds and outdoor tanks is influenced by ambient temperature and frequency water exchange. In tanks, water temperatures can be managed by recirculating heated water or housing the units under green houses.

5.2.3 Organic Matter

During production, organic matter input is from feeds and manure. Organic matter increases the demand for DO and the likelihood of pollution unless; it is broken down into smaller less complex particles that are less toxic. The ***break-down and assimilation*** of organic matter requires oxygen and bacteria; and is faster at warmer temperatures.

Controlling organic input levels is key for managing DO and other water quality parameters such as ammonia.

Feeds: As soon feed is fed, DO consumption in the production unit rises due to the oxidation of feed, ingestion and digestion by the fish and assimilation of uneaten feed and faeces. Therefore, minimise the presence of left-over feed and faeces within production units by:

- Feeding only what the fish can consume at each meal

- Preferably feed highly digestible feeds that have a high water-stability (for example steam extruded floating pellets).
- Ensure that dissolved oxygen levels in the pond do not go below 3 mg/l for several hours at a time after feeding, especially in tanks.
- Give less feed when using a low-quality feed that disintegrates easily in water.

For more details see **Module Six.**

Organic fertilisers. It is better to add small amounts of manure more frequently, rather than add large amounts on an occasional basis. In this regard, chemical fertilisers are advantageous because they are concentrated soluble nutrients of nitrogen and phosphorus (for more details see section 5.4).

5. 2.4 Ammonia

Ammonia is the by-product of protein ***metabolism*** by fish and bacterial decomposition of organic matter. It occurs in two forms depending on the acidity of the water. The unionised form of ammonia (NH_3) is more dominant when the water is alkaline and the ionised form, ammonium (NH^{4+}) when the water is acidic. Total Ammonium Nitrogen (TAN) is the combined measure of its two forms, unionised ammonia (NH_3) and ammonium ion (NH^{4+}). The levels of either form also depend on water temperature.

Controlling levels of Ammonia

Levels of ammonia are managed by:

a. Limiting Feeding Rates.
b. Controlling water pH to prevent it from rising above 8.
c. Fertilisation Regime.
d. Increase Water Exchange through production units.

5.2.5 Turbidity and colouration of water

Turbidity is the relative clarity or cloudiness of water due suspended solid particles dispersed within the water column. Suspended solids are usually invisible to the naked eye and may be organic or inorganic. In ponds, turbidity from green water is a good indication of pond productivity. However, in indoor tanks, clear water is preferred.

5.2.6 Dissolved Gases

Gases when dissolved into the water under high pressure can be harmful for fish (see **Module Eight**). Volatile dissolved gases can be removed by stripping water with an aerator or letting the water stand exposed to air.

5.2.7 Water volume and exchange rates

Water volume and flow are important in water quality management for the dilution and flushing of wastes.

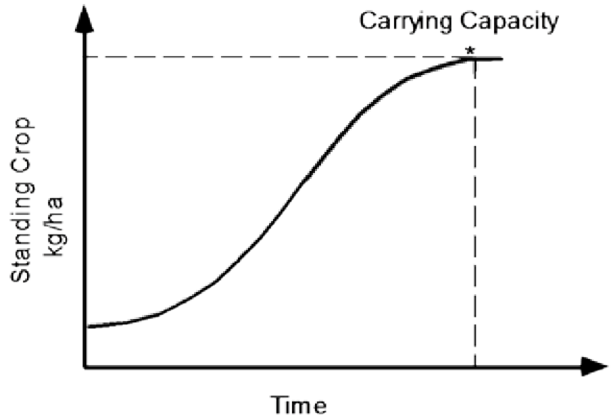
5.2.8 Fish Density

The physical crowding of fish at high stocking density is not the primary limiting factor for production. The primary limiting factors at high stocking density in production units are the low levels of dissolved oxygen and the build-up of metabolic wastes.

5.3 Carrying Capacity

The carrying capacity is the maximum biomass that can be achieved in any production system (figure 49).

Figure 49. Carrying Capacity



Carrying capacity is simultaneously determined by the following factors:

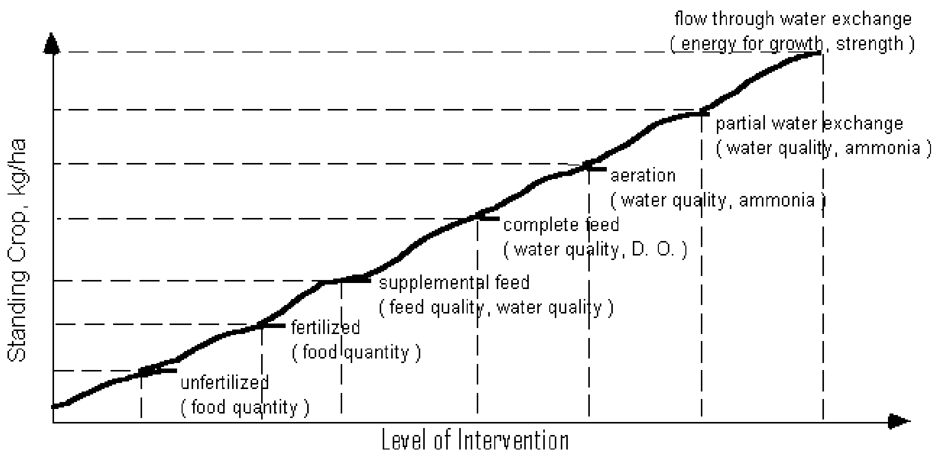
(i) fish species and size;

(ii) water quality factors notably dissolved oxygen, temperature, ammonia, water flow and volume

(iii) Feed.

Different species and sizes of fish have different water quality requirements. Fish fry for example, have higher metabolic rates and need more DO. Feeds influence carrying capacity because of their impact on the levels of suspended solids and ammonia. Water flow and volume influence carrying capacity because they determine the extent to which wastes are flushed and diluted within production units respectively (figure 50).

Figure 50: Limiting factors and their impact on Standing Crop *at* Carrying Capacity



The management of water quality in the various production systems aims at overcoming water quality constraints to achieve the system's optimum carrying capacity.

5.4 Managing Water Quality in the different Production Systems

5.4.1 Water Source

Water quality from the different sources can be improved as described in table 23.

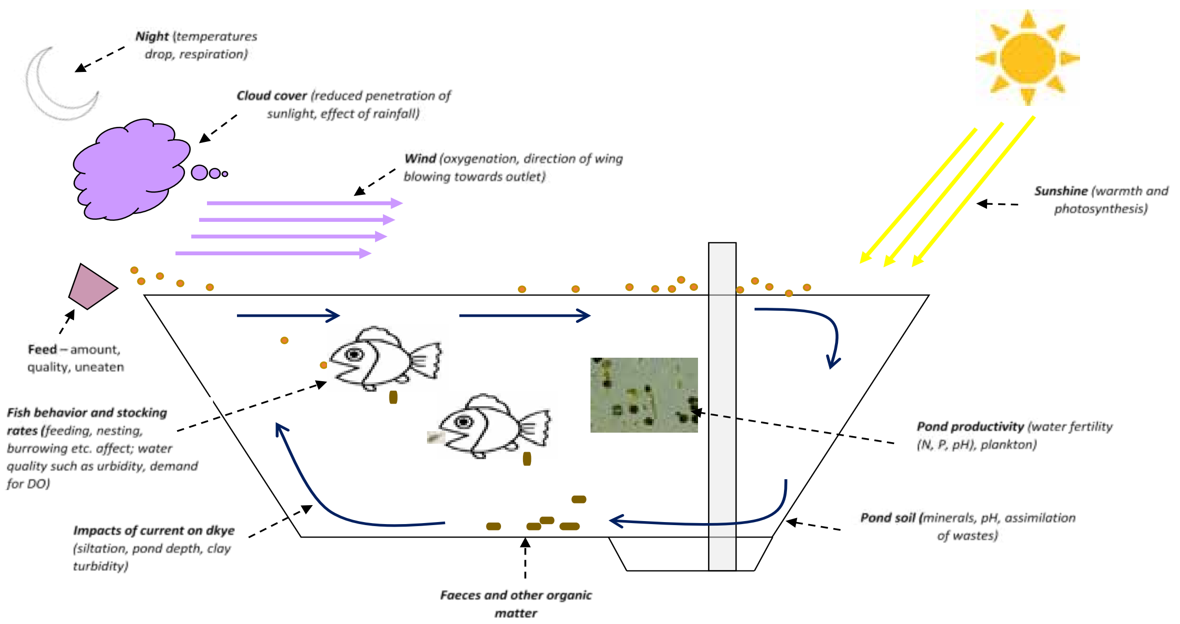
Table 23. Comparison between the water quality characteristics of underground and surface waters

Water Quality Parameter	Under-ground Water		Surface Water	
	Common Issue	Recommendation	Common Issue	Recommendation
Dissolved Oxygen	low	Expose to air, oxygenation or aeration	Water drawn from wetlands usually low DO	Expose to air, oxygenation or aeration
Temperature	low	Stand in open reservoir, heat water	n/a	
Alkalinity/ hardness	Generally Medium to high	Verify levels	May be soft water	Add agricultural lime
pH	Often acidic	Expose to air, oxygen-ation or aeration	Swampy waters often acidic	Expose to air, add agricultural lime
Ammonia	n/a		Run-off from animal establishments	Siting of farm, channel
Turbidity	n/a		Run-off, eutrophic waters	Prevent erosion, by-pass water channels, settle water. Treatments for algae
Dissolved Gases	high	Degas water by expo-sure to air, aeration	n/a	
Organic Matter	n/a		Swampy area, trash, waste	Screen major inlets, settlement pond prior to entry, clean inlet channel
Wild Fish	n/a		Various aquatic animals and plants	Screen inlets, keep inlet channels clear
Pollution	rare	Site selection, check water profile at source	May occur	Site selection
Toxic Metals	May occur	Avoid such sites	May occur	Avoid such sites. If due to environmental or industry accidents, put in place mitigations measures and monitoring.

5.4.2 Water Quality Management in Earthen Ponds

The interaction of factors that influence water quality dynamics in earthen ponds are illustrated in figure 51.

Figure 51: Factors that affect water quality dynamics in ponds



5.4.2.1 Liming Ponds

Ponds are limed to neutralise the acidity of pond soils and water in order to:

(i) improve or permit the survival of the farmed fish,

(ii) permit normal reproduction and growth,

(iii) Improve response to fertilisation in acidic or low alkalinity ponds.

Liming is beneficial when pond pH is less than 6 or total alkalinity is less than 20 mg/l. The commonest locally available materials for liming are:

- Agricultural lime (calcium carbonate),
- Hydrated lime (commonly known as builders' lime),
- Quick lime (calcium oxide, burnt lime or whitewash).

NOTE: Calcium oxide and calcium hydroxide cause the pH to rise rapidly above 10. pH 10 and above is toxic for fish and other aquatic organisms. Fortunately, because they are less stable, the pH also falls back down in a few days. **Calcium oxide and calcium hydroxide are therefore recommended as disinfectants in aquaculture**.

Agricultural lime is preferred for managing soil and water pH levels. It provides a better ***buffering capacity*** because it contains carbonate. Consequently, pH changes are not as drastic and fluctuate between 7 and 8. Additional benefits of using agricultural lime in ponds include:

- ***Increased soil pH***. This in turn results in the increased availability of phosphorus in the water column which improves phytoplankton production.
- ***Increased alkalinity and hardness of water***.
- ***Flocculate's suspended soil particles*** which helps reduce clay turbidity.
- Inc***reased buffering capacity of water.*** Therefore, less pH fluctuations in ponds.
- ***Increased availability of carbon in the water column for photosynthesis.***

When used in combination with fertilisation, improvements in water quality and production are realised.

NOTE: If ponds are **not acidic**, liming will not be beneficial.

a. Recommended Liming Rates

The pond's lime requirement determines how much lime to apply.

For new ponds, soil samples to the laboratory to establish the lime requirement.

During production, acidity levels of water can be deduced by the pond's response to fertilisation and fish behaviour. Use litmus paper, pH meter or water quality test kit to assess the level of acidity and estimate lime requirement. About 150 – 200 kg/ha agricultural lime may be adequate.

b. Application of Lime to Ponds

- Lime before fertilisation to obtain maximum benefits from the fertiliser
- In empty ponds, spread the lime uniformly over the pond bottom (figure 52).
- Ponds might require liming during production. This is more likely to happen where ponds are made from permeable acid soils with high seepage rates. In such case mix the lime with water and then sprinkle over the pond.

Figure 52: Application of lime before filling the pond water

5.4.2.2 Fertilisation

The major objective of fertilising tilapia ponds is to improve water quality for production by encouraging natural pond ***productivity to enhance*** phytoplankton production. The materials used to fertilise ponds, are sources of nitrogen and phosphorus which promote the growth of plants. The same fertilisers used in crop production are also used to fertilise ponds.

a. Types of Fertilizers, their Advantages and Disadvantages

The commonly available fertilisers for pond production are:

1. Organic Fertilisers – Animal manures and grasses
2. Chemical fertilisers

1. Organic Fertilisers

Sources of organic fertilisers include:

i) Poultry droppings
ii) Cow dung
iii) Pig manure
iv) Goat and sheep droppings
v) Rabbit droppings
vi) Green manure (grasses and leaves)

2. Inorganic Fertilisers

Inorganic fertilisers contain nitrogen, phosphorus and potassium either alone or in combination. The commonly available inorganic fertilisers on the local market are for:

(i) Phosphorus sources – Di-ammonium Phosphate (D.A.P.) and Triple Super Phosphate (T.S.P.).

(ii) Nitrogen sources - urea

Inorganic fertiliser is available in either a granular or liquid form. Table 24 provides a comparison between pros and cons of organic and chemical fertilisers.

Table 24: Comparison between Organic and Chemical Fertilisers

Organic Fertilisers	Chemical Fertilisers (eg. DAP, TSP, Urea, MAP)
• Contains trace minerals and vitamins	• Contains only what the label says plus filler
• Uses oxygen to decompose	• Does not use oxygen when dissolving
• Is highly variable in composition depending on feeds given and bedding used	• Varies little in composition from what is indicated on the label
• Can help reduce turbidity due to clay silt in the ponds	• Does not reduce turbidity
• Can help reduce seepage in ponds	• Does not act on seepage
• Some of the ingredients can be directly consumed by fish • Animal manures may contain unwanted substances such as antibiotics	• Is not directly consumed by the fish

ATTENTION!! Do not use Nitrogen-containing fertilisers in a reservoir whose main function is drinking water for people.

b. Fertilisation Rates

When fertilising ponds, the aim is to ensure adequate levels of dissolved nitrogen and phosphorus in the water column to support phytoplankton production without adversely affecting DO levels. The recommended fertilisation rates to sustain adequate phytoplankton blooms in tilapia ponds are 16 kg/ha/week of nitrogen and 5 kg/ha/week of phosphorus (table 25).

Table 25: Guidelines for Fertilising Tilapia Production Ponds

Type/Combination of Fertiliser	Amounts to Use*	Comments
Organic Manure's		
Poultry Droppings	3 kg/m²/week	The actual quantities of organic manure to apply will vary depending on whether it is fresh or dried for reasons mentions above (i.e. organic loading and nutrient content
Poultry litter + urea	3 kg/m²/week + urea 0.6 g/m²/week	
Cow dung	10 kg/m²/week	
Composts	Variable	
Plant Meals		

Cotton seed meal/cake Sunflower seed meal/cake	Usually 25 to 50 kg/ha	Plant meals are also used primarily as a feed in the more extensive aquaculture systems (see section 5.5.1.)
Inorganic Fertilisers		
Urea + TSP	3.5 g urea/m^2/week and 2.5 g TSP/m^2/week	
Urea + DAP	3.5 g urea/m^2/week and 2.0 g DAP/m^2/week	
Urea only	3 g urea/m^2/week i.e. 300 g/100m^2/week (about 30 tablespoonfuls).	
DAP	2 g/m^2/week i.e. 200g per 100m^2 per week, or 15 tablespoonfuls weekly for every 100m^2	

*****The specific amount of fertiliser required is practically influenced a lot by specific pond and management characteristics. Hence, every farmer should adjust quantities to obtain optimum levels of fertility.

Other things to note when fertilising ponds:

- The amount of phytoplankton production hence photosynthesis, depends on the proportion of the total water surface area exposed to sunshine. Fertilisation rates are therefore expressed as kg/ha/week or kg/m2/week.
- To avoid DO falls after fertilisation, apply small amounts of manure frequently rather than large amounts infrequently.
- Tilapia continuously grazing off the phytoplankton in ponds. Optimal plankton density should be monitored and maintained during production (table 26).
- It is preferable to purchase single-nutrient fertilizers rather than compound fertilizers containing all the three main nutrients for plant growth. This is because there may be moments when one may only need to add nitrogen only or phosphorus only depending on soil and water quality variables to maintain optimum phytoplankton bloom. If all that is available is a compound fertilizer, purchase the one that contains a higher level of phosphorus (P) because in most cases, phosphorus is the limiting nutrient in fish ponds.

f. Managing Pond Fertility Levels

Tilapia production in ponds is more productive when the 'green water' technique is used. Phytoplankton alone can provide a significant amount of nutrition for young tilapia up to about 100 - 150 g. Avoid having too much or too little phytoplankton production (table 26)

Table 26: Challenges with too little or too much pond fertility

Too Low	Too High
• Inadequate phytoplankton for fish to graze	• Excessive phytoplankton production. Uneaten phytoplankton dies off and settles to bottom of pond. Increased organic matter
• Low DO	• Greater likelihood of anoxia during night and early morning

Too Low	Too High
• Clearer pond water making it easier for birds to prey upon fish	• Extreme diurnal pH fluctuations
• Growth of aquatic weeds because sun rays penetrate deeper	• Light cannot penetrate far in such ponds
	• More stressful to fish and fish kills become more likely
	• Ponds with too high fertility are difficult to manage. Avoid this situation

Measuring Pond Fertility

The most practical way of measuring levels of turbidity in ponds is with a simple tool called a ***secchi disc*** (figure 53). When used and interpreted in combination with the colour of water in the ponds', one is better able to decide whether to add more fertilizer to the pond (figure 54 and table 27). The secchi disc, should be used taking into account the colour of the water to make management decisions as described in table 27.

How to Use a Secchi Disc with the Reference Water Color Chart and Interpret the Results

Figure 53. The Secchi Disc

A secchi disc can easily be made 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 as shown. In the centre, drill a small hole and pass a string or piece of wood through. Graduate the piece of string or wood in cm.

- Taking Secchi Readings

Step 1. Take secchi readings during the day at about mid-day when there is no shadow. If this is not possible, take readings at about the same time every day.

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 (figure 55).

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 becomes visible. Measure this depth.

Step 5. Get the average of these two readings. This will give you the secchi depth.

Step 6. Look at the reference colour chart in annex 5 to assess what sort of turbidity you have (whether phytoplankton or clay)

Figure 54: How to take Secchi Readings

Table 27: Management Requirements for Maintaining Phytoplankton Blooms at Different Secchi Readings.

SECCHI DISC READING (cm)	COMMENTS
Less than 20 cm	Pond too turbid. If pond is turbid with phytoplankton, there will be problems with low dissolved oxygen concentrations especially at night. When the turbidity is from suspended solids (eg. clay), productivity will be low. Do not add more fertiliser. If there is a foul smell, flush the pond.
20 – 30 cm	Turbidity is good for tilapia production. Do not add more fertiliser if turbidity is less than 25 cm. Levels of fertilisation during production should be to maintain this level with the prescribed level of fertilisation.
30 – 45 cm	If turbidity is from phytoplankton (greenish water), then the pond is in good condition, but tilapia growth will improve if more plankton can be produced so continue the weekly applications.
45 – 60 cm	Phytoplankton is becoming scarce. Add more fertiliser your pond to get a better bloom. If you do not get a bloom then probably check your pH and alkalinity. Also make sure your pond is not leaking and that it is not being "flushed".
More than 60 cm	Water is too clear. Inadequate productivity and danger of aquatic weed problems. If there are aquatic weed growing in the pond, do not add more fertiliser. Weed them out first before fertilising the pond.

g. *Application of Fertilisers*

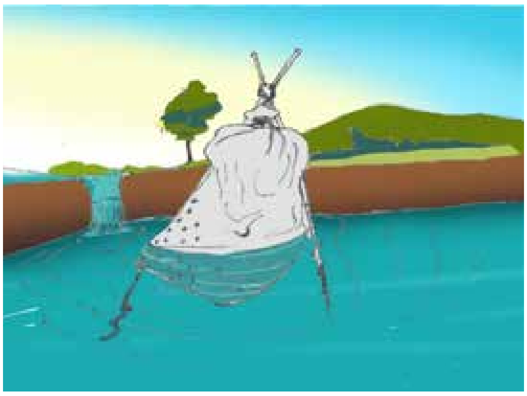
Methods of Applying Organic Manure

(i) **Crib Method** – A compost crib is made of wooden poles at one or more sides of the pond. Nutrients from the compost are slowly released into the pond. In so doing, the pond gradually becomes fertilised. Cribs require frequent turning to facilitate the release of nutrients. A crib should be about 10% of the total pond area. Considering the management requirements of a crib, they are more appropriate for smaller ponds.

(ii) **Bag Method** – A porous bag is filled with manure and tied in the corner of the pond. The bag is shaken and turned weekly or daily to allow the nutrients within, seep out.

(iii) **Directly into the pond** – Manure may be spread directly into the pond. When ponds already have water, it is better to mix the dung with some water first, then sprinkle the mixture around the pond (figure 55).

Figure 55: Application of Organic Manures in Ponds



Bag Method	*Spreading manure direclty into pond*

- Methods of applying chemical fertilisers

  (i) **Granular Fertilisers** – When broadcasted over, the pond, granular fertilisers settle on the pond bottom first, before dissolving into the water. Phosphate in the fertiliser is strongly adsorbed (binds) by pond mud. When this happens, much of the phosphate never enters the water column. Therefore, it is better to dissolve the fertiliser first in water, to prevent it settling to the pond bottom. Sprinkle the mixture over the pond.

  Granular fertilisers can also be applied by heaping on under water platform or placing them in a porous bag on underwater platforms or suspended on pole near the pond inlet or from the end of the pond where the prevailing wind blows. The water currents slowly wash the fertiliser into the pond.

  The platforms or bags should not sit directly on the pond's bottom. This is because the phosphate will be rapidly adsorbed by the bottom soil and become unavailable for the phytoplankton. The use of bags and platforms to apply fertiliser is more practical in large ponds.

  (ii) **Liquid fertilisers** should also be diluted first with water before application into the pond. When still concentrated, liquid fertilisers are heavier than water and if poured directly, will settle at the bottom. Dissolve the fertiliser in a bucket of water by stirring first, and then splash the solution at different points around the pond.

  It is better to apply fertilizers mid-morning when dissolved oxygen levels are picking up to allow enough hours of sunshine to obtain maximum benefits from sunshine.

h. Other Important Points to Note on Fertilisation

1. **If you are fertilising your pond to enhance fish production, use the *'static water'* technique.** Do not allow water to continuously flow through your pond otherwise pond fertility and plankton are lost. Only top up water to replace evaporation and/or seepage or when there is a need to flush the pond.
2. **Do Not Fertilise your Pond if;**
   a. Just before harvesting and/or sampling fish in the pond.
   b. If the pond is very muddy. When muddy ponds are fertilised, one gets a euglena bloom that forms on the water surface rather than a blue-green phytoplankton bloom uniformly distributed within the water column. The general response to fertilisation is also poor.
   c. If there are macrophytes (large plants) growing in the pond since only macrophytes grow. Nile tilapia cannot consume these macrophytes.

d. If you notice the fish piping in the ponds late into the morning for a number of consecutive days. This is an indication that levels of dissolved oxygen are dropping to almost zero during the night. Adding more manure in this case, increases the demand for oxygen as more organic matter is put into the pond. In addition, increasing the amount of phytoplankton will only serve to worsen the situation at night when the phytoplankton ***respires***.
e. If your secchi disc reading is less than 25 cm. This is a sign that turbidity levels are high. If the pond water is brown, then the pond is muddy. If on the other hand the pond is green, then the fertility levels of the pond are too high.
f. If your pond water has a bad smell. This is a sign of a nutrient overload. You would have to ***'flush'*** the pond instead.
g. Do not fertilise ponds on a rainy days. There is no need to fertilise ponds on rainy cloudy days because the rain shall dilute the fertiliser and there will be inadequate sunshine for photosynthesis.

3. Trust your Observations

Do not rely entirely on numbers. When deciding whether to add more fertiliser to the pond or how much you should add each time, observe the water colour, water turbidity, take note of the smell and fish behaviour. If the fish show signs of stress (or abnormal behaviour), the pond smells bad or the turbidity levels are too high **do not add more fertiliser**.

5.4.3 Control of Key Water Quality Parameters in the Different Production Systems

Table 28: Managing Common Water Quality Issues in the Different Production Systems

Water Quality Parameter	Earthen Ponds	Flow Through Tanks and Raceways	Cages	Re-Circulatory Systems	Aquaponics
Low DO	• Improve pond fertility if too low • Flush pond/do not add fertiliser if secchi reading lower than recommended. • Reduce stocking densities • Reduce feeding • Aerate at night when DO levels are consistently low • Don't' continuous flow water through in ponds under static green -water management • Pond design and maintenance: Free-board height should not be too high, control siltation and avoid shallow ponds.	• Aeration and oxygenation • Do not overfeed • Remove excess feed and waste • Maintain optimum water exchange rates and water volume • Reduce stocking densities • Daily monitoring of DO in production units; after feeding	• Site selection – avoid sites with a lot of silt, close to a lot of vegetation, points of effluent discharge from land and highly eutrophic sites • Optimum stocking rates • Cage alignment with respect to currents, mesh sizes and distance between cages inconsideration of effective water exchange through cages • Regular monitoring of DO in consideration of seasonal and diurnal changes	• Aeration and oxygenation • Do not overfeed • Remove excess feed and waste • Maintain optimum water exchange rates and water volume • Reduce stocking densities • Daily monitoring of DO in production units; after feeding • •	• Aerate water • Do not overfeed • Remove excess feed and waste • Maintain optimum water exchange rates and water volume • Reduce stocking densities • Daily monitoring of DO in production units; after feeding •
Low temperature	• Not much can be done due to seasonal or weather • In high altitude areas green-housing depending on cost-effectiveness	• Not much can be done due to seasonal or weather • In high altitude areas green-housing depending on cost-effectiveness	• Not much can be done due to seasonal or weather	• Not much can be done due to seasonal or weather • Heat water to units • Green-housing	• Not much can be done due to seasonal or weather

Water Quality Parameter	Earthen Ponds	Flow Through Tanks and Raceways	Cages	Re-Circulatory Systems	Aquaponics
Low Alkalinity/ hardness	• Lime ponds with $CaCO_3$ (agricultural lime)	• Dose inlet water with $CaCO_3$ (agricultural lime)	• Avoid such sites	• Dose inlet water with $CaCO_3$ (agricultural lime)	• Dose inlet water with $CaCO_3$ (agricultural lime)
Too high pH	• Control pond fertility where associated with extreme diurnal changes • Lime ponds with $CaCO_3$ (agricultural lime) to improve pond buffering capacity • Flush ponds with higher than normal fertility (low secchi readings)	• Daily remove excess feed and waste from tanks • Adjust water exchange rates • Adjust feeding regimes • Aeration or oxygenation	• Not much can be done if due to seasonal variations in diurnal cycles • If consistent, change sites	• Daily remove excess feed and waste from tanks • Adjust water exchange rates • Adjust feeding regimes • Aeration or oxygenation	• Daily remove excess feed and waste from tanks • Adjust water exchange rates • Adjust feeding regimes • Aeration or oxygenation
Low pH	• Likely to be at towards early morning. Control levels of pond fertility • Check alkalinity and hardness. If low, lime pond.	• Daily remove excess feed and waste from tanks • Check alkalinity and hardness. • Adjust water exchange rates • Adjust feeding regimes • Aeration or oxygenation	• Site selection – avoid sites with a lot of silt, close to a lot of vegetation, points of effluent discharge from land • Not much can be done if due to seasonal variations in diurnal cycles • If consistent, change sites	• Control levels of CO_2 build up in system e.g. by degasing • Daily remove excess feed and waste from tanks	• Control levels of CO_2 build up in system e.g. by degasing • Daily remove excess feed and waste from tanks
Ammonia	• Flush ponds • Adjust feeding regimes and techniques • Reduce stocking rates	• Adjust water exchange rates • Adjust feeding regimes and techniques • Reduce stocking rates	• Check sediment quality. • Relocate cages	• Check functioning of biofilter • Adjust water exchange rates	• Check functioning of biofilter • Adjust water exchange rates • Adjust feeding regimes and techniques

Water Quality Parameter	Earthen Ponds	Flow Through Tanks and Raceways	Cages	Re-Circulatory Systems	Aquaponics
	• remove uneaten feed and organic matter accumulated at pond bottom	• Clean tanks and removed uneaten feed and other organic matter • Feed highly digestible feeds with high water stability. Floating pellets preferred.		• Adjust feeding regimes and techniques • Reduce stocking rates • Clean tanks and removed uneaten feed and other organic matter • Feed highly digestible feeds with high water stability. Floating pellets preferred.	• Reduce stocking rates • Clean tanks and removed uneaten feed and other organic matter • Feed highly digestible feeds with high water stability. Floating pellets preferred.
High Turbidity	**Clay turbidity** • Follow recommended pond design and construction criteria • Prevent runoff and erosion • Avoid shallow ponds because of wading birds • Fertilise with organic manure to enhance colloid binding capacity where construction soil was of high clay content **Plankton** • Reduce fertilisation rates • Flush ponds	If clay turbidity due to runoff at water source: • prevent runoff entering water source and control erosion around water source If due to suspended feed/ waste in water: • adjust flow rates and water exchange • clean tanks after feeding (siphon out uneaten feed and waste) • control feeding and adjust feeding techniques	• site selection • May be due to seasonal variation • if consistent, change site, particularly if cause is inorganic or related to activities on land in farms proximity.	• Check that settlement tanks and filters for suspended solids are working well • adjust flow rates and water exchange • clean tanks after feeding (siphon out uneaten feed and waste) • control feeding and adjust feeding techniques	• Check that settlement tanks and filters for suspended solids and plant tanks are working well • Adjust flow rates and water exchange in system. • Siphon out uneaten feed and waste from tanks • control feeding and adjust feeding techniques

Water Quality Parameter	Earthen Ponds	Flow Through Tanks and Raceways	Cages	Re-Circulatory Systems	Aquaponics
Organic Matter	• Remove excess organic matter • Control feeding	• Siphon out uneaten feed and waste daily • Adjust water exchange rates to effectively flush out waste.	• Site selection avoiding areas with high organic matter • Alignment of cages with respect to currents to wash away accumulated wastes at bottom • Move farm site after so many years	• Siphon out uneaten feed and waste daily • Adjust water exchange rates to effectively flush out waste • Check that settlement tanks and filters for suspended solids are working well •	• Siphon out uneaten feed and waste daily • Adjust water exchange rates to effectively flush out waste
Wild Fish and predators	• Screen inlets • Prevent entry into farm • Free-board height should not be too high and ponds should not be too shallow.	• Prevent entry into farm	• Prevent entry into farm	• Prevent entry into farm	• Prevent entry into farm

5.5 Methods for Monitoring Water Quality Parameter

There is an assortment of equipment to measure water quality parameters ranging from electronic meters, test strips, thermometers and field water analysis kits. Most are multipurpose. Electronic meters require calibration to give accurate and reliable results. Have this demonstrated to you by the supplier.

Figure 56: Water Quality Tools and Equipment

Meters			Conductivity meters *measure the electrical conductivity and give an indication of the level of mineralisaiton of the water, pollution. Used in intensive aquacuture.* Salinity meter Turbidity meter
	Oxygen meter	***pH meter***	***Other meters used in aquaculture***
Test strips			
	Multi-purpose		Single parameter test strip - pH
Test kits			Measures: • *Ammonia Nitrogen: 0.2-3.0 mg/l* • *Nitrite: 0.05-0.8 mg/l* • *pH: 5.0-10.0* • *Alkalinity: 0-200 mg/l* • *Carbon Dioxide: 0-50 mg/l* • *Chloride: 0-200 mg/l* • *Dissolved: Oxygen 0-10 mg/l* • *Hardness: 0-200 mg/l* • *Temperature: -5 to 45°C*
	Single parameter	***Multi-purpose field aquaculture test kit***	
Turbidity/ transparency		Turdity meters meausure cloudiness/ transparency caused by suspended solids	
	Secchi disc		
Temperature		Most of the various water quality meters can measure temperature	
	Thermometer		

ee) Collecting and sending water quality samples to a laboratory

Not everyone is able to have the necessary equipment to assess water quality parameters. In addition, sometimes extra parameters need be measured for example when:

- Establishing a new farm,
- There are fish health challenges on-farm such as sudden fish kills
- Adopting new production systems, equipment and management practices.
- Undertaking comprehensive routine annual or bi-annual sampling to determine if the water quality needs to be adjusted.

In such situations water samples can be collected and taken to the nearest laboratory.

When collecting water samples:

- Obtain a clean 0.5 litre sample bottle (in the field one may use a new unopened mineral water bottle. Empty out the mineral water). Otherwise clean bottles can be obtained from laboratories
- Label the bottle with sites information
- Obtain samples from water column where there is no debris, mud, algae in surface film. Be careful not to stir up sediments of accumulated debris from bottom of tanks
- Prior to collecting sample, rinse the bottle three times with the water you shall take to the laboratory (by filling bottle ¼ full, close cap then pour out – not back into same spot)
- Submerge bottle about 30 cm from water surface (depends on depth of water column) to draw water for sample.
- Water samples should be kept cool, preferably on ice and out of the sun, and submitted to the laboratory as soon as possible. If possible, reduce delays during shipping and avoid submitting samples at times
- When they will reach the laboratory on a holiday or weekend, as the concentrations of the variables may change over time in unpreserved water samples.

5.6 Water Treatment

Treatments may be added to water, to improve quality in extreme cases, particularly during live transportation during which the possibilities for water exchange are minimal.

<table>
<tr><td>Alum</td><td rowspan="2">Alum is used to reduce turbidity from clay particles suspended in water.

Alum is acid forming and can substantially reduce total alkalinity and pH. This makes alum unsuitable for use in ponds with low total alkalinity as it may lower pH to points where it is toxic to fish. Alum also reduces phosphorus in water.

Therefore, use of alum may necessitate;
• Liming if pH drops too low
• Fertilization to increase levels of dissolved phosphorus.</td></tr>
<tr><td></td></tr>
</table>

Zeolite 	**Zeolite** is an effective means of reduces levels of ammonia dissolved in water. It is recommended for use in transportation tanks when undertaking long distance live fish haulage. Zeolite may be recharged several times by overnight immersion in a salt solution or oven drying. Zeolite is not effective in salt water.
Rock Salt (Magadi) 	**Rock salt** is used to manage water quality in live fish transport containers. Since it is a balanced salt, it helps buffer the water. It also helps control the build-up of nitrite levels in the transportation tanks. Consequently, fish stress is reduced.
Salt 	**Salt** is one the easiest and cheapest forms of medication available for freshwater fish. Salt (sodium chloride or NaCl) is safe for most species of fish. It can also be used in live fish transportation if one has no rock salt.

MODULE SIX:

FISH FEEDING AND NUTRITION

The objective of feeding fish is to provide them with the nutritional requirements for good health, optimum growth, optimum yield and minimum waste within reasonable cost so as to optimize profits. Every farmer should be particular about the quality of feed fed because it determines the:

(i) Nutrient loading and carrying capacity of the production unit.

(ii) Growth rate of the fish.

(iii) Economic viability of the enterprise. 60-70% of operational costs are normally due to feed

(iv) Health status of the fish.

(v) Quality of the flesh at harvest. The feed influences taste, texture, colour and residue levels in the flesh.

This module gives recommendations on nutrition, feeds and feeding.

6.1. What are the Attributes of a Good Fish Feed?

A good feed should:

- Be nutritious with no un desirous substances;
- Have an attractive smell and taste for the fish;
- Be of the right particle size that can be easily ingested by the fish;

- Have low or no negative impacts on water quality.
- Be able to maintain its form in water without breaking apart until it has been ingested by the fish (i.e. water stable);
- Not be mouldy or have any contaminants; and
- As much as possible, nutrients should not leech out of the feed into the water.

6.2 Nutritional of Requirements of Fish

The nutritional requirements for fish refer to the minimum amounts of energy, protein, fat, minerals and vitamins fish need for maintenance, growth, reproduction and health. Nutritional requirements vary between species, age, size and reproductive state of fish. Table 29 below lists the basic nutrition requirements for the commonly farmed species. The ability of fish to utilise nutrients in the feed depends on the digestibility of the feed.

Table 29: Nutritional Requirements for Farmed Fish

Nutrient	Uses	Desired Levels in Diet		
		Tilapia	African Catfish	Mirror Carp
Protein	• Provides the proper ratio of amino acids • Necessary for the building muscle, connective tissue, blood, enzymes, hormones, etc.	28-30% depending on pond fertility	32%	28 – 35%
Dietary Energy	• Not a nutrient but required to drive chemical reactions for tissue maintenance, growth and activity	8.5-10 Kcal/g protein	8.5 – 9.5 Kcal/g protein	8.9 Kcal/g protein
Fats	• Major source of energy for fish. • Means by which fat soluble nutrients like some vitamins (e.g., A and D) can be absorbed by the body • Hormones, some sub-cellular components as well as structural elements of the cells. • Flesh texture and flavour • Feed flavour, taste, attractant	0.5 %	4 – 6% (increase as protein level increases)	5%
Carbohydrates	• Minor source of energy in fish. Fish do not digest carbohydrates well enough for them to be their major source of energy from feed. • Major use in fish feeds is as binder or filler.	25-35%	20 – 35%	30 – 40%
Fibre	• Not really a nutrient. Fish hardly require it and do not derive much benefit from high levels of fibre in diet. Excess fibre will increase pollution of the pond.	< 2%	<4%	<3-7%

Nutrient	Uses	Desired Levels in Diet		
		Tilapia	African Catfish	Mirror Carp
Minerals and Vitamins	• Wide variety of functions • Structural component of hard and soft tissues • Co-factors and/or activators of enzymes • Osmo-regulators and acid-base balance • Production of membrane potentials	Phosphorus- 1.0 4.5 to 6 g/kg diet Calcium – 7.0 g/kg diet Vitamin C – 500 mg/kg diet	Vit C – 50 ppm	Phosphorus 6 g/kg diet Calcium 0.3 – 3 g/kg diet

6.3 Type of Fish Feeds

There are three types of feed:

- Natural food
- Supplementary feeds
- Complete feeds

6.3.1 Natural food

Natural foods comprise aquatic plants and animals that fish in the wild eat. They include zooplankton, benthos, phytoplankton, detritus, bacteria, plankton, worms, insects, snails, macrophytes, amphibians (frogs) and fish. Their abundance in fish production systems depends on the water's productivity (see **Module Five**).

The nutritional content of natural foods is highly variable. It depends on the biochemical composition, size, digestibility, production of toxic compounds and the culture conditions of the natural foodstuff. Pure cultures of selected zooplankton are farmed for feeding larvae and fry in hatcheries as ***'live feeds'*** (see **Section 6.6.2.**).

6.3.2 Supplementary feeds

Supplementary feeding is done to compensate for the nutritional deficits from feeding natural foods that arise as fish grow larger in fertilized ponds. They are given to supplement the inadequate energy and protein levels of natural foods to sustain fish growth. When this is done, the culture system is referred to as a semi-intensive culture system.

Supplementary feeding may be done with one or a mixture of ingredients. The ingredients most used for supplementary feeding include farm-residues, household waste and agricultural by-products such as cereal brans, oil seed cakes and slaughter-house waste. These are fed as dry powders, pellets or moist dough. Sometimes nutritionally complete diets are given as supplementary feeds.

6.3.3 Nutritionally complete diets

Factory-made nutritionally complete diets contain all the necessary nutrients for optimum growth and health. They are available as sinking or floating feeds in the form of powders, crumbles, pellets or flakes (figure 57).

Figure 57: Forms of Commercial Feeds

Powders *Crumbles* *Pellets* *Flakes*

A good commercially manufactured feed particle should have a uniform texture and size with no fines and a water stability of at least thirty minutes.

Table 30 compares the above-mentioned feed types.

Table 30: Advantages and Disadvantages of the Major Types of Feed

Feed Type	Advantages	Disadvantages
Natural Food	• Environmentally friendly • No energy required to make them • Contain most nutritional requirements especially for early life stages • Easy to digest • cheaper	• Limited in energy • Difficult to generate adequate amounts to meet nutritional needs of growers in most commercial units.
Supplementary Feeds	• Can be made on-farm using ordinary farm implements and/or simple equipment • Easy to make • Utilise local waste products • Dry supplementary feeds last longer than	• Higher risk of fouling • Higher FCRs hence more feed is required to produce a kilo of fish. • Not recommended for use in tanks, cages and intensive culture systems
Complete Diets (pellets)	• Better digestibility and water stability than supplementary feeds. • Floating pellets have lower FCRs than sinking pellets because starch and anti-nutritional factors are completely broken down during the steam extrusion process. • When floating feeds are used: - Can see the fish feeding - Can see how much feed is left over • Can be used in all production systems	• Require skilled labour, machinery and energy to make • More expensive • May not be suitable for feeding larvae soon after hatching in some species

6.3.4 Selecting the right feed

Table 31 lists the factors to be considered when selecting a feed.

Table 31: Factors to Consider when Selecting Fish Feeds

Factor	Reason
1. Species	• Fish may be carnivores, omnivores, herbivores and limnivores. • The nutritional requirements and ability to digest certain feedstuffs consequently varies. • For examples carnivorous fish have more acidic guts with a larger stomach whereas herbivorous fish have more alkaline guts with long intestines.
2. Life stage of the Fish	• There are four key life stages: egg, larvae, juvenile and adult. • The ability to ingest, digest and fully utilise certain feeds and/or nutrients differs with each life stage. • Breeding fish need extra nutrition for gamete production
3. Fish size (weight)	• The amount of food that can be consumed at each meal varies with fish size and size of the stomach. • Fish with large stomachs can hold more food in their stomachs and so eat less frequently • Juveniles (smaller fish) have higher metabolic rates so digest feed faster and need more frequent meals.
4. Production unit and culture system	• Complete diets are more suitable to intensive systems • Natural foods and supplementary feeds are more suited to ponds and semi-intensive systems • Larvae can be fed live feeds in tanks.
5. Cost	• The feed should be affordable for the production system in use (more details in Section 6.4.5.).
6. Availability of the feed	• The feed should be easily available. Fish find sudden changes in feed stressful.

6.4 Feeding fish

To get the best results from feeding, feed:

- The right nutritional quality for the specified age of fish,
- The right size of feed for easy consumption,
- The correct amounts at each meal,
- The right number of meals per day.

The above constitute the feeding regime. Feeding charts provide a guide for this (Appendix 3).

When fish are fed correctly, growth rates are good and uniform across the population, feed conversion ratios (FCRs) are low and pond water quality is better managed.

6.4.1 Establishing the correct feeding regime

Fish can be allowed to eat any time until they are satisfied (i.e. ***fed ad lib to satiation***) or only at specific times. The choice on whether to feed *ad lib* or at specific times depends on the fish age, feeding strategy and production objectives. Juveniles in fed live feeds in both extensive and intensive systems are typically fed ***ad lib.***

When fish are fed at intervals, feeding charts are a useful tool to help guide on the how much to feed and when. However, depending on their appetite fish will not always eat the amounts indicated in the feeding chart.

The appetite of fish is influenced by:

- Feed type
- Characteristics of the feed
- Water quality at the time of feeding.
- Stress and health status of the fish
- Fish behaviour (see table 32).

Table 32: Factors that affect fish appetite

Factors	Eat less	Eat more
Characteristics of the feed	• Sudden changes in feed formulation, taste or texture • Wrong pellet size even when nutritional content and formulation remain the same	• Consistency in the quality, texture and taste of feed given • Given the correct type and pellet size of feed for each respective stage
Water Quality	• When water temperatures drop (e.g. during rainy season) • If feeding is done when DO and pH are low, ammonia is high and dissolved gases in water • Sudden and/or frequent fluctuations in water quality (e.g. when rain wash-off enters units). This is stressful for fish, especially juveniles	• Water quality conditions are optimum in the production unit • Water temperature rise within acceptable limits
Stress and health status	• Up to two to three days after being exposed to stressful management practices such as grading and sampling • Sudden sharp noises and movements that scare the fish (e.g. attacks by predators, diving birds) • Disease	• Not stressed • Not sick
Fish behaviour	• Territorial behaviour and bullying by larger fish • Inconsistent feeding	• Uniform access to the feed • When fish are uniformly sized

6.4.2 When should I feed?

Table 33 below summarises when it is best to feed fish.

Table 33: When to Feed

When to Feed	When not to Feed
• **In ponds and other outdoor units:** When water temperatures and DO levels have begun to rise. Normally from *about 10.00a.m. with the last feed being at about 4.00 pm.*	• Feeding response is poor • The fish are sick • Low temperature • Two days before harvest and transportation • Afternoon before sampling • High levels of soil and plankton turbidity • A lot of left-over feed in unit • Darkened cage nets • Pond bottoms showing signs accumulation of left-over feeds (such as bubbles) in feeding areas. • The meal after applying treatments to pond or treating fish
• **Indoor units:** Where water temperature and aeration are done, timing can be set by manager	• Feeding response is poor; • The fish are sick • Two days before harvest and transportation • Afternoon before sampling • Low DO levels • A lot of left-over feed in unit • The meal after applying treatments to tank or treating fish

6.4.3 Determining the ration

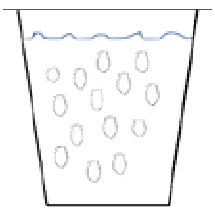
The ***ration*** is how much feed/food each fish should be given per day and at each meal.

6.4.3.1 Estimating the ration and measuring amount to feed

(i) **Pond productivity** - in extensive and semi-intensive systems where fish forage off zooplankton and phytoplankton production, secchi readings and colour of water give an indication of plankton availability (see **Module 5** for more details).

(ii) **Natural foods** – The availability of live feeds is measured in terms of number of organisms/litres. Counting can be done with the aid of a glass or petri-dish with known volumes of water as illustrated in figure 58 below.

Figure 58: Estimating the quantity of Live Feed



glass	***Petri-dish***

(iii) **Dry Feed** – Weigh out the total daily requirement and distribute the total daily amount between the total number of meals to be fed per day as illustrated in appendix 4.

Measuring out the Quantities to Feed

It is important to know how much feed is consumed so that one can estimate FCRs. However, a weighing scale may not be available at each farm to measure out the amount of feed to be fed each day.

In such situations, different sized containers can be calibrated to establish ***weight-volume*** equivalent (figure 59 below). The calibration must be done for each different type and pellet size of the feed farm because they have different densities.

Figure 59: Graduated bucket.

6.4.3.2 Adjusting the ration

Rations should be adjusted regularly in consideration of the factors listed in table 34 below:

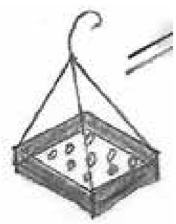
Table 34: When to adjust the Ration

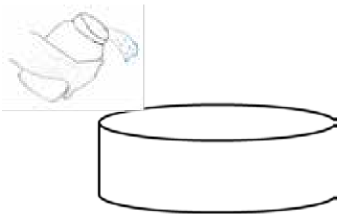
Factor	Remarks
a. Size of the Fish	• Small fish have a higher metabolic rate and so grow faster • Adjust their rations every 7 to 14 days.
b. Growth rate	• Sample units regularly to determine average size of fish. • Determine new ration based on the average size at sampling and NOT based the weeks in production as would be indicated by feeding charts (Annex 5)
c. Environmental conditions and feeding response	• Fish do not eat the same amount every day or at each meal • The amount consumed each day depends on the water quality on that day, whether the fish are stressed or sick. • Low temperature, low DO, high PH, high ammonia, stress and sickness reduce appetite
d. Carrying capacity	• When production units are at carrying capacity reduce the amount of feed. • At carrying capacity feed for body maintenance to prevent loss of weight. • DO NOT feed for growth because no matter how much additional feed is given, there will be no increase in growth (see Module 5 for more details) • Grow out fish maintenance rations range 0.5 to 1% of body weight • If at least 30% of fish in the unit are due for harvest within a couple of days, stop feeding until after harvesting.

6.4.4 How should I administer feed to fish?

The different methods of feeding fish are summarised in Table 35 below.

Table 35: Fish Feeding Methods.

1. **Broadcasting.** Feed is broadcast into the production unit manually or with a blower in large ponds. Used when feeding floating or sinking powders, crumbles or pellet.s	
2. **Demand Feeders.** Hung over production unit. Release feed when the fish hit them. Used for feeding floating or sinking crumbles and pellets • Disadvantage: Fish sometimes play with the feeders which results into feed being released but not eaten.	 
3. **Feeding Ring.** Used in hapas to feed juveniles floating feeds**.** The ring prevents the feed floating away and larvae and early fry cannot swim to the feed as fast as older fish.	
4. **Automatic Feeders.** Are designed with in-built timing belt. Feed is released into the production unit continuously over a given duration of time, normally six of twelve hours. Used for sinking or floating crumbles or pellets.	
5. **Trays.** Are used to feed wet meals such as cooked doughs or mashed/fresh ground sinking by-products (e.g. trash fish, offals).	

7. **Platforms.** Are used to feed wet meals such as cooked doughs or mashed/fresh ground sinking by-products (e.g. trash fish, offals).	
8. **Pouring.** Live feeds in suspension are poured into the production unit.	

- The choice of feeding method depends on:
  a. Feeding habit of the species;
  b. Age of fish;
  c. Size of the production unit;
  d. Number of times per day the fish will need to be fed;
  e. Type of feed to be fed;
  f. Labour requirements and costs of feeding; and
  g. Cost of feeder.

  The best FCRs are obtained when the fish:
  a. Rapidly eat up the feed.
  b. Spend little energy feeding because the feed is easy to get to and of the right size.
  c. Have equal access to the feed.

To achieve this, train the fish to feed by response.

6.3.4.2 Feeding by Response

Once the fish are above the early rearing stage, train them to feed by response. This has the following advantages:

- Enables one feed the fish based on their actual needs at each meal thus minimising overfeeding or underfeeding;
- Enables one visually monitor the fish numbers and growth rates without handling them (figure 60 below); and
- Enables one detect when fish have lost ***appetite***. Problems and remedial measures can therefore be identified early.

Figure 60: A Good Feeding Response. All fish come to feed at the same time

DO NOT OVER-FEED fish as it results into feed wastage, deterioration of water quality and subsequently poor growth. Overfeeding reduces your profit margin. Under-feeding results in poor growth and production. The optimum ration is obtained when fish are fed just below satiation.

a. ***Assessing the feeding response***

It is ***extremely important*** to establish exactly how much to feed to feed the fish at each meal and each day. To do this, assess the following:

1. How fast the fish move towards the feed and how their feeding behaviour compares with that of previous feedings?
2. Whether or not the fish are interested in the feed?
3. The colour and smell of the water prior to feeding?
4. Proportion of fish in the unit that come to feed?
5. What the weather was a few days before, and on that day ***(especially for outdoor units)***? Was it raining, cold or hot?
6. In tanks, the water quality parameters just prior to feeding and an hour or two after.

Spend time to observe the fish feed every day. Relying entirely on calculations from feeding charts or books frequently results into wastage, high FCRs and poorer water quality.

Feeding based on calculations only, is ***'dumping' the*** feed, **not** feeding the fish.

b. ***Criteria for judging the feeding response***

E – Excellent – Fish are very active and come to feed immediately. They finish all the feed given within 5 to 10 minutes.

G – Good – Fish are less active. They complete feeding within 15 to 20 minutes.

F – Fair – Fish are sluggish and consume about three quarters of the feed over more than 30 minutes.

P – Poor – When feed is given, fish do not come to feed. More than three quarters of the feed given is not eaten.

NOTE: The above criteria are subjective. Always observe and make decisions based on fish's actual feeding behaviour. Therefore, it is strongly recommended that the same person should feed the fish each day. In addition, the person who feeds the fish should be the one who keeps the daily feeding records.

c. ***How to train fish to feed by response***

Fish are trained to come up to the surface to feed as follows:

(i) Administer the feed at the **same place in the pond and at about the same time every day.** This gets the fish into the habit of being in a certain area of the unit at feeding time. If the fish do not come to the area to feed initially, do not add any more feed until they learn to come to the assigned feeding area. It may take up to a week to train fish to come and feed from the same area and learn their feeding times. Do not worry if in the meantime they do not eat much. Fry and fingerlings in fertilised ponds will take longer to feed by response because they eat plankton available in ponds. To get the fish learn to come to the same feeding spot, make a sound. For example, by stumping the edge of the pond each time before feeding them.

(ii) When most of the fish have come to the feeding area, then broadcast a handful or a plate full of the feed. If the fish come out to feed and immediately consume the feed, add another scoopful until the fish's response starts falling and they stop eating more. Weigh any leftover feed and keep it for the next meal.

Do not trickle in feed in small bits while feeding

When one trains fish to feed by response, one is deliberately creating competition for food. The fish soon realise that if they do not come to feed at mealtimes, then they will not have food until the next mealtime. The fish therefore actively compete to get to the feed at mealtimes and eat as much as they can, as fast as they can. Because all the fish eat at the same time, growth rates become more uniform and FCRs consequently improve.

6.4.5 Evaluating the Feed Performance

The ***Feed Conversion Ratio*** (FCR) is the amount of food required to produce a unit weight of fish (see equation 1 below). It is an indicator of the:

(i) Performance of a feed,

(ii) Efficiency of the response to feeding, and

(iii) Cost-effectiveness of using the feed.

$$FCR = \frac{\text{total amount of food given (kg)}}{\text{total amount of fish produced (kg)}} \qquad \textbf{Equation 1}$$

Box 1. How to Calculate FCR and use FCR to Assess Returns to Feed

i) If at the end of a production cycle, a total of 140 kg of fish are harvested from a pond and a total of 200 kg of feed was fed to the fish during production, how much feed was required (used) to produce each kilogram of fish harvested? The total number of fish stocked weighed a kilo. Half a kilogram of fish was stocked.

The FCR will be:

$$= \frac{\text{200 kg (total amount of feed fed during production)}}{\text{140 kg – 0.5 kg (increase in fish weight during production)}}$$

= 1.4

This means a total of **1.4 kg** of feed was used to produce each kilogram of fish from stocking.

ii) If each kilogram of feed cost USh.500/=, how much did it cost to produce 1 kg of fish?

= Amount of feed required to produce 1 kg of fish (FCR) x Unit Cost of feed (USh.)

= 1.4 kg X USh. 2,000/=

= USh. 2,800/=

USh. 2,800/= was spent to feed each kg of fish produced.

Poor FCR's are obtained when:

i) Poor quality feed is fed. Examples of poor-quality feeds include those do not meet the nutritional needs of the fish, poor physical attributes, are mouldy, rancid or contaminated.

ii) The wrong size and feed type is fed to the fish.

iii) The culture conditions are stressful.

iv) Fish are ***'over-fed'.***

v) Survival rates at harvest are low.

vi) One continues feeding for growth when the production unit is at carrying capacity.

b. ***Assessing the Cost-Effectiveness of a Feed***

The FCR and unit cost of the feed should be considered simultaneously and not independently of each other. Using the cheapest feed available, does not always result into the lowest feeding cost per kilogram of fish produced (Table 36 below).

Table 36: Assessing the Cost-Effectiveness of a Feed

	Maize bran	Farm mixed fish feed[a]	Complete diet/pellets
Unit Cost of feed/kg	400/=	515/=	4,000/=
FCR of the feed	9	5	1.8
Amount of feed required to produce 1 kg of fish	9 kg	5 kg	1.8 kg
Total Cost (USh.) of feed used to produce a kilo of fish	= 9 kg bran x USh. 400/= **= 3,600/=**	5 kg feed x USh. 600/= **= 2,575/=**	= 1.8 kg pellets x USh. 4,000/= **= 7,200/=**

Note: [a]*Farmer's feed mixture – 60% maize bran, 15% fish meal, 15% sunflower cake and 10% cassava flour.*

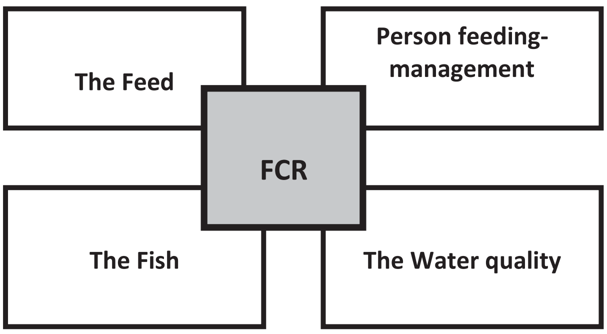
The lower the FCR, the less amount of feed required to produce a kilogram of fish. Therefore, the feed which gives the lowest FCR, even though it might be more costly, is often the one with the lowest production cost.

c. ***Managing FCRs***

To make profits, the FCR must be within an economic range. This is because feed normally constitutes about 70% of operational costs. Any drop in the FCR, results into increased profit margins.

The feed given, the fish themselves, pond water quality and management of feeding influence FCRs (figure 61). These factors determine the fish's appetite. A lapse in any of the four factors at any one time, will cause FCRs to rise.

Figure 61: Factors that Influence the FCR



Therefore:

1. **The person feeding** is the most important person on the farm. He or she must be in position to:
   a. Train fish to feed based on response.
   b. Keep track of and evaluate fish feeding response as well as performance through actual observation as well as keeping of records (i.e., with both quantitative and qualitative information).
   c. Keep track of fish numbers and sizes in the various production units during production.

d. Deduce correctly from the pond and feeding records and the fish's feeding behaviour, what the next course of action should be ***(e.g. what type of feed to give, how much feed to give, whether or not to adjust or withhold feeding, how best to administer the feed, what pond/water management details need adjusting, etc.)***.

If the person feeding cannot do this, then it is not worth spending money on commercial feeds as you will end up losing money instead.

2. **The feed**
   a. **Quality** (both physical and nutritional).
   b. **Quantity.** It is important that the right amounts are fed.

3. **The fish**
   a. **The species being raised.** For example, tilapia fingerlings will perform better than catfish fingerlings in an earthen pond receiving only fertiliser as an input.
   b. **The size of fish.** Fry require a higher protein level in their feed as well as a smaller feed pellet compared to adult fish.
   c. **Quality of seed stocked.** Was the fish stressed at stocking? Was it of the correct stocking size for the unit and intention for which it is being raised?

4. **The water quality within the production pond**, notably;
   a. The water temperature,
   b. Levels of oxygen,
   c. Levels of ammonia, pH and other pollutants in water,
   d. Pond fertility levels. Having adequate amounts of plankton in the pond reduces the demand for feed in juvenile tilapia.

6.5 Transport and storage of feedstuffs

The quality of a feed begins to deteriorate steadily soon after it has been made. The rate and magnitude of decline can significantly be slowed, through proper handling during transportation and storage. The following are recommended guidelines for handling and storing dry pelleted fish feed from the time of purchase.

a) Dry Feeds

- Check the labels and buy the freshest feed in the store. Feed utilized within 4 weeks of manufacture, often meets the nutritional and physical standards stated on the label.
- Purchase only the quantity of feed that will be consumed within 4 to 6 weeks. The longer the feed is in storage, the lower its nutritional quality over time.
- During transportation and handling, protect the feed from moisture, heat and direct sunlight. Heat and sunlight directly destroy feed nutrients like vitamins.
- Store the feed in a cool, shaded, dry and well-ventilated room. White, wooden buildings with reflective metal roofs are excellent for storing feed. Warm, moist and stagnant air enhances mould growth and attracts insects.
- Protect the feed from rodents, bats, chickens and other animals because they consume the feed and contaminate it with their urine, faces and dirty feet. Feed can be stored in cages made of coffee wire mesh to keep off such animals (figure 62).
- Do not stack bags of feed directly against a wall or on a concrete floor. Stack them on top of

pallets off the walls of the building, to prevent moisture coming into contact with the bags. Otherwise feed will go mouldy.

- Minimize insect contact and infestation.
- Do not use pesticides or other toxic materials near the feeds.
- Do not keep feed that is mouldy or spoilt. Signs of spoilage include changes in colour, smell, taste, appearance and texture.
- Inventory should be used on a first-in first-out basis.
- Human theft and indirect damage to feed stores may also increase other control problems.

NOTE: If you are feeding during the rain and the feed gets wet, feed all that wet feed that day. Do not store wet feed or feed it to the fish the following or another day.

Figure 62. Feed Storage. Left – *Bags on feed stored in a cage off the wall and on pallets.*

b) Moist and Live Feeds

- Keep in refrigerated

6.6 Making Feeds On-Farm

The following are among the main considerations when making feeds on-farm:

- Nutritional quality, supply, cost and availability of each of the ingredients
- Levels of anti-nutritional factors in ingredients (this sets the maximum inclusion rate in the diets)
- Processing requirements of the ingredients to make them suitable for feed making
- Life stage of the fish
- Costs and returns from making and using the feed

6.6.1 Formulated Feeds

6.6.1.1 Ingredients

The major ingredients used are:

a. Proteins

Fishmeal generally is the best source of protein and essential amino acids. However, it is expensive. It can partially be replaced by animal by-products, oilseed meals and cakes, legumes, cereal by-products and aquatic plants because they do not supply all the essential amino acids.

d. Sources of energy

Cereals and grains provide a major source of energy. However, fish do not digest cereals and grains well because plants are made thick cell wall, complex carbohydrate molecules and have high fibre. They must be cooked to improve their palatability and digestibility for fish.

e. Fats

Oil seed cakes are the commonest source of fat for on-farm feeds. Fish oil is expensive. Controlling the oxidation of fats and oils is often a challenge where diets require high levels of fat.

f. Additives

Additives are optional. They are added in small amounts as recommended by manufacturer to improve the nutritional profile, palatability, water stability, and shelf-life of the feed. Medications on prescription can be dispensed through the feeds.

Examples of additives:

- **Mineral and vitamin premixes –** normally purchased from veterinary pharmaceutical outlets. There are water stable formulations for aquatic feeds.
- **Binders –** help ingredients bind into pellet. Examples wheat gluten, cassava flour, wheat flour, calcium lignosulphate, polymethylcarbamide.
- **Anti-fungal agents –** mycotoxin binders, mould inhibitor
- **Preservatives -** propionic acid, Poly N-vinylbutylrolactam and sodium monmorillonite, butylated hydroxytoluene.
- **Treatments –** sex reversal hormones, prescribed antibiotics, immunostimulants, growth promoters.
- **Anti-oxidants** – Butylated hydroxyanisole (BHA), Butylated hydroxytoluene (BHT), ethoxyquin
- **Attractants –** citric acid, lactic acid

Appendix 5 gives examples of formulations for on-farm fish feeds.

6.6.1.2 Preparing the feed

a) Selecting and Estimating amount of Ingredients to Use

When mixing the feed ingredients together, it is important to ensure that they are:

- **Dry ingredients do not exceed the recommended moisture content** – nutritional profiles and mixture rate are given on a dry matter basis
- **Free from moulds** – prevent poor growth and possible disease from mycotoxins
- **Finely ground** – to ensure equal distribution of ingredients within the feed
- Contain no contaminants or undesirable materials such as sand, stones, chemicals
- **Each ingredient is prepared as recommended** e.g. roasting of legumes to destroy anti nutritional factors prior to grinding and mixing in the feed.
- Do not exceed the maximum requirement for feed ingredients with recommended limits

The quantities of each ingredient to mix can be done using:

a. The 'Pearson's square' square for feed with two or more ingredients
b. Least cost formulation for several ingredients excel spreadsheets.

See appendix 6 for an example on how to use the Pearson's square to formulate feeds.

c) Mixing the Ingredients

After calculating the quantities of ingredients to use, measure out the ingredients. If premixes are to be added, do so following the recommendations of the manufacture.

During mixing of dry ingredients, make sure all the ingredients are uniformly mixed. Deepening on the quantity being mixed, one may use a spade or various feed mixers.

The mixture may thereafter be cooked and fed as dough or pelleted. Doughs fed immediately. Pellets should be dried after use.

6.6.2.3 Other important things to note

- Keep and record of the feeds with batch number of the feeds you make and use in the event of any eventuality with the feed mixture
- Use the feeds you finish first
- If the pellets are to be sold, they must have a label, cooled and properly dried before packaging. Pack in clean bags and label each batch with the respective batch number.
- Store are recommended in 6.4 above.

6.6.2 Live feeds

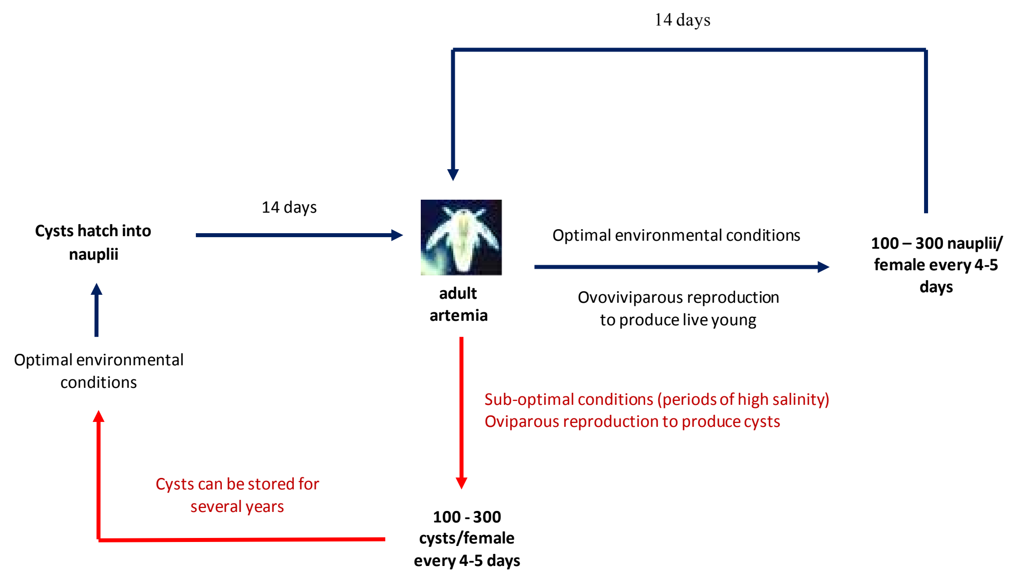
Zooplankton and other living aquatic organisms are raised to feed fish larvae. They provide a source of easily digestible high-quality protein in the form of a motile sizeable singe cell for the larvae.

The ability of fish larvae to see and swim a long distance in search of feed is low. They are attracted to feed more by movement of particles. Live feeds remain suspended within the water column and are motile which makes feeding for the larvae easier.

6.6.2.1 Artemia (Brine Shrimp)

Artemia are crustaceans, that live in salt lakes. Artemia reproduce either live young or cysts depending on the conditions within their natural environment. When growing conditions are unfavourable in their natural environments, they form cysts that hatch into nauplii when conditions become favourable. The nauplii are a good source of live feed for fish larvae.

Figure 63: Life Cycle of Artemia



The cysts are harvested and marketed as artemia cysts (figure 64). The cysts are decysted or hatched in hatcheries for larval feed.

Figure 64: Artemia packaged for sale

- Up to 40% protein
- High quality easily digestible protein.
- Live motile high-quality food
- Can be stored for several years without deterioration in quality
- Easy to decyst
- Materials for decysting available locally

Disadvantage

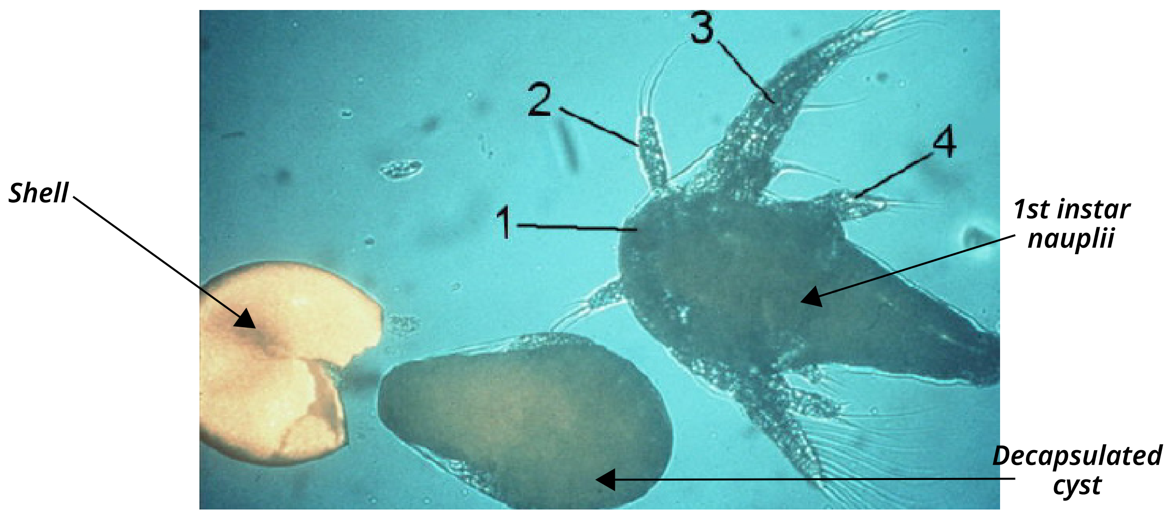
- Not yet locally produced
- Expensive
- Once decysted, do not last in fresh water for more than 3 hours

Preparing artemia cysts for feeding

Step 1: Decapsulation (decysting)

The shell of the cyst is too hard for fish larvae to digest. It should be removed prior whether the larvae are to be fed decysted cysts or hatched nauplii (figure 65).

Figure 65: The Artemia Shell, Cyst and Nauplii



Ingredients for Decapsulation

- 500 g artemia cysts
- 4.8 litres sodium hypochlorite (household jik)
- 75 g sodium hydroxide
- 2.2. litres of cold water

Cyst colour: brown gray or orange

Rinse in freshwater

Neutralise with 0.1. Hydrochloric acid and/or sodium thiosulphate

Step 2: ***Hatching of artemia***

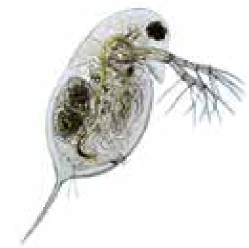
1. Add 250 ml of water to a zoug jar or inverted conical container or large mineral water bottles.
2. Add 3 teaspoons of dehydrated artemia cysts to the 250 ml water.
3. Bubble air through the mixture for 1 hour.
4. Add 150 ml JIK (sodium hypochlorite) for 5 min. Continue bubbling air through the mixture.
5. Wash several times with water. Use a piece of fine polyester cloth as a filter. The artemia is collected in the cloth.
6. Wash in vinegar for 10 minutes.
7. Wash several times with water (till there is no smell of vinegar).

6.6.2.2 Cladocerans.

a) Moina

Moina favour a parothgenetic environment (figure 66). They produce a new brood every other day of up to 40 larvae/brood

Figure 66: *Moina* sp.



Production of Moina in Outdoor Tanks

Requirements

- Concrete or plastic tank or tube
- Cover like black shade cloth for the tank
- Organic fertilisers (such as manures, agricultural by-products such as straw or yeasts)

- Fill the tank to a depth of half a meter with water
- Cover the tank at least a third of the tank to allow only diffuse light. No direct sunlight
- Fertilise the water with fertiliser
- Inoculate about 24 moina/litre of water about 24 hours after fertilising water

Recommended Growing Conditions

- Water temperature – 24 to 31oC
- Non-polluted water
- Gentle aeration
- pH neutral
- low ammonia

b. Daphnia

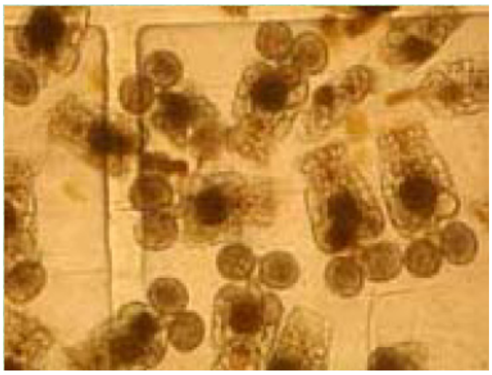
Figure 67: Daphnia

Production outdoors

- Tanks
- Initial fertilization, 1.5 kg/m3 water fresh cow-dung (any animal manure can be used. Preferable because of the straw in the manure)
- Wait 24 hrs for bacterial growth
- Seed at 8 Daphnia/litre

6.6.2.3 Rotifers

Figure 68: Rotifers



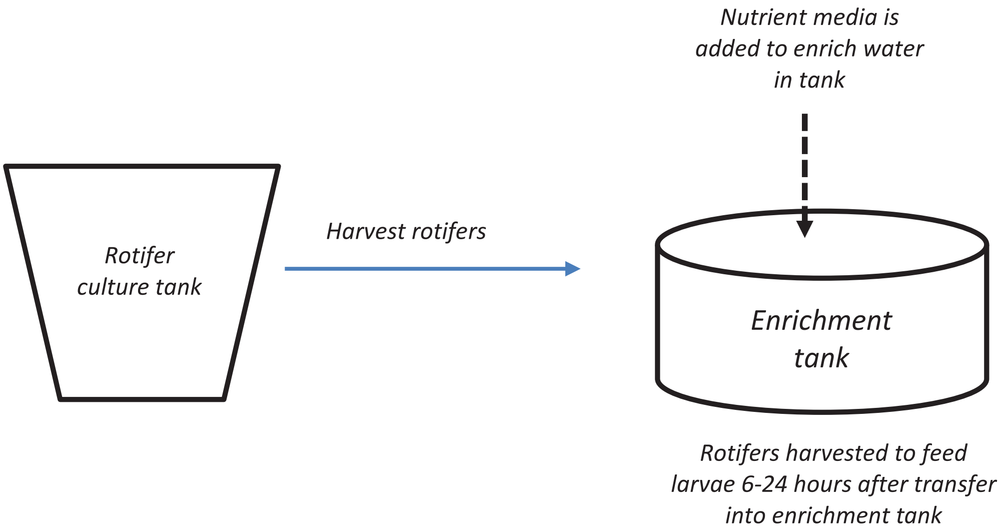
Brachionus rotifers production:

- Female life span 6-8 days, males 2 days at 25°C
- First reproduce 18 hr post-hatch 20-25 offspring/life cycle.
- Algae or Yeast given as food

g. Enrichment of live feeds

Just before feed, live feeds can be placed in nutrient rich media just before feed (figure 69). Normally these would contain extra Vitamin C and linoleic acid to improve larval survival and growth.

Figure 69: Enriching Live Feeds



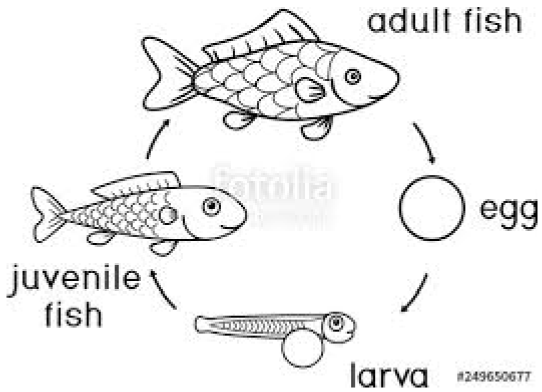
MODULE SEVEN:

PRODUCTION MANAGEMENT PRACTICES

7.1 INTRODUCTION

Production management practices comprise the different set of activities one does to transform the input into a product. In aquaculture production management practices are based on the meeting the needs of the fish at the different phases of its production cycle (figure 70).

Figure 70: Fish Life Cycle



Hence:

a) Hatchery Management –

The objective is to produce live high-quality gametes from parent fish (broodstock) to produce juvenile fish for stocking grow-out units.

The major management activities undertaken in fish hatchery management are:

- Broodstock management for gamete production
- Gamete collection (spawning and milt collection)
- Fertilization of eggs
- Egg Incubation
- Hatching
- Larval rearing
- Fry production
- Fingerlings

b) Grow-out Management

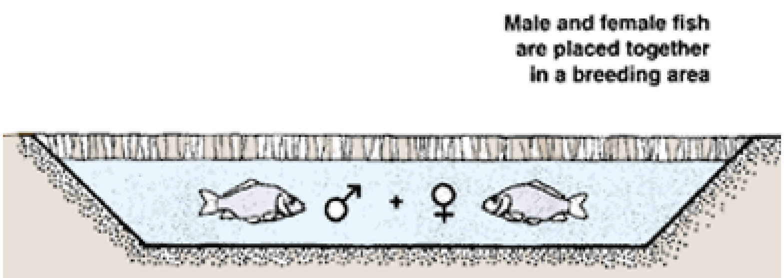
The objective is to rear fish for table. It covers the juveniles to adult stage of the fish's life cycle.

7.2 Hatchery Management

There are three basic methods for propagating fish to produce fry:

a) Natural Propagation - Males and females are placed together in a small pond or tank where females spawn naturally (figure 71).

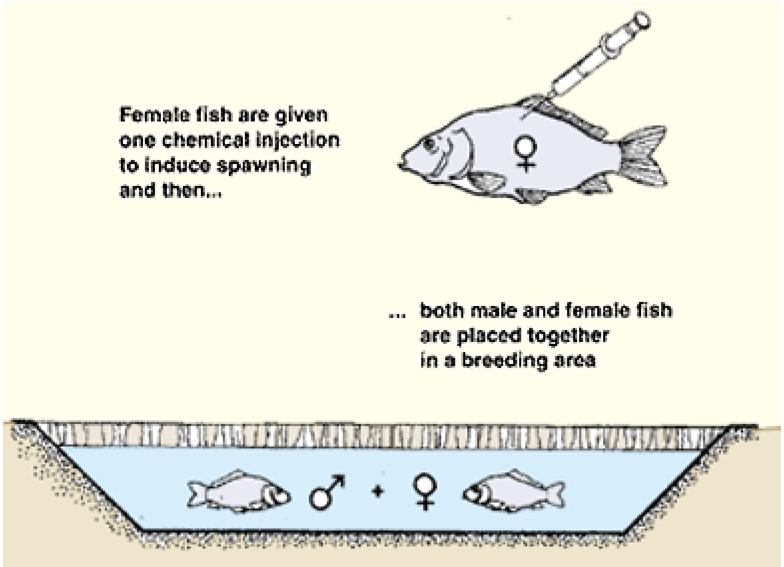
Figure 71: Natural Propagation



The successful breeding of some species such as African catfish and mirror carp often require some manipulation to mimic the environmental changes that trigger spawning in nature such as *(i)* sudden increase in water volume *(ii)* providing substrate for egg attachment or nesting.

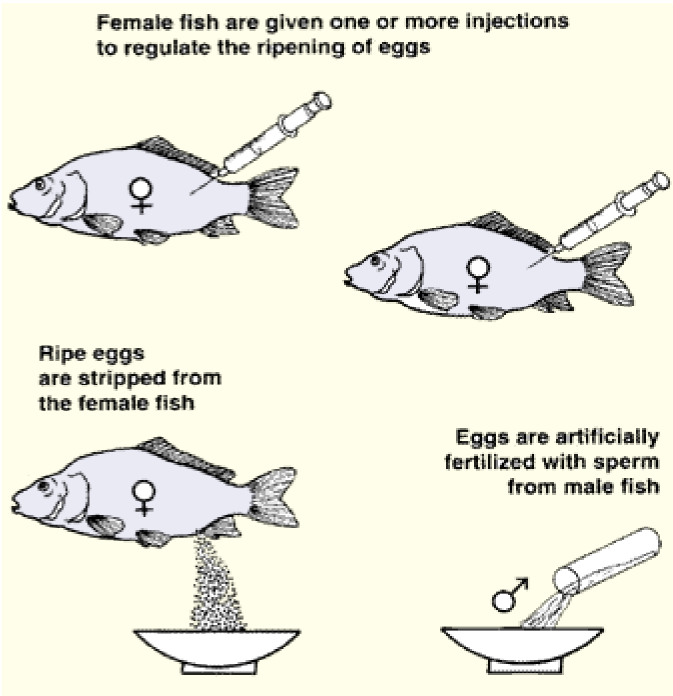
b) Semi-Natural Propagation – The female is induced to spawn using artificial gonadotropins or pituitary extracts after which the male and females are placed in the same unit to propagate as described in *(a)* above. Figure 72 below.

Figure 72: Semi-Natural Propagation



c) Artificial propagation - The females are given artificial hormones or pituitary extract trigger both the maturation and release of eggs. Once the eggs are ripe for spawning, the female is manually aided to release her eggs; a process known as stripping. Gametes from the males (milt) are also extracted manually. The eggs are fertilised by directly squirting the collected milt over the eggs (figure 73).

Figure 73: Artificial Propagation of Fish



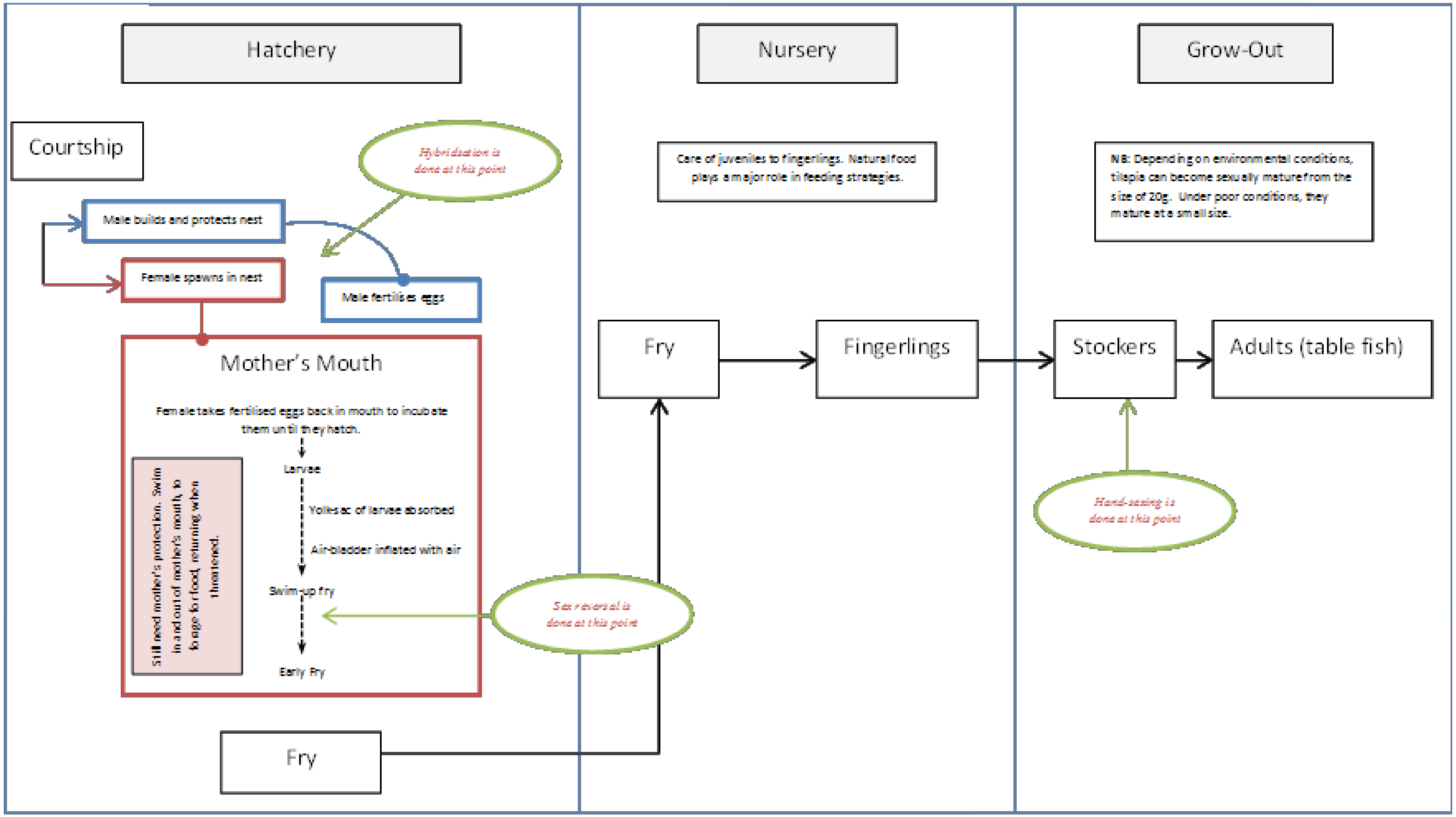
7.2.1 Tilapia Hatchery Management

Table 37 and figure 74 list and illustrate the major steps in tilapia seed production.

Table 37: Description of Stages in Tilapia Production

Production Stage	Description	Product	Location/Kind of Farm
Phase 0	Hatching	Fry	Hatchery
Phase 1	Sex Reversal in Hapas – 28 days	Monosex (All male) fry	Hatchery
Phase 2	First Nursery (SR to 1 g)	Fry	Hatchery
Phase 3	Second Nursery 1 g to 10 g	Fingerlings	Hatchery or nursery
Phase 4	Stocker 10 g to 100 g	Stockers (hand-sexing)	Grow-out farm
Phase 5	Table Size 100 g to 500 g	Table Fish	Grow-out farm

Figure 74: Tilapia Seed Production



7.2.1.1 Broodstock Management

Key Objectives	It is preferable to maintain pure high quality stock on the farm as this affects the quantity and quality of offspring. Managing one's own broodstock puts the hatchery operator in a better position to ascertain pre-spawning condition. The condition of the broodstock determines egg quality, hatchability, larval growth and survival.
Pond Preparation	1. Ponds should meet standards for commercial earthen ponds. 2. Screen to ensure that no wild fish or eggs can enter pond at any time during the cycle. 3. Eradicate all other fish or aquatic life in ponds before stocking with builders lime. 4. Lime and fertilise to have green water in ponds. Ponds can be fertilised with artificial fertilisers. 5. Fill ponds
Stocking	1. Only stock **genetically pure stock**. Under local practical conditions this is often limited to stocking fish with typical physical characteristics of Oreochromis niloticus. 2. Only stock fish from a **known source**, i.e. either the wild, a known breeding station. If you collect fish from the wild initially (or regularly) rear you own stock on the farm in grow-out ponds. This is more reliable, reduces incidence of disease, the negative effects of wild stock populations and of continuously harvesting ripe fish from the wild. 3. **Never ever** obtain stock from another pond/farm where fish are of mixed sizes within the unit, no screening is done and there are no records or history of the source of fish. 4. Stock males and females in separate ponds. 5. **Size to stock:** Select fish of about 300 g or more as broodstock. Fish that are too small will be less fecund, less efficient at egg incubation and fry protection. Stock fish of uniform size. 6. **Age of Fish:** Do not stock fish that have spawned several times before because fecundity decreases with maternal age and successive spawning. Likewise, males should not be too old. Regularly replace males with year old fish. 7. **Physical Condition:** Fish should have no physical deformities, injury or signs of disease. 8. **Stocking Rate:** 5,000 to 10,000 kg/ha (5 to 10 fish per m^2)
Pond Management	1. Manage ponds as static green-water managing fertility levels at a secchi reading of 30-45 cm. 2. Ensure ponds are below carrying capacity. As much as possible ensure that early morning dissolved levels of oxygen do not fall below 3 mg/l. When levels drop below this regularly drop below this ovarian growth becomes affected. 3. Screens must always be attached to inlet and outlet. Ensure screens are not clogged and in good condition. Any inflowing water must be continuously filtered through a fine mesh.
Feeding	1. High quality diet of 35-45% protein level. A diet rich in protein is important as this influences the quality of egg yolk hence embryonic and early larval nutrition. 2. Feed twice a day at 1% body weight per day.
Harvesting and Handling for Spawning	1. Do not feed fish the meal before harvest. 2. Harvest preferably with a seine with a bag. 2. Ensure fish are always in good quality water. 3. Select the fish for spawning and transfer to prepared spawning pond.

nests

7.2.1.2 Spawning, Fertilisation, Egg Incubation and Hatching

Natural and artificial propagation can be done.

(i) In ponds mimicking the natural reproduction process.

c) Natural Propagation in Ponds

Key Objectives	Provide an environment in which fish can spawn efficiently with no contamination of the offspring. While tilapia can spawn in any pond; pond size, shape and depth affect harvest efficiency and seed production.
Pond Preparation	1. Ponds should meet standards for commercial earthen ponds. Harvest basin is important. Line harvest basin with 2 cm mesh nylon netting before filling in order to help remove broodstock at drainage. 2. Screen to ensure that no wild fish or eggs can enter pond at any time during the cycle. 3. Eradicate all other fish or aquatic life in ponds before stocking with builders' lime. 4. Lime and fertilise to have green water in ponds. 5. Fill ponds
Stocking	1. Stock both males and females in the same pond. 2. Select fish from broodstock pond that are in good condition, have good gametes. 3. **Stocking Rate:** 2 fish/ m^2. 4. **Stocking Ratio:** A ratio between 1 male:1 female to 1 male:3 females. Generally there should be more females than males.
Feeding	1. **Feeding options:** In green water, do not add feed to spawning ponds. Feed fish after spawning 2. If one opts to feed, feed diet of 45% protein level at rate of 20-50% of satiation. If feeding a 35% diet may feed at rate of 2% body weight per day. Remember, females do not feed while brooding. 3. Feed restriction reduces growth rates but increases spawning frequency, total number of eggs over a given period as under such conditions, the female's body opts to allocate energy to egg production. When fish are fed to satiation in spawning ponds, somatic (i.e. body size) growth is favoured over egg production.
Pond Management	1. Static green-water management with optimum levels of pond fertility (30-45 cm secchi reading). 2. Ensure early morning dissolved oxygen levels do not drop below 3 mg/l. When levels drop as low as 0.5 mg/l there is a negative impacts on ovarian growth, courtship, seed production and quality as well as the ability of tilapia females to mouth-brood eggs and fry. Low dissolved oxygen reduced feed intake and stress to broodstock, larvae and fry. 3. Water temperatures in pond should be about 25-30 ^{o}C, hence the recommendation for static water management. 4. Control predators, e.g. birds, Frogs egg masses should be removed. 5. Keep screens on inlet and outlet fixed and in good condition.
Harvesting	1. First seine with a 2 cm mesh seine to remove broodstock. This reduces stress to young fry being caught in with broodstock. 2. **For Sex Reversed Fry:** Harvest fry within 3 weeks of stocking spawning pond if one intends to sex reverse fry. Grade and to sort out fry greater 14 mm. Stock fry less than 14 mm for treatment in hapas. Larger fish discarded. 3. **Mixed Sex Fry:** Harvest after 4 weeks. Grade and stock fish of uniform sizes in selected nursery ponds. **NB:** At all times, ensure fish are handled as recommended and are always in good quality water.

Figure 75: Draining and Harvesting a Spawning Pond.

d) Artificial Propagation of Tilapia

In tilapia,

- Collect ripe eggs from the female's mouth into a dry basin.
- Gently press the abdomen of the male to express the milt over the eggs
- Gently mix the mixture for about a minute
- Rinse out with water and add water to the basin and pour mixture into McDonald jars.
- Ensure upwelling movement of water during incubation. Water should be well aerated and temperature kept constant between preferably 25 to 28oC
- Hatched larvae will float and flow into basins at the side
- Stock these in larvae tanks or hapas (figure 76).

Figure 76: Tilapia Egg collection and l Incubation

(a) Hapas for Female Broodstock.
Finer netting lines the side of the hapa females are harvested from to prevent eggs held in the mouth being lost.

(b) Eggs within Mouth of a Female Brooder.
Ripe eggs look geenish with a black do.

(c) Incubating fertilized tilapia eggs in McDonald Jars

(d) Method for harvesting female brooders and early fry from hapas.

Larval rearing to fry

- 5-10 fry/litre. Cannibalism.
- Continuous grading in fry units because of cannibalism
- Feeding rate 30-45% 65% body weight.
- Red/blue diets better for visibility

7.2.1.3 Production of Single Sex Tilapia

After larval rearing, the decision on whether to produce single sex (all-male) or mixed sex fish must be made. There are two methods for producing all-male fish:

(a) Hormonal sex reversal

(b) Hand-sexing.

All-male culture is preferred in tilapia farming because the males grow faster and to avoid reproduction in grow-out ponds stocked with both male and female fish.

Figure 77: Options for Tilapia Seed Production

Production Phase	Description	Monosex Tilapia		Mixed Sex and Hand-Sexed Tilapia
		Sex Reversed Tilapia		
Phase 0	Broodstock selected and stocked in spawning pond/ hapa, spawned eggs are fertilised by male, egg incubation, hatching and rearing of yolk-sac larvae to swim-up fry. Grading of eggs and swim-up fry.	Broodstock stocked in ponds. Swim –up fry harvested from spawning pond and graded before stocking into another unit.	Broodstock stocked in hapas. Fertilised eggs collected from females, graded based on stage of embryo development and incubated in appropriate jars. Eggs at the same stage of development are placed in the same jar.	All staged done in pond or hapa. Fry harvested slightly older than swim-up fry when they are easier to handle. Harvesting may be done weekly.

Production Phase	Description	Monosex Tilapia		Mixed Sex and Hand-Sexed Tilapia
Phase 1	Swim-up fry fed hormone treated feed for about 28 days in protected production units (hapas or tanks) that prevent contamination with other fishes and ensure that all fish in the unit have access to only the treated feed.	Swim-up fry less than 12 mm stocked in hapa. Stock uniform sizes. Feed treated feed for about 28 days. At harvest fry should be about 0.1 g.	Swim-up fry stocked in hapa or tank. Stock uniform sizes of less than 14 mm. Feed treated feed for about 28 days. At harvest fry should be about 0.1 g.	Swim-up fry not treated
Phase 2	First Nursery. Nursery ponds or hapas where management focuses at early rearing of fry until they are about 1 g each. Primary source of food is natural production. Artificial feed also given, especially when reared in hapa.	Fish reared in nursery pond or hapa till about 1 g each	Fish reared in nursery pond or hapa till about 1 g each.	Swim-up or slightly larger fry.
Phase 3	Second Nursery. Fry reared from 1 g to fingerling size in ponds. Natural pond productivity a major source of nutrition for the fish. High protein artificial feed (35%) may also be given depending on level of management.	Pond rearing. Fish harvested at fingerling size	Pond rearing. Fish harvested at fingerling size	Pond rearing. Fish harvested at fingerling size
Phase 4	Stocker: Fingerlings (from 7-10 g) stocked and reared to 30-100g depending on the objective of the on-grower. 30-50 g fish are suitable for stocking in cages. Larger sized fish for stocking in grow-out ponds. Also part of grow-out system.	This phase optional for hatchery. Depends on farmers' specifications	This phase optional for hatchery. Depends on farmers' specifications	This phase optional for hatchery. **Hand-sexing** done when fish are between 30-50 g depending on grow-out farmers requirements.
Phase 5	Management of fish of fingerling or stockers to table size.	Monosex fish for stocking grow-out in ponds or cages	Monosex fish for stocking grow-out in ponds or cages	Mixed or monosex fish for stocking grow-out in ponds or cages

b) *Hormonal Sex Reversal*

Key Objectives	**Produce all males and prevent contamination of fish with females or other wild fish.**
Pond Preparation and Management	1. Ponds should meet standards for commercial earthen ponds. Harvest basin is important. Line harvest basin with 2 cm mesh nylon netting before filling in order to help remove broodstock at drainage. 2. Screen to ensure that no wild fish or eggs can enter pond at any time during the cycle. 3. Eradicate all other fish or aquatic life in ponds before stocking with builders lime. 4. Lime and fertilise to have green water in ponds. 5. Fill ponds. Stock when pond is green. **Do not stock** any fish in pond set aside as hapa ponds 6. Set in hapa ensuring that nothing enters hapa as it is being placed in pond. Therefore, only use hapas with no holes, hold hapa upright with top opening close tight, then pull outward to fish on 'dead-men' without tilting. 7. Hapa when placed in pond should be at least 15 cm above pond floor, have a water depth of at least 80 cm.
Stocking Hapa	1. **Size:** Stock only graded fry less than 14 mm long (estimated average weight 0.01 g). Fry into each hapa should be of uniform size. 2. **Stocking Rate:** Stock 3,000 to 5,000 fry/m2.
Feeding	1. Feed methyl testosterone treated feed for a period of about 28 days. 2. The feed high quality feed of 45% protein level; pellet size crumbles. 3. Feeding rate four times a day at an initial feeding rate of 20% body weight per day until fish are about 15 mm, then feed 10% body weight per day until end of treatment. 4. Use feeding ring for feeding.
Hapa Management	Clean outside hapa with a soft brush weekly to prevent clogging.
Sampling, grading and Harvesting	1. Sample weekly in order to readjust feeding level. 2. At final harvest, grade fish. Estimate fish weight at harvest 0.25 g 3. Transfer harvested fish to first nursery pond.

e) ***Hand Sexing***

The following physical features are used to hand-sex tilapia:

- Genital papillae (figure 78-b)
- Body size and colour (breeding males have a reddish hue on their tail and abdomen (figure 78-a)

Figure 78: Sex Differentiation of Nile Tilapia

(a) Difference in size between female (above) and male (below) tilapia of the same age

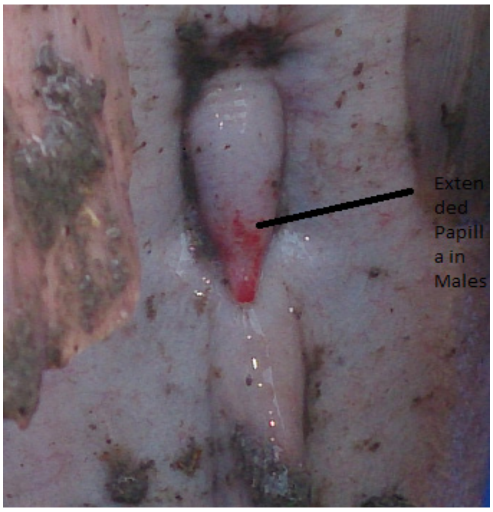
(b) Female (left) and Male (right)

7.2.2 Catfish Hatchery Management

a) Broodstock Management

- Stock males and females separately in broodstock management ponds at the rate of 3 males/ m2 and 4-5 females/m2 (figure 79)
- Stock in small ponds of average pond sizes 500 to 1,500 m2
- Feed a diet of 45% CP
- Average size above 400 g each

Figure 79: Sex differentiation of African Catfish. *Male (left) and Female (right)*



f) Spawning, fertilisation, Incubation and hatching

- Conditioning of Parents
- Gamete collection
- Select females with ripe eggs (eggs look brownish green with a black eye dot). Have a swollen abdomen full of eggs

Figure 80: Selecting Female Catfish for Breeding

Large abdomen in a gravid female (fish on the right)

Checking for readiness of female fish. Ripe eggs will be brownish-green with a black dot

- Anaesthetise them to calm them down and inject with LHRH or with pituitary extract to induce spawning. Dosage is based on weight. Inject into the dorsal muscle See also Appendix 7 for details on how to prepare pituitary extract.
- Hold injected females in a covered tank to keep it dark and prevent females jumping out for about 10 hours. Tank should have flowing water at rate of about 6 litres per minute.
- Check females eggs are ripe – they will be dark green
- Strip eggs into a shallow bowl.
- In catfish, the milt cannot easily be expressed from the males as opposed to tilapia. Cut out the testis in quarter and with a piece of cloth squeeze out the milt over the eggs
- With feather mix milt into eggs then rinse out with water
- Fertilised eggs become sticky once mixed in water. Spread over a screen. Place in hatching tank
- Hatching occurs within 24 to 30 hours at 29-30oC.
- Incubation tanks must be well aerated; good quality water (constant temperature, little iron). (Figure 81)

Figure 81: Artificial Propagation in African Catfish. *Stripping ripe females (Left) and fertilisation of eggs collected with milt from testis (Right).*

g) ***Larval Rearing***

- Catfish larvae will have absorbed their yolk sac and be ready to start consuming their first feed about four days from hatching.
- Their first feed natural foods form ponds or artemia. This is because their digestive system is not yet fully developed (Module 6).
- After 3 days of feeding zooplankton (natural foods), start weaning them onto dry feeds by progressively reducing the amount of zooplankton and increasing the amount of artificial feed over a period of 7 days.
- After 7 days can feed only dry diets.

h) ***Rearing Fry to Fingerlings***

- Fry can be stocked from the fourth day into ponds, tanks or hapas

Flow through Tanks

- Good water quality, aeration and gentle water flow (4 to 6 litres per minute)
- Every morning clean walls and siphon out dirt and dead fry
- Feed adlib based on feeding charts (appendix 3)

- Avoid stressing fish.
- Transfer after about 8 to 10 days into a larger tank or pond.
- Grade by removing the obvious shooters with a scoop net and spoon.
- After 6 weeks fingerlings will be about 2 to 3 inches long. (figure 82)

Figure 82: Catfish Fingerlings in a Tank

Ponds

- Fertilise ponds to promote zooplankton production prior to stocking
- Maintain water depth of 30 to 40 cm prior to stocking. Pour old engine oil or gasoline prior to stocking in order to kill off all insects. These are potential predators. Be sure that they are no frogs
- Feed based on feeding chart. Fry may eat slightly less are they have zooplankton available to them.
- After 4-5 days, water depth can be increased to 60 cm
- Stock 50 to 85 fry per m2. 100,000 fry in 200 m2
- Raise fish for 4 to 6 weeks in nursery pond or tanks
- Grade every 10 days to remove shooters
- Expected survival rates are 60 to 80%

Harvesting fry and fingerlings

- After 6 weeks fingerlings will be about 2 to 3 inches long.

Recirculatory Systems

- Fry (0.05-0.1 g) are fed with Artemia and 0.25 mm fry feed for 14 days in 100-1 000 litre tanks (600 g/m3 stocking density).
- Advanced fry (0.1-1.0 g), stocked at 10 000/m3, are fed 0.3-0.8 mm dry feed for 26 days in 600-1 000 litre tanks.
- Juveniles (1-8 g) are reared in 600-6 000 litre tanks at 400/m3 for 20 days and fed 0.8-1.5 mm dry feed.
- Water temperature is maintained at 28 °C, pH at 7, and biofilters ensure that NH3 and NO2 levels remain below 3 and 1 mg/litre respectively.
- To avoid disease problems, all components of the system are disinfected between each cycle.

7.2.3 Mirror Carp Hatchery Management

a) Natural Method

- The broodfish are kept in broodfish ponds, segregated by sex.
- Select breeding fish of from 800 g. Ripe females will have enlarged abdomen with yellowish eggs with a black dot. Males should have running milt.
- Pond cleaned and prepared as a nursery pond
- Substrate of papyrus heads, threads from sacks are placed into the ponds.
- Matured broodfish are transferred to 25-30 m^2 spawning ponds.
- The fish lay their eggs on both sides of the substrate.
- When spawning is completed, the substrate is transferred to hatching/nursing ponds where they hatch, and larvae are left to grow to fry.

i) Artificial Method

- Broodfish conditioned in tanks with water saturated with oxygen, within the temperature range of 20-24 °C.
- Given two doses of pituitary gland injection, or a mixture of GnRH/dopamine antagonist, to induce ovulation and spermiation.
- The eggs are fertilized as for catfish and:
  a. Spread on trays
  b. The adhesiveness of the eggs is eliminated using salt/urea treatment, followed by a tannin acid bath. Incubation is carried out in Zoug jars.
- The hatched fry raised in tanks for 1 to 3 days to stage of 'swim-up' or 'feeding fry'.
- Fry transferred to ponds or tanks for onward rearing.
- Approximately 300 000 to 800 000 newly hatched fry can be expected from a single female.

j) Nursery Ponds

- Nursery ponds must be prepared before stocking to encourage the development of a rotifer population, since this constitutes the first food of feeding fry.
- The stocking density is 100-400 fry/m^2.
- The ponds should be inoculated with Moina or Daphnia after stocking.
- Feeding:
  a. Supplementary feeds, such as soybean meal, cereals meals, meat meal, or mixtures of these materials.
  b. Nutritionally complete diets fed based on response guided by feeding charts
- The length of the nursery period is 3 to 4 weeks. The final fish weight is 0.2-0.5 g. The survival rate is 40-70 percent.

7.3 Harvesting, Handling, Grading and Distribution of Fish

In hatcheries, the frequency of harvesting, handling and transferring fish is much higher than it is in grow-out operations. These procedures are extremely stressful and are a common cause of mortality among juvenile fish. Minimising procedural stress is paramount (**Module 8**).

Therefore, before undertaking any activity that requires handling of fish:

1. Plan when and what will be required,
2. Prepare the materials, including all personnel beforehand,
3. Execute the procedure and evaluate the results,
4. Improve upon the process each time.

7.3.1 Handling Fish

Stress can be avoided or minimized at handling by observing the following:

- Only handle fish that have not been fed for at least 24 hours.
- Ensure fish are always in water with adequate dissolved oxygen (ideally about 5 mg/l). Only take fish out of water when necessary (e.g., during weighing) and for not more than a few seconds at each time (figure.83).
- Work with fish when water temperatures are warm, preferably above 24 oC. The optimum water temperature for raising tilapia and catfish is between 26 oC and 28 oC. Handling fish in cold water pre-disposes them to stress and disease. Never handle tilapia and catfish when the water temperature is 21 oC or below.
- Stock fish when water temperatures are preferably above 25 oC.
- Do not expose fish to temperature differences of more than 3 °C without adequate acclimation.
- Avoid exposing fish to chemicals and pollutants. If you must treat fish, do so using only approved treatments and only as prescribed. The only exception is with salt for treating external injuries (use 1 - 2 % as a **dip** for prophylaxis. For details see Module 8.
- Avoid holding fish temporarily in tanks and similar strict confinement for longer than necessary. If you must, use aeration or flowing water.

Figure 83: Fish Basket. *During handling, fish must be kept within water most of the time. Fish baskets come in handy.*

7.3.2 Sampling

Sampling is the temporal removal of fish from the pond. The major reasons for sampling are to:

1. Monitor growth and general performance,
2. Re-calculate feed requirements,
3. Determine when fish are ready for market
4. Determine if the pond has reached its carrying capacity
5. Assess the health of the fish

After making the observations required, fish are returned to their unity pond. Sampling is a stressful because fish are crowded, physically handled and removed from water during the process. Handling can lead to physical rubbing of the fish's body, causing the removal of the surface mucus layer and injuries.

Sample broodstock ponds once a month, early juvenile stages every 7 to 10 days and older fry to fingerling stage, once every two weeks. Nursery units are sampled more frequently at this stage, fry is growing rapidly, and their feed requirement needs to be adjusted more frequently (appendix 3).

Grading is important at the nursery stage to ensure uniform sizes within the pond so as to avoid cannibalism.

a) How Best to Sample

- The sample taken should be random and truly representative of the rest of the population. All fish caught in the net should be weighed.
- To avoid stressing fish:
  - (i) Do not feed fish the meal just before sampling. For broodstock do not feed the day before.
  - (ii) Prepare all equipment such as scoop nets, basins and scales the day before
  - (iii) Execute the task at hand fast and efficiently in well aerated water.
  - (iv) Keep the fish in water all the time or as much as possible (figure 76). The only time they should be out of water is when the fish basket is lifted to the weighing scale
  - (v) Larvae and fry should be weighed in water. Weigh a specified volume of water, place the fry inside and get the total weight of the water and sample. The difference between the two, give the weight of the fish.

Do not sample when:

1. Fish are sick and show signs of extreme stress.
2. In ponds, when there is lightening during a rain-storm. This is because during such moments, a person standing upright in water becomes a good conductor for the lightening. The risk of getting struck is therefore, high.
3. If it has just rained and there has just been a lot of run-off into the pond.
4. When the water quality is poor, such as when;
   - a. Bad smell
   - b. Fish show signs of stress and in tilapia, piping for air (Module 8)
   - c. The water temperatures are less than 22oC,
   - d. DO levels are less than 4 ppm.

In such situations, one should postpone the sampling until when the water quality and fish's condition have improved.

7.3.3 Harvesting

When fish are removed from the pond and not returned, they have been *harvested*. Fish are normally harvested for the following reasons:

1. Sale.
2. Transfer to other ponds.
3. Mortalities are also regarded as harvest but provide negative income.

a) *How to Harvest Hatchery Units*

Spawning Units must be drained **slowly** so as to minimise stress on the fish.

Fingerling and broodstock units can be drained faster. Harvest small fingerlings by lowering the pond water level as rapidly as possible without stranding the fish or catching them on the outlet screen. Remember that these fish are to be kept alive for restocking in on-growing facilities or for reproduction in the case of broodstock. The screen at the outlet should be large with a large surface area and of the appropriate mesh size.

When a pond is to be harvested completely, it is better to pass a seine (preferably one with a bag) two or three times before completely draining it in order to reduce the number of fish in the pond. Once the number of fish caught in the successive seines drops to about a quarter of the estimated stock, the water level in the pond can be reduced. After this, drain the pond completely and gather the fish using scoop nets from the harvest basin. During drainage ensure that the screen on the outlet (as well as inlet pipe) is properly fixed to prevent fish going out of the pond and frequently remove debris that might clog it to maintain the gradual flow of water through.

In nursery ponds**,** there will be fry left at the pond bottom once all the water has drained. Do not pick these fish. Such fry stuck in the mud are already extremely stressed (due to the exposure to air, mud on their gills) and are unlikely to survive in on-growing units. If one cannot harvest pond in a day, then partially refill for overnight holding. Holding partially harvested pond at a low level for long periods of time should be avoided – loss to predators and disease. Crowding and the lack of food also reduce the ability of small fish to withstand handling stress. A fresh supply of water should be provided while the fish are confined to the collection basin.

Ponds must easily be accessible so that transfers to other units are quick.

k) *Temporary Holding Fish after Harvest*

Batches of fish removed from nets at harvest, should straight away be transferred into a fish basket placed within a tub of water with similar water quality (taking note of temperature and oxygen levels) that preferably has aeration. It is best to fill the tub with water from which the fish are being harvested or a similar pond. The fish should then be transferred straight to their destination.

If fish are being weighed, it is best that they are batch weighed as they are being removed from the water into the container. This prevents the fish being out of water for a significant duration twice. If an entire nursery unit has been harvested, a random sample can be batch weighed and counted in at the destination, while the rest is done volumetrically.

7.3.4 Sorting and Grading

Grading fish means sorting fish by size.

a) Benefits of Grading Fish

1. Minimising size variation in production units.
2. When fish in the unit are of a similar size, it becomes easier to select the appropriate feed type and feeding regime (e.g. a 2 mm pellet if the fish in the unit are say 5 g).
3. Reduces incidences of cannibalism and territoriality that are major causes for loss of apparently healthy larvae and fry in hatcheries.
4. Permits more accurate sample counting and inventory estimates as fish of differing sizes are eliminated.
5. Enables assessment of the health and vigour of the stocked which can easily be assessed during movement.
6. Makes it possible to stock and/or supply uniform sized fish which is important for production management programs.

l) How to Grade Fish

Fish are graded using a grader. A grader can be made of any material as long as the spacing between the bars is uniform (figure 84).

Figure 84: Grading Fish with a Grader Box in a Hapa. *The smaller sized fish (passes) pass through and the larger fish (holds) remain within the grader. A series of several sized graders may be needed where size variation is big within a cohort.*

Passes (approximately 95%) are stocked in hapas

Holds (approximately 5%) are stocked in a reservoir pond

m) Minimizing Stress during Grading and Harvesting

During grading, most of the stress arises due to physical handling and changes in water quality. Therefore:

a. Do not Overload Grader – otherwise:

- The fish at the bottom shall bear the weight of those above when the grader is lifted.
- Avoid skin abrasions.
- The amount of fish in grader should not exceed 7.5 kg/m^3 of grader capacity.

b. Do not Touch Fish with your Hands. If small fish remain attached to or inside the grader, drive them into the grader by pouring water gently into the grader.

c. Minimise Physical Trauma.

- Containers should be full of water so that fish are not thrown against the sides of the container.
- The water in the container should be able to slosh (swill) and not bash.
- A dip net and tub can be used to avoid physical damage when small weights of fish or tiny fish are moved.
- Avoid large-meshed nets especially when scales are involved. Use the right sized net for the size of fish being transferred.

d. Water quality Maintain optimum DO, temperature, ammonia and minimize suspended solids.

e. Keep grading records. This will enable you know what size of fish passes through each grader size after which there shall be no need to keep re-weighing clusters.

7.4 Fish Seed Handling and Transportation

Live fish transportation is stressful due to the confinement of large numbers of fish within a container. Mortalities occur as result of osmo-regulatory problems triggered by exposure to poor water quality, overcrowding and improper handling or the activation of latent disease organisms. Fish exposed to such conditions, even though they survive, are unlikely to be healthy enough to survive stocking in grow-out facilities.

A hatchery must supply healthy fingerlings that survive after stocking. Successful live transportation fish fry and fingerlings depends on:

a) Maintain Optimum Water Quality within Transport Containers

- **Do not use** water from ponds with heavy plankton blooms (see Module 5).
- Use only water of good quality as described above. Dissolved oxygen levels should be at saturation (minimum above 5 mg/l), water temperatures between 25 oC to 30 oC, ammonia – zero, suspended solids negligible.
- The volume of water should be adequate to hold fish and dilute wastes.
- Add salt (preferably *'magadi'* salt that has bi-carbonate) to the water in order to prevent fish loosing salts, help control nitrite and pH levels.
- Conditioning fish for 48 hours before transportation does a lot to control ammonia build-up during transportation. However, if levels of ammonia do go up in transport tanks above 0.1 mg/l, then zeolite can be added to adsorb it.
- Do not overload containers. A general rule is 2 kg of fish for every 20 litres of water. Oxygen

utilization is extremely high during transportation. Levels of aeration or oxygenation should be adjusted to ensure that optimum dissolved oxygen levels (+ 5 mg/l) are maintained during the journey.

- Keep containers out of from direct sun. Cover containers or polythene bags at the back of open trucks to prevent this with papyrus mats or gunny bags if one is travelling a long distance.

b) The Fish's Condition

Only handle, package and transport healthy fingerlings in good condition. Fry and fingerlings in good condition are:

- Not emaciated (not thin)
- Alert and active,
- Look bright,
- Have no physical deformities,
- No signs of disease and
- The right size
- Uniform size.
- No signs of fish stress.

Before packaging and transportation, it is recommended that fingerlings are conditioned so that only those that meet the above criteria are packaged.

7.4.1 Conditioning Fish

Fish should be conditioned for 48 Hours before Collection. Two days before collection, the fingerlings have to be seined, sorted, graded, counted and then held in temporary holding (conditioning) facilities (either tanks or hapas) with good water quality and aeration without feed until the collection day (but for not more than 3 days). Conditioning provides time for the fish to empty their guts before transportation and for the weak/deformed fish to be identified and removed.

7.4.2 Methods for Live Fish Transportation

a) In Closed Polythene Bags

Polythene bags are commonly used with a column of oxygen sealed in above the water column with fish. They are versatile and easy to store. Clear bags are preferred because one can see the fish in the bag.

Packaging in Bags for Live Transportation.

- A 300-400 gauge plastic tube is recommended because it is thick enough to withstand pricks from fish fin and is pliable enough to be folded over and tied in a close knot to prevent loss of air.
- Cut off about 3 meters from the roll and tie a simple reef knot half-way so that finally the packaging will be double layered. Having a double layer is done to safeguard against loss of air in the event of a puncture.
- Set the tied bag in a basin or basket, open it up and fill it a third –way with water (10 – 15 litres of water depending on the length). The water temperature in the bag should about that of the holding water or not more than 2 oC above or below it. Add some salt (magadi salt can be used) at the rate of 0.05% of the volume of water. Stir the salt in and ensure it is properly dissolved before fish are added into the bag.

- Add fingerlings at the rate of 0.5 to 1 kg total biomass for every 10 litres of water into the bag. Use 0.5 kg for every 10 liters if fish are 5 g or less because smaller fish have a higher metabolic rate. Do not exceed 1 kg for every 10 liters of water for fingerlings.
- Immediately close the inner bag over and squeeze out all the air in the bag that is above the water.
- Insert the delivery tube from the oxygen cylinder into the bag while still holding the top close to prevent air entering the bag.
- Release oxygen into the bag and fill the bag with oxygen. Ensure that the amount of air above the water column is at least about twice the column length of the water.
- Twist the top of the inner bag tight as you pull out the delivery tube from the cylinder. Twist tight, fold the twist over and tie the fold tightly in place using a rubber band from an old tyre tube.
- Place the sealed bag in a cardboard box, bucket, or within any container that can provide it support and protection from puncture during **transportation (figures 85 and 86)**

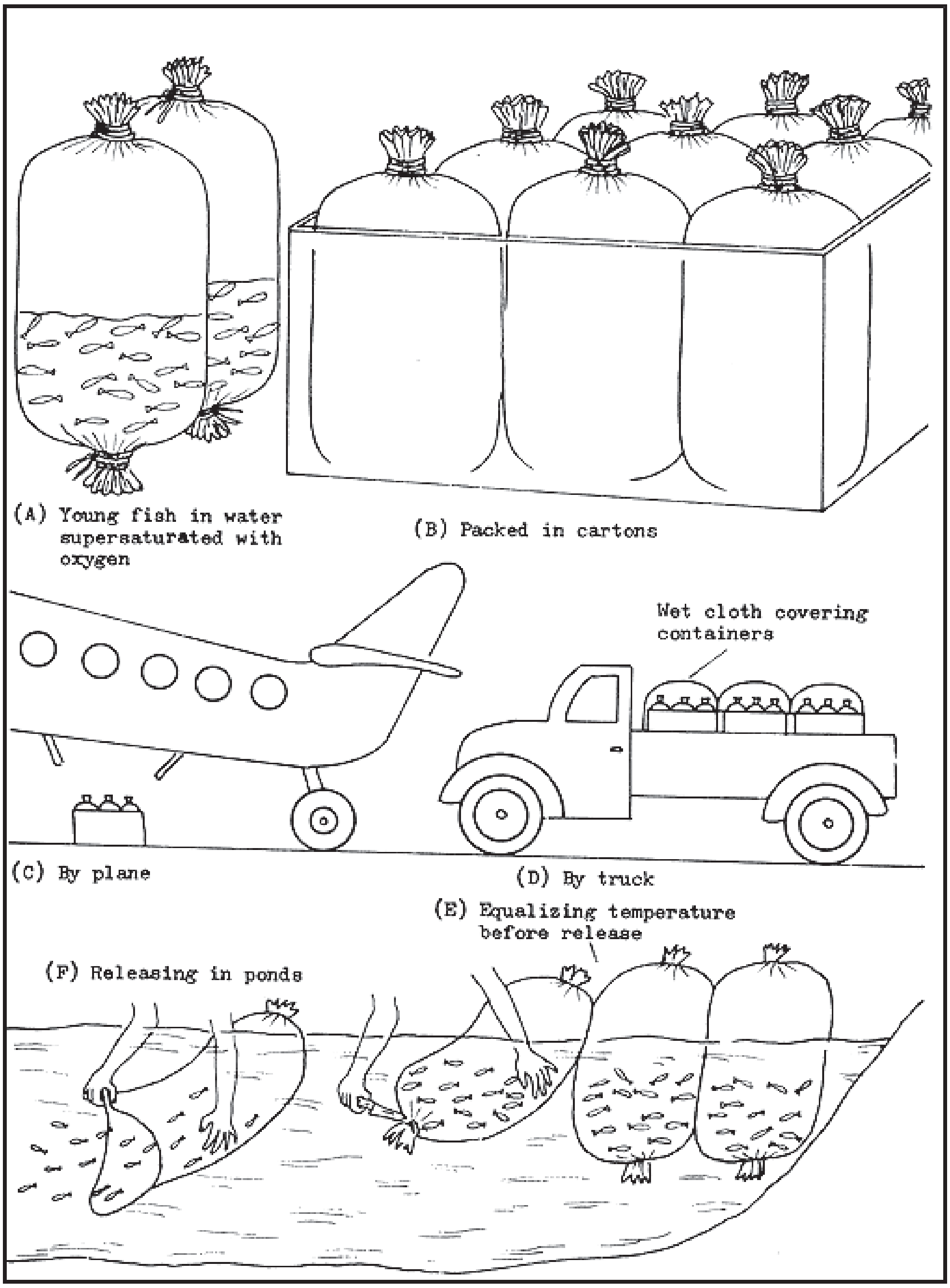
Figure 85: Packaging Live Fish in Bags for Transportation

a) Packing Fingerlings for Live Transportation in Bags with Oxygen. *Note the double bagging. It is important to do so to reduce the risk of loss of oxygen in the event of a puncture in either layer during transportation*

b) Packed Bags Ready for Transportation

c) Transporting Fingerlings Packed in Bags to Farm. *Bags should be placed in boxes, basins or baskets to help support them during transportation and prevent punctures.*

Figure 86: Live fish Transportation in Bags



b) Tanks

Tanks can be of any shape with a wide opening but preferably rectangular. This makes it easy to load fish, check on the fish during transportation and provides wide surface area exposed to air. Large tanks (not specifically designed to carry large volumes of water) should be reinforced at the side to prevent them bulging out.

When transporting fish, there should be aeration in the tank. The tank should be covered with a solid cover at such moments to prevent the escape of oxygen or air. If there is no mechanical aeration, cover the tanks with some form of netting to prevent fish from escaping.

Packaging in Tanks for Live Transportation.

- Calculate the volume of the tank.
- Fill it with water to about two-thirds. Add salt or magadi salt at a rate of 0.05% of the total water volume. Stir the salt in and ensure it is properly dissolved before fish are added into the tank.
- Set in the aeration unit into the tank and turn it on.
- Add the fish into the tank at a rate of 0.5 to 1 kg of fish for every 10 litres of water as in above.
- Remember, the fish added will displace a volume of water equal to their weight. This should be taken into consideration when determining how much fish can actually be transported in a tank of a certain volume.
- Cover the tank once the fish are in the tank with a solid and keep it covered during the course of transportation. The lid prevents not only water from splashing out of the tank but also excess oxygen escaping to the atmosphere.
- Check the water temperature and oxygen readings before you set off. If the oxygen levels are stable and above 5mg/l of dissolved oxygen, the flow-rate of oxygen into the tank can be reduced. Monitor oxygen levels and fish behavior frequently during the course of transportation. If the dissolved oxygen levels keep falling fast to below 4 mg/l, then increase the oxygen flow rate.

N.B. For long distance travel likely to exceed eight hours, zeolite packs can be added to both transport bags and tanks to adsorb any excess ammonia that might be released by the fish.

c) ***Labelling Containers and Bags***

Only harvest, grade, condition and package correctly what is required by your client to avoid incidences of fish being returned to production units. Obtain the following information from the fingerling buyer:

1. The number and sizes of tanks, ponds or cages to be stocked.
2. How many fish are to be stocked into each unit
3. The size of fish you required. The minimum recommended size for stocking tilapia grow-out ponds is 10 cm or 7 g. For cages it is 30 g
4. The distance to the destination.
5. On which day and at what time you intend to collect the fish.
6. How the fish is likely to be transported. For example, will the farmer use public transport in which case the hatchery operator might need to arrange for packing boxes so that the transport bags remain secure in the bus? Farmers depend a lot on the advice of hatchery operators in such cases.

This helps one confirm the number to condition.

Label each of the transport containers with the following information:

- Hatchery Name and Contact Details
- **Fish Species**
- **Number/Weight of fish in bag**
- **Average Weight of Fish (g)**
- **Lot or Batch No.** (this should be traceable back to unit from which the fish were obtained and the date of harvest)
- **Estimated DOB** (Date of birth) (fish sold as a lot or batch should be within a month old from each other)

- **Any other Specifications or Required Details** (eg. if selected stock; intended destination – ***e.g. Johns farm, pond C***; whether or not the fish are all- males sex-reversed or all- males hand-sexed etc.)

The objective of having each bag/tank labelled independently is to:

- Assure Quality.
- Minimise the Amount of Physical Handling at stocking.
- Ensure the Fish are in Good Quality Water up to Stocking.

7.4.3 Live Transportation from Hatchery to the Farm

The survival of the fish from the hatchery to the farm is the transporter's responsibility. Transportation should be as stress-free as possible. Therefore:

- Minimise transit time; Do not stop to run errands after collecting fish from the hatchery.
- Do not leave bags or tanks standing out in the direct sun
- Keep records of information on the labels and sales.

7.5 Grow-Out Management

7.5.1 Stocking Grow-Out Production Units

a. Guidelines for stocking fish from bags.

The following are the recommended steps to follow when stocking fish into ponds from bags.

- Transport all bags to the edge of the designated pond. **Do not** open any of the bags before they get to the pond because once a bag is opened, all the oxygen in the bag will leave into the atmosphere. The **fish only have about 5 to 10 minutes before they run out of oxygen after a bag has been opened.**
- Acclimatise the fish. Set the bags right next to the pond in basket or box to support the bag or in the pond.
- If you have the equipment, check the water quality of the pond before opening the bags for oxygen and temperature.
- Open only one bag at a time. Check water quality in bag for DO and temperature If you have no tools for checking water quality, use your fingers to detect for any obvious temperature differences between the pond water and water in the bag.
- Add water from the pond into the bag gradually over a period of 10 to 20 minutes to allow the temperature and other water quality parameters of the transported water to slowly become similar to that of the pond water. The total amount of water added should be double or triple the amount already in the bag.
- While doing this, you can allow the other un-opened bags to float on the pond. Cover these bags to shade and prevent excessive sunlight.

NOTE: Floating the un-opened bags on ponds alone is insufficient to acclimate the fish properly.

- Lower the bag in the pond and tip it so that the fish can swim out on their own gently. Observe how they swim out.

b) *Guidelines for stocking from Transport Tanks/Containers*

1. Drive down as close as possible to the pond.
2. Check the water quality in the pond and in the tank.
3. With a bucket, remove about a third of the water in the tank. Then add pond water. Repeat this process 2 or more times giving time for the parameters to gradually re-adjust as mentioned in 4.6 above.
4. Scoop out a few fish at a time into a bucket with adequate water using a scoop net.
5. Gently lower bucket into the pond and let fish swim out on their own.

NOTE:

1. Keep the aeration going in the tank right through the process until all the fish have been stocked.
2. It is important to stay around and observe how the fish swim out of the bag or container:

- Any fish that lie immediately on the pond bottom will likely die within a day or two.
- Fish that swim erratically or have any discoloration on their bodies or fins may die within 2 to 4 days.
- If the fish swim back into the container, it is probably due to the fact that the water current has reversed (fish swim against the current) or that the fish are shocked.
- Be around to ensure no birds take the fish during stocking or soon after.
- Record all stocking information (Module 11).

7.5.2 Tilapia Table Fish Production

The following are the options for tilapia table fish culture

7.5.1.1 Ponds

ii) ***a) Fertilized Static Water Ponds***

Activity/Item	Recommendations
1. Pond Preparation	• Remove silt from pond and ensure that the pond is not leaking **(Module 4)**. • Correctly screen the inlet and outlet. • Lime ponds if the water alkalinity is less than 20 mg/l or the pond is acidic (below pH 6) at rate of 350 kg agricultural lime per hectare water surface area. This is to ensure positive response to pond fertilisation (Module 5). • Fertilise the pond adequately to ensure optimal levels primary productivity at stocking (Module 5). • There should be no old fish left in pond before filling and stocking. • Fill pond. Ponds should be stocked within a week of filling with water.
2. Stocking	• Stock only fish in good condition from a registered hatchery (see section 7.4). • Calculate numbers to stock based on the ponds carrying capacity and the targeted market size. The carrying capacity for tilapia ponds of an average water depth of one (1) meter fed commercial pellets is 8 to 10 tons/ha (i.e. 0.8 to 1.0 kg/m2). The maximum feed input in such fertilised ponds receiving no aeration is 100 kg/ha/day (i.e. 10 g/m2/day). • Stock fish of uniform size. • Preferably stock only males - mono sex. • Stock 10% catfish for population control if mono sex tilapia is used and 20-30% if mixed sex tilapia stock is used. The catfish can wait 2 months after stocking with tilapia fingerlings.

MODULE EIGHT:

FISH HEALTH AND BIOSECURITY

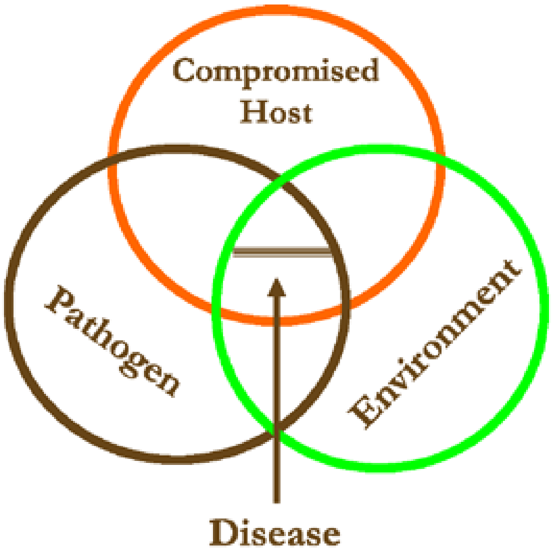
8.1 Introduction

The goals of health management are preventing diseases from happening; reduce the frequency of diseases and severity of diseases in order to produce safe food products profitably. When fish are not healthy:

- Growth rates, reproduction rates and survival rates are poor
- Costs are incurred for treatment and disinfecting premises.
- Fish quality is poor, and fish cannot be sold during treatment

Diseases occur when the fish's immune system is compromised, permitting pathogens to cause infection. Commonly, the fish's immune system becomes compromised when fish are stressed (figure 90).

Figure 90: The Disease Triad



8.2 Fish Welfare

Fish ***welfare*** is the state in which fish can cope with their environment. Once they cannot cope, fish become stressed. Changes in its behaviour and physiology ensue that lower the fish's immunity. The fish then become more prone (susceptible) to infections infected by disease causing agents (***pathogens***) and eventually fall sick (state of diseases).

Ensuring fish welfare entails good water quality management, nutrition, handling, stocking and sanitation. It is among the first steps in disease control as most pathogens live naturally in the fish's growing environment of the fish. When fish welfare is poor therefore, the likelihood, frequency and severity of diseases is higher. The primary role of medications in health management is to support fish overcome infections. Medications are not substitute for poor management.

The overall benefits of implementing fish welfare and humane treatment of farmed fish are summarized in the Box 2 below.

Benefits of Fish Welfare

Aquaculture Producers

- Increased production and productivity
- Optimal animal health, public health & aquatic animal food safety
- Better quality products
- Premium price for products & increased income

Supporting Industries (slaughter, processing, sales, recreation)

- Meet public & consumer expectations
- Premium price for products & increased income

Countries

- Increased production / product will directly affect:
- Global product appeal & meet expectations
- Increased trade

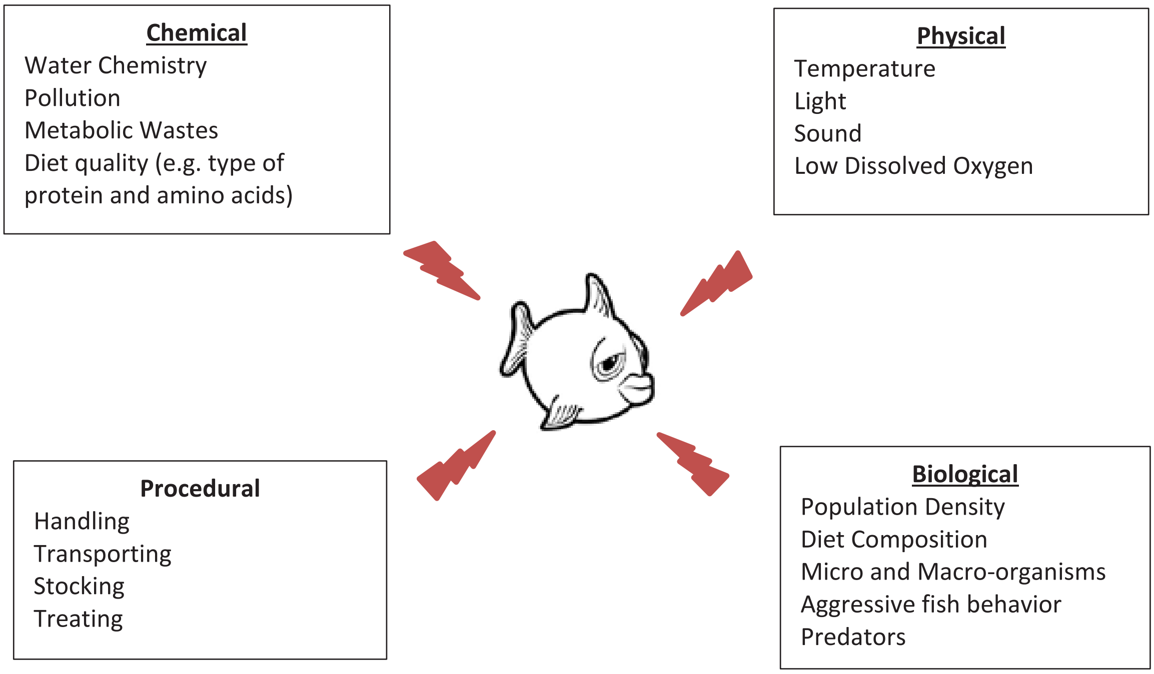
8.3 Stress

Stress is the condition under which fish become unable to maintain a normal physiological state (body functions) because of various factors that adversely affect their well-being (welfare).

8.3.1 Major Causes of Stress

The four major sources of stress in aquaculture are chemical, physical, biological and those as a result of management procedures (figure 91).

Figure 91: Common causes of fish stress

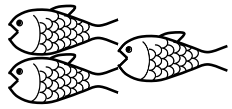
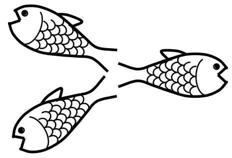
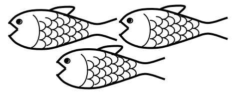
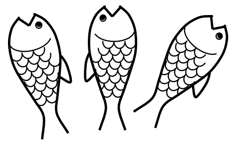
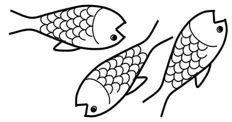


8.3.2 Signs of Stress in Fish

There are four distinct stages of stress that are physically identifiable in fish:

1. **Alarm Reaction.** This is when the fish try to escape the stressor. An example of this is when stocking the pond and instead of swimming out freely into the pond, they try to swim back into the bag or container being used to stock the fish.
2. **Resistance.** When the fish react to the stressor through physiological adaptation. For example, when dissolved oxygen levels are low, tilapia will come out of the water to ***pipe***.
3. **Fatigue.** The fish are noticeably weak but respond to stimuli.
4. **Exhaustion.** This is when the fish's physiology is unable to sufficiently adapt to a persisting stressful condition, and it can no longer respond to stimuli. The impact of stress on fish depends on the duration and magnitude of the stress condition. Death is the ultimate result. Sub-lethal stressful conditions cause reduced fish growth, low yields, poor feed conversion and poor health, including obvious disease (table 38 and figure 92.).

Table 38: Typical Appearances of Fish at Different Stages of Stress

	**NORMAL** Healthy, alert, normal activity, normal body colour, social (schooling) activity
	**ESCAPE** Healthy, alert, increased activity and body movement, slight increase in opercular (respiration) movement, possible slight body colour change (usually darker), schooling fish remain together.
	**ADAPT** Healthy, alert, usually swimming higher than normal in water, increased opercular movement, schooling fish remain together
	**FATIGUE** Lethargic but sufficiently alert to avoid dip-net capture, reduced activity and movement, usually gasping at or near surface, color change distinct (usually much darker), schooling fish separate to individuals
	**EXHAUSTION** Hanging listlessly, usually disoriented (commonly upside down) at surface, little or no response to avoid dip-net capture

Adapted from Schmittou et al., 1998.

Daily observation of fish behaviour and feeding activity allows early detection of health problems before the majority fish in the the population becomes sick. Treatments are more successful if given early in the course of the disease when the fish are still in good shape.

The figure below describes stress responses under certain conditions

Figure 92: Generalized illustration Warm-Freshwater Fish's Response to Environmental Stressors.

Fish Response			Environmental Factor		
			pH	Ammonia	Temperature
Exhaustion and Death		Death	11.0	0.5	34
Fatigue		Short-term tolerance limit	9.8	0.4	33
Adapt		Long-term tolerance limit	9.5	0.2	31
Escape		Upper optimum limit	9.0	0.0	30
Normal		Ideal	6.5 to 8.0	0.0	26 to 28
Escape		Lower optimum limit	6.0	0.0	15 to 24
Adapt		Long-term tolerance limit	5.5	0.0	<1
Fatigue		Short-term tolerance limit	5.0	0.0	<1
Exhaustion and Death		Death	4.0	0.0	0

When DO are low in the water, tilapia begin to ***pipe*** in order to breathe atmospheric oxygen (figure 95). Tilapia can pipe for about an hour every morning with very little problems. However, if they ***pipe*** for long periods (like six hours per night), this will severely reduce growth rate because extra energy is spent piping and eventual stress. Fish fins become erode when fish are stressed.

8.3.3 Why are stressed fish more likely to fall sick?

Stressed fish are more likely to fall sick because the body's protective barriers to infection ***(immune system)*** starts to break down. It becomes easier for pathogens to enter the body and affect the fish's physiology (see table 39.).

Table 39: Protective Barriers against Infection in Fish

Protective Barrier	Normal Function	Effect of Stress
Mucus (slime coat)	• Prevents entry of pathogens into fish from the environment • Contains enzymes and antibodies that kill pathogens • Lubricates fish making their movement easier through water • Involved in osmoregulation	• Loss of mucus resulting in easier entry of pathogens into fish. • Chemical changes in mucus that reduce its effectiveness of enzymes and antibodies • Reduced ability osmoregulation. Fresh water fish consequently take up more water and salt-water fish become dehydrated. • ***Common causes of mucus loss:*** physical handling, changes in water quality, chemical
Scales and skin	• Protects fish against injury	• Loss of scales or damage to skin creates entry points for pathogen into fish's body • ***Common causes of damage:*** physical handling, fighting among fish, parasites,
Inflammation	• Isolate and destroys invading proteins (can be/from bacteria, virus, parasites, fungus or toxins)	• Hormonal changes • Temperature stress can halt activity of 'killer cells'
Antibodies	• Molecules produced to fight targeted invading proteins or organisms • Sub lethal concentrations of pathogens thus help develop more competent immune system compared to when fish are raised under sterile conditions (and is rationale for vaccination)	• Temperature stress impairs fish's ability to release antibodies • Prolonged stress limits effectiveness of the immune system, increasing opportunity for invaders to cause disease.

8.4.3 Preventing Stress

Good management is key to preventing stress:

- Maintain good water quality, good nutrition and sanitation.
- Minimize unnecessarily physical handling.
- Protect against sudden scares (e.g. by predators)

Observe fish daily changes in fish behaviour, physical appearance and feeding response as these are indicators for stress. Stress often precedes occurrence of disease.

8.4 Fish Disease

Disease is an abnormal condition whereby the fish increasingly becomes unable to maintain its normal physiologic functions in balance with the environment (figure 90 above).

8.4.1 Classification of fish diseases

Fish diseases are described based on the characteristics of the infection and the pathogen type.

a. ***Characteristics of the Infection.***
   - **(i) Infectious diseases:** are caused by pathogenic agents in the environment and spread between fishes and fish populations.
   - **(ii) Non-infectious diseases:** are caused by environmental problems, nutritional deficiencies, genetic anomalies or physical injuries. Such diseases do not spread from one fish to another and usually cannot be cured by medications

b. ***Type of Pathogen***
   - (i) Bacteria
   - (ii) Fungi
   - (iii) Viruses
   - (iv) Parasites

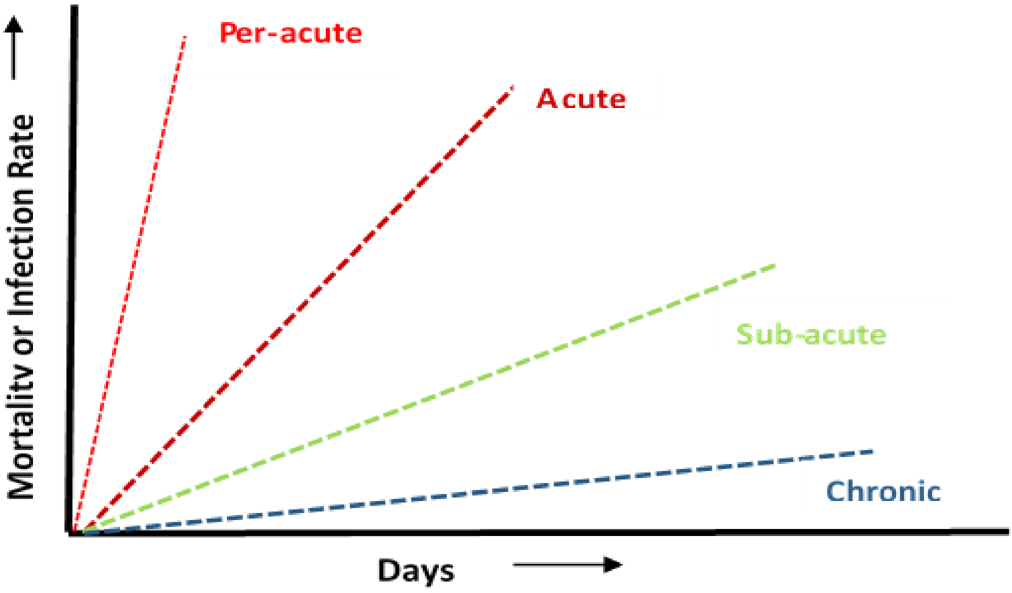
8.4.2 How to identify sick fish

The signs (symptoms) of fish disease are associated with abnormal changes in fish feeding, behaviour, and physical appearance (table 40 and figures 93 and 94 below).

Table 40: Symptoms of Fish Disease

Parameter	Abnormalities to look out for
Feeding	• Reduced feeding • Uncontrolled over-eating (gold fish)
Behaviour	• Swimming (whirling, circling, erratic, bottom sitting, curling, drifting, inverted swimming) • Social behaviour (aggressive, isolation, dull) • Position (head-standing, lying on one-side) • piping
Physical Appearance	• Change in colour • Patches, wounds, loss of scales • Swellings, growth • Enlarged organs • Deformities in shape • Eroded fins • Bleeding (haemorrhages)
Mortality	• Characteristics of mortality (acute, chronic) (see figure 93) • Proportion of the population

Figure 93: Description of Mortality and Infection Trends



The above signs do not necessarily tell you what the cause of the disease is but alert you to an on-going condition. Identifying the cause will help institute corrective measures to prevent spread, reduce severity and mortality.

Figure 93: Some common Signs of Fish Disease

Brownish gills

Pale gills

Eroded gills and excess mucus

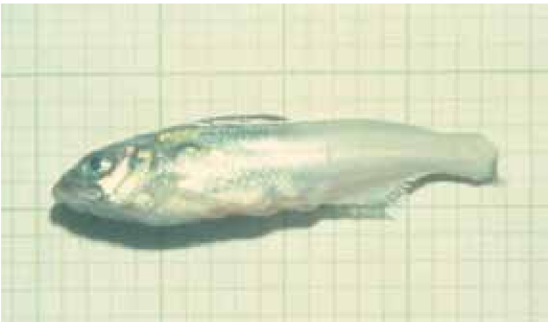
Gas bubbles within gills

Fluid behind eye (pop-eye)

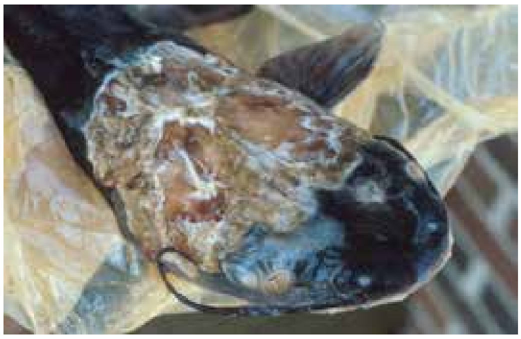
Fluid in abdomen (ascites)

Body deformities and wounds

Bleeding



Eroded fins



Dead tissue in living fish (necrosis)

Changes in skin colouration

Swollen inflamed internal organs

8.4.3 What should I do if I notice sick fish?

- Stop feeding
- Evaluate the environment (water quality, flow rates, breakdown of equipment, entry of predators). Check and key improve water quality parameters
- Obtain case history (review daily production records for period when fish may have been exposed to stressors and when symptoms started, species, size, age, mortality rates)
- Examine fish for more detailed clinical signs
- Identify pathogen, toxicant or other cause. Samples may need to be submitted to laboratory.
- Implement recommended control measures

8.4.4 Collecting and sending samples to the laboratory

It is important to verify the cause of infection even though treatment may have begun based on diagnosis from disease history and symptoms observed at the farm. This is because, often:

- The common symptoms of disease are typical for more than one disease
- The fish may simultaneously be running more than one infection at the same time.

8.4.4.1 Samples to Send

(a) **Fish Samples.** Fish showing typical signs of the disease in question are the best samples to send. It is better to send ***moribund*** fish that are alive **and not:**

- Dead fish
- Fish that look normal
- Samples from seine or
- With physical injuries from handling

Live, frozen or preserved samples may be sent to the laboratory. However, it is better to send live fish samples packed in bags with oxygen given the constraints in Uganda's cold chain and it provides additional material for the laboratory to take more tissue from the fish it may require (Table 41).

Table 41: shipment of Fish Samples.

Fish Samples	Shipment Conditions
Live Samples	• Bags with oxygen in water from the production unit (see **Module Seven** section on transportation of live fish)
Very Fresh Dead	• Place in refrigerator or on ice in an icebox • Keep sample moist, **NO**T wet • **DO NO**T allow the ice or water to touch the sample
Frozen Samples	• Cannot be used for pathology • Some bacteria and viruses may be retrieved • Only use if sample is not likely to reach laboratory in timely
Fixed Samples	• Preserve in 10 % formalin or Bouin's fixative • Use ONLY fresh tissue for preservation. • Alcohol is NOT a fixative

(b) **Aquatic plants -** ship moist in plastic bag. Take samples from above and below water line. Pack them separately.

(c) **Pesticide analysis-** 500 ml glass bottle covered with aluminum foil.

(d) **Water sample-** at least 1 L in clean bottle, cooled kept on ice

N.B: Always:

1. Alert the laboratory prior to sending samples and obtain information from them on exactly:
   - What samples and what quantity to send ***(not all samples may be necessary)***
   - How to preserve and send the samples
   - What additional information need be sent along with the samples?
2. Label each sample bag or container

8.4.4.2 Basic Information to Send with Samples to the Lab

1. Your name
2. Contact address and location of farm
3. Phone number
4. Date and time samples were taken
5. Description of sample being sent
6. Size of production unit and management practices
7. Number of dead fish
8. Number dying per day
9. Date fish started dying
10. Number of fish stocked
11. Physical appearance of the fish
12. Behavior of fish
13. Water sample (at least 1 pint in a separate container)
14. Previous treatments

8.4.5 Controlling fish diseases on-farm

Disease are controlled on farm by health maintenance, prevention, early disease recognition and control.

In order to prevent diseases from happening, one must understand the fish, culture system and potential pathogen(s) well enough to pre-empt and institute measures against the occurrence of disease. Table 42 explains how this may be done in practice.

Table 42: General Approaches to Disease Control

	What to control/Observe	Control Measures in Event of Disease
Fish	• Water quality tolerances of the fish being reared • Needs and requirements during the different stages of life • Changes on the fish and its behavior that occur when its exposed to physical, chemical or biological stressors • Fish as cold-blooded animals will immediately adapt to changes in their environmental • Factors that influence natural resistance to disease	• Early diagnosis from observation of changes in behavior, gross lesions, % population affected • Limit severity by improving water quality • Enhance immunity and/or treatment • Select broodstock and eggs • Rear disease resistant stock if available
Culture System	• Site selection (e.g. prior land use, water source) • Water quality parameters lie within optimum ranges • Production capabilities • Water temperatures • Protection from predators and other animals • Management practices • Anticipate and/or be observant of changes (water quality parameters or temperatures) • Record keeping • Species and human activities within the water shed (i.e. upstream and downstream of the farm) • Potential disease carriers in the environment	• Disinfection of equipment and production units • Remove dead fish • Quarantine • Dry ponds • Control other animals and • Eliminate wild fish • Screen/or Filter water
Disease	• Cause of the disease (infectious or non-infectious) • Non-infectious (Is it nutritional, water quality related, genetic, pollutant, tumour, physical injury?) • Infectious (Is it caused by a bacterium, virus, parasite, fungi; is the pathogen an opportunistic or an obligate pathogen; virulence of the organism) • Possible source(s) of pathogen entry into the farm (e.g. other infected fish, equipment on farm, snails, birds, etc) • Method of spread of the disease (e.g. from one fish to another through contact, from parent to offspring via gametes) • Source of entry of the pathogens into the fish (water, gills, nares, wounds, via feed) • Severity and patterns of mortality (chronic, acute, sub-acute, acute, per-acute, latent).. • Clinical signs of the disease • Factors that affect resistance of the fish to the disease (e.g. species, age, prior exposure) • Environmental changes that enhance virulence of the pathogen and infection rates	• Lab diagnosis • Eliminate predisposing factors • Prevention, treatment and control measures for the disease • Institute biosecurity measures

8.4.5.1 Immuno-stimulants and Vaccines

The purpose of giving vaccines is to safely expose the fish to a pathogen in a cost cost-effective method to improve survival and production efficiency.

Vaccines against bacteria, bacterins, are available for use in aquaculture. Protection is by antibodies produced only and boosters are usually required.

Advantages and Disadvantages of Bacterins

	Advantages	Disadvantages
Bacterins	Safety Low cost	Efficacy is poor to moderate Often need booster

Factors that affect the efficacy of Vaccination

The efficacy of vaccination depends on the health status of the fish, the type of vaccine being used and environmental factors that may affect the quality of the vaccine and vaccination process (see table 43).

Table 43: Factors to Consider for Fish Vaccination

Fish	Vaccine	Exposure dose to wild–type organism
• Age – young fish have to be immuno-competent • Nutrition status– vitamins and minerals are co co-factors for many immune functions • Genetics – variability in immune responses • Selection for protection against one disease may lead to increased susceptibility to others • Stress factors - override effects of vaccination • Population characteristics	• The organism • How it causes disease and type of immune response that 'combats" it. • Antigenic similarities/differences • Type of vaccine (killed or live) • Delivery method used for administering the vaccine: – Injections: usually require adjuvant to increase efficacy – Baths: often used of young fish – Oral: often problems with vaccine uptake • Dose	• Interference from multiple vaccines • Concurrent diseases • Husbandry practices • Handling practices • Stocking density • Environmental management • Record management

Successful vaccination programs:

- Show consistent efficacy and safety under field conditions
- Use application methods that can be integrated into production cycle
- Net reduction in production costs/risk losses
- Reduced mortalities
- Improved production parameters
- Not necessary for complete eradication
- Can be produced in commercial volumes and are available

8.4.5.2 Sanitation and Disinfection

Liming to Sterilize ponds and other facilities

Hydrated lime (calcium hydroxide) is used disinfect production ponds and other units (see also Module 5). It does this by causing a rapid rise in pH to 12 or higher, a level which will kill most disease agents and/or pests.

Drain and clean ponds or premises prior to application. Enough hydrated lime should be added to cover the entire pond bottom with a thin layer, and then water added. The elevated pH will last for about a week. **Do not stock** fish during this period.

Also Note:

- Always check the pH before stocking.
- The use of hydrated lime is recommended when there is concern of carrying diseases or pests over to the next crop.
- Do not add hydrated lime when fish are present in a pond or tank. The rapid increase in pH is almost always lethal for fish.
- Hydrated lime is a strong base. Care should be taken when applying it to avoid breathing the dust or allowing contact with skin or eyes.

8.4.5.3 Treatments

Treatments are only given to help reduce the severity and other negative impacts of a disease by interrupting an infectious process. Treatments supplement the fish's natural immunity. They are **NOT** a substitute for good husbandry.

a) Types of Treatment

Anti-bacterial, anti-parasitic agents, vaccinations, anesthetics

b) Determining whether to treat

Before giving any treatment, the following questions should be asked:

1. Whether or not the disease is treatable and if so, the likelihood of successful treatment?
2. The likelihood of the severity and spread of the disease increasing
3. The cost: benefit of administering the treatment taking into account:
   - costs of giving the treatment,
   - Impact of handling on an already stressed population,
   - Likelihood of the disease waning
   - Overall cost of giving treatment versus value of the fish?
4. Whether the fish are in good enough condition to withstand the treatment?
5. Do the severity and mortality trends of the disease warrant treatment?

c) How to Give Treatments to Fish

Table 44. Lists the different methods for administering treatments to fish.

Table 44: Methods for Administering Treatments to Fish

Type of Treatment	Description	Advantages	Disadvantages
Topical	• Drug or chemical applied directly to lesion	• Direct contact with lesion	• Each fish must be physically handled • Labor intensive
Injection	• Antibiotic injected directly into fish into the abdomen or muscles. • Method also used for vaccination	• Each fish receives exact amount of drug	• Each fish must be physically handled • Labor intensive
Food additives	• Antibiotics incorporated into the feed or mixed with oil and sprayed on after extrusion.	• Easy to apply to ponds and cages	• Not all fish receive same dose • Not applicable if fish are not feeding
Dip	• Fish are placed in a strong concentration of chemical for up to two minutes; • Usually for small numbers of fish	• All fish are treated	• Fish have to be handled; • Fish are exposed to high chemical concentration which adds to stress; • Labor requirements
Bath	• Fish are placed in a moderately strong chemical for up to 1 hour. • Aerate and observe fish during process • In a flow through system, turn off water, treat fish, and then turn water on to flush out chemical. • Recirculating system: set up the system to prevent damage to bio filter	• All fish receive same dose • Fish are not handled in this method.	• Fish must be handled if not done in rearing tank
Flushing	• Concentrated chemical dosed into the inlet of a flow-through system and "flushed" through. • Usually done in raceways.	• Not labor intensive • Fish are not handled • All fish receive same dose	• Fish may react adversely to chemical
Indefinite	• Chemical applied in a relative low concentration to a pond and is allowed to dissipate naturally.	• Easy application; • Fish are not handled • Not labour intensive •	• Not all fish receive same dose if chemical is not distributed evenly.

d) Calculating the Required amount of Treatment

$$\textit{Weight of chemical required} = Volume \times CF \times ppm\ needed \times \frac{100}{\%\ ai}$$

Where:

Volume = water volume in container/production unit

= area of unit x depth of water

CF = conversion factor to give weight of chemical equivalent to 1 ppm in one-unit volume of water

ppm = desired treatment concentration in parts per million*

% ai = % active ingredient of the chemical as indicated on the label

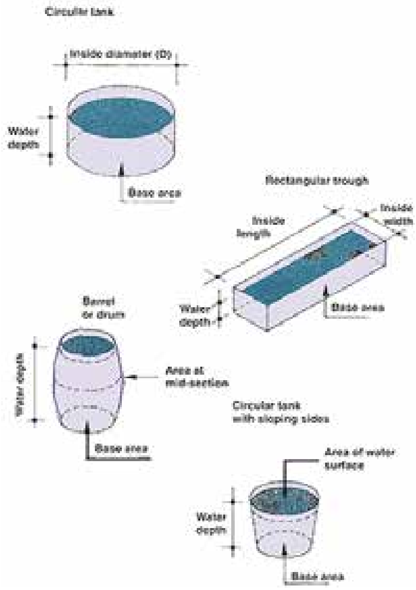
***Equivalents**

PPM = One weight unit of a chemical is added to 999,999 weight units of water

1 **gram** in 1000 ml = 1000 **ppm**

1 ppm= 1 mg/liter

I.0 litre = 1,000,000 mg



How to estimate water volume in different shaped containers (Adapted from FAO).

e) Selecting the Treatment

The choice of treatment depends on the:

- **Disease:** Know all treatment options
- **Fish:** Age, Species
- **Culture system:** Volume, acres, water quality parameters
- **Chemical:** potential toxicity of chemical to be used, its effectiveness, temperature tolerance, effects on oxygen, potential impact for the environment and consumers.

f) Common Treatments

Use only treatments known to be approved for use in food animals if the fish is for consumption. The following are treatments that may be used in food fish (table 45):

Table 45: Treatment Rates

Chemical	Administration Rate	Indications	Contra-indications
A: TOPICAL TREAMTENTS			
Formalin *(37% formaldehyde)* *Comes in various trade names*	• Ponds 10-25 ppm (0.015-0.025 ml/L) • Bath (tank) 125-250 ppm for 1 hr	• Control of protozoan parasites, Monogenic trematodes and fungal infections on eggs	• Do not use at less than 5o C • Phytotoxic: will kill algal bloom • Diseased or young fish may not handle upper rates • May be cost prohibitive in large ponds

Chemical	Administration Rate	Indications	Contra-indications
Copper Sulfate *(CuSO4)*	• Considered 100% active • Treatment rate (ppm) = total alkalinity / 100 • Ex. TA=75 ppm as CaCo3 • 75/100 = 0.75 mg/L • This will also be called "a full part". Some will use "half" or "3/4" part • **Chelated copper** – chemically bound to either inorganic or organic compound - Allows copper to remain actively in water for longer period of time - Rate depends on formulation; read directions	• Treatment of protozoan parasites such as ***'Ichthyophillus mulitphillis*** and ***Flavobacterium columnare*** infections	• Use extreme caution in water less than 30 ppm TA - Very toxic • Labeled with EPA as algicide: will kill the algal bloom and cause oxygen problems • Do not use "Full" rate on very young fish
Potassium permanganate	• Considered 100% active • Oxidizer (effects cellular membranes and function) • Rate - **Pond**: depend on the oxidative demand of water o Add 2-3 ppm at a time o Purplish "wine" color to develop in water for 4-8 hrs - **Tank**: 2-4 ppm for 1 h	• Protozoan parasites and ***F. columnare*** infections	• Phytotoxic • Diseased or young fish may not handle high rate
Salt	1-3% solution 10-30 min	• Parasites • Disinfect wounds	
Organophosphate *(Dylox or Masoten)*		• Monogenetic trematodes, leeches, crustacean parasites (copepods, ***Lernea sp***. and ***Argulus sp***.)	• Can be toxic to both fish and humans
Nitrofurazone	antibiotic • Used as a bath or indefinite water treatment	• ***Used in baitfish, tropical fish systems, ornamentals;***	• Absorbed into fish no food fish

Chemical	Administration Rate	Indications	Contra-indications
Romet (ormetoprim and sulfadimethoxine)	Antibiotics incorporated into the feed. Only 2 approved for use in food fish • Formulated to feed at a rate of 1% or 3% of the body weight. This gives a final rate of 50mg/kg of fish. • Feed 5 days • Withdrawal 3 days in catfish • Withdrawal 42 days in salmonids	• ESC in channel catfish; Furunculosis in salmonids	• Heat stabile • Palatability problems
Terramycin (oxytetracycline)	Rate fed 50-75 mg/kg BW; Formulated to feed 2% of the body weight per day Feed 10 - 14 days; Withdrawal 21 days in all species before slaughter Heat labile	• Labelled to treat motile ***Aeromonas*** infections • Very effective for ***F. columnare*** infections (INAD). • Get in sinking feed or in "cold" extruded feed	• With all antibiotics, feed until dose and time frame is complete; do not give more than two "rounds" or treatment periods. o *antibacterial resistance* • Prophylactic treatments are contra-indicated because of antimicrobial resistance
Tranquilisers	• Used to immobilize fish for handling • MS-222 (FDA approved) - Use 20-200 mg/L – depending on need - 21-d withdrawal before slaughter in food- fish • Clove oil regarded as safe for use in food fish but is not an approved drug - Up to 150 mg/L depending on species and need - No withdrawal time		

8.5 Common Diseases in Ugandan Aquaculture and their Control

8.5.1 Non-Infectious Diseases

8.5.1.1 Environmental (Water Quality) Diseases

a) Low Dissolved Oxygen Syndrome (LODOS or Environmental Hypoxia)

In production systems, DO levels can also suddenly drop to lethal or near lethal levels or slowly over several days. When DO levels suddenly fall, fish immediately show signs of stress and/or mortality (figure 95).

Gradual declines in DO over several days results into LODOS. The common causes of LODOS include:

- Overcrowding
- Low Water Flow or exchange rates
- Algae Population Crash: may be due to natural causes or because of deliberate treatment to reduce levels of algae in ponds and/tanks
- Cloudy Days: On cloudy days algae respire; there is no photosynthesis so dissolved oxygen is used up rather than produced during the day

Clinical Signs

- Acute Mortality
- Piping for air
- Gathering at inflow
- Fish non-responsive to external stimuli
- Death with operculum flared/mouth agape

Figure 95: Tilapia piping for air

Prevention of LODOS

- Maintain DO at or above 5 mg/l

Diagnosis

- Measure DO trends on site
- In ponds, it is beast to measure early in the mornings between 5.00 to 6.00 a.m.

Management of Low Dissolved Oxygen Levels

- Increase aeration
- Reduce feed rates
- Reduce fish density
- Manage algal blooms

Temperature

- Sudden changes in temperature are extremely stressful for juvenile fish.
- Fish need to be acclimated when temperature differences are greater than 3oC at rate of about 1oC per to avoid stress
- Deaths as a result of sudden temperature changes are not immediate. Mortalities begin to occur several days after sudden temperature changes.

b. Low pH

The optimum range of pH is 6.5 to 9.

- Acute low pH causes acute mortality, acute stress and hypoxia.
- Chronic low pH results in increased mucus production and chronic stress response.
- Indirect effects of low pH include:
  - Increased toxicity to other water quality parameters (see Module 5)
  - Some metals become more toxic at low pH (e.g. aluminium)

Clinical Signs

- hypotrophy and mucus production in gills (see figure ... above)
- Sloughing of cells from skin and gills
- Causes hypoxia
- Increase unionised ammonia at high pH

Treatment

- Change and add buffer to water
- In aquaria if pH is too high, add an acid such Muratic acid (HCl) or acetic acid.

c. Ammonia Poisoning

The levels of ammonium (non-toxic) and ammonia (toxic) in water are temperature and pH dependant (Module 5).

Clinical Signs

- Hyper-excitability
- Fish stop feeding
- Is among the chronic causes of hypertrophy and hyperplasia of the gills
- Reduced growth and resistance to diseases

d. Excessive Levels of Dissolved Carbondioxide (Hypercarbia)

Hypercarbia is commonly associated with in recirculatory systems and hatcheries sourcing underground water. It is also observed where there is over-crowding, algal bloom crushes and poorly buffered water is used for production.

It occurs when water has low pH and levels of dissolved CO_2 exceeding 15 mg/l.

High levels of dissolved carbondioxide in water:

a. Inhibit diffusion of CO2 out of the blood
b. High blood CO2 reduces blood pH
c. Reduces the ability of fish to get oxygen into blood

Fish consequently become weak, loose appetite, reduced growth and increased susceptibility to disease.

Diagnosis:

water quality test kit

Treatment:

aeration, decrease stocking density and add lime (slaked or hydrated to immediately raise pH)

e. Nitrite Poisoning (Brown Blood Diseases)

Commonly associated with re-circulating systems

Clinical Signs

- Brown blood in the gills and internal organs (Figure 96)
- Signs of hypoxia even when DO levels are suitable
- Fish non-responsive to external stimuli

Figure 96: Brown Blood Disease

Diagnosis

Measure nitrite levels with water quality kit.

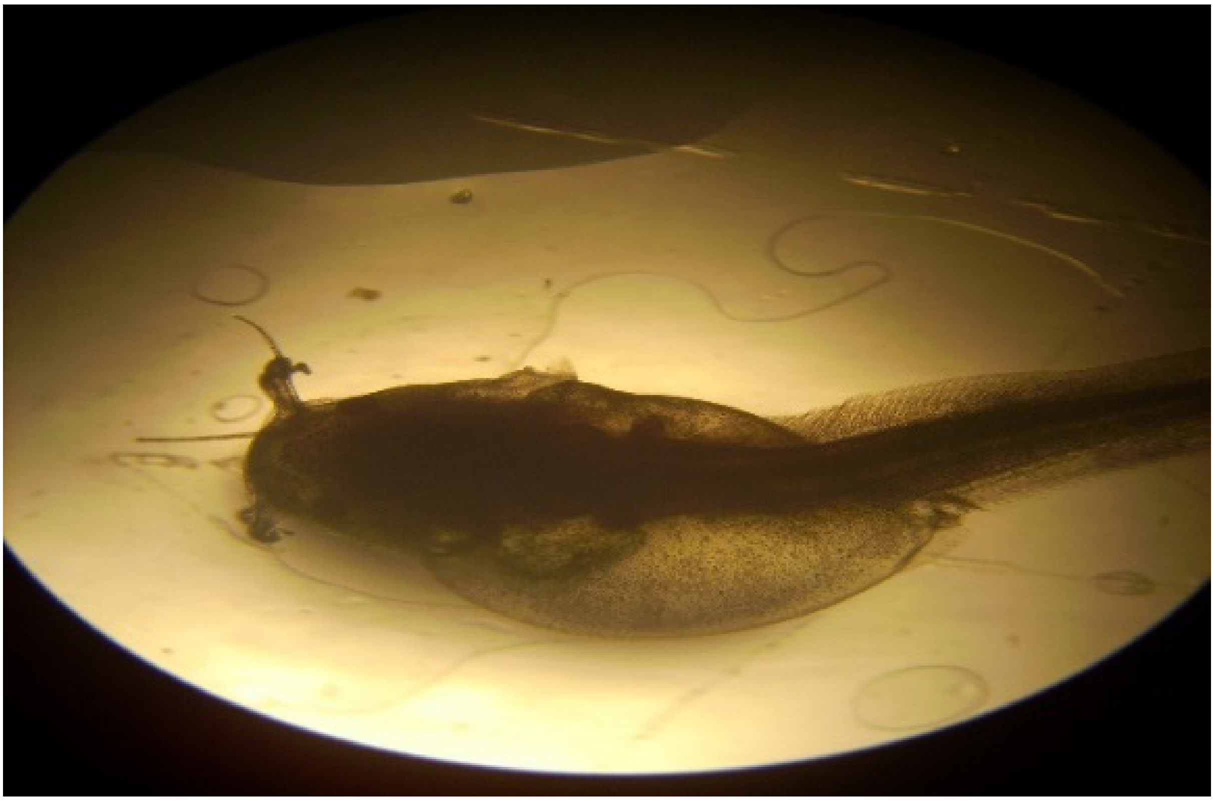
Treatment

- 25 to 50% water exchange
- Increase aeration
- Add nitrifying bacteria to bio filter
- Decrease fish density
- Reduce feedings
- Add common salt to the water at the rate of 10 times chlorine per ppm nitrite

f. Gas Bubble Disease (Gas supersaturation)

When there's super saturation of gases under pressure in the water, the gases diffuse the blood vessel. Gas bubbles appear in the blood vessels of the various body organs including the eyes, gills, skin, viscera and peritoneal cavity (figure 97).

Figure 97: Gas bubbles in larvae associated with supersaturated levels of carbon dioxide in water



8.5.1.2. Nutritional Diseases

Most nutritional diseases develop slowly over an extended period and are difficult to distinctly diagnose.

a) Malnutrition/Stunting

When fish do not get enough food (energy and protein) their growth becomes impaired, they are lethargic, poor body condition (thin) and are more susceptible to diseases. For their age, they will be much smaller – commonly referred to as stunting.

b) General Vitamin Deficiencies

General signs of vitamin deficiency include anorexia, tissue deformities, reduced growth, mild anaemia and reduced resistance to disease.

c) Vitamin C Deficiency

In Uganda, signs of Vitamin C deficiency are common on farms feeding on-farm made feeds and when feeds are used after two-three months of the manufacturing date. Growth rates are poor, increased susceptibility of secondary infections and skeletal deformities are observed (figure 98). Fish in ponds with good productivity rarely show signs of vitamin C deficiency.

Figure 98: Skeletal deformities arising from Vitamin C deficiency. *Catfish cannot produce Vitamin C. It must be added in feed. Vitamin C is often lost in the processing of feed so stabilized forms that will not be break down are required in the feed.*

a) Scoliosis and skin ulcerations as a result of vitamin C deficiency

b) Levels of progression of Broken-Head Syndrome in catfish

Control and Treatment:

Increase amounts of feed C in the diet:

- Add premixes to the feed (**Module 6**)
- Spray onto the feed stabilised forms of Vitamin C, or
- Chop finely or crush and mix greens into the fishes feed. Russian comfrey and sukuma wiki (kale) are a good source of vitamin C.

i) *Mycotoxins in Feed*

Are released from moulds found in feedstuffs and the feed. They cause liver and kidney necrosis which progressively results into decreased growth and increased susceptibility to diseases (figure 99).

Figure 99: Mould and symptoms of Mycosis from Consumption of Mould Feeds

a. Good Pellets. *Note the uniform colour and with no powdery substance.*

b. Mouldy Pellets. *Note (i) the colour of pellets is not uniform, (ii) the powdery substance that remain on the hand and (iii) the eyes in the pellets. The whitish tinge and powdery substance that remains on the hand are due to mould.*

(c) Gross lesions (right)

Preventive Measures

- Keep feeds in a dry, cool place and out of direct sunlight
- Ensure short turnover between batches of feed
- Avoid using or storing feed in metal or other containers that on which water can condense.

8.5.1.3 Physical Trauma

Physical injury as a result of poor handling, aggression by fish, exposure to rough surfaces and sharp objects can depending on intensity result into loss of scales, fractures, damage to tissue and tears in skin.

This causes stress, pain and damages the external barrier to pathogen entry into the fish. Performance and secondary infections are more likely in such fishes.

Control

1. Handle fish gently
2. Prevent aggression between fish within production units by reducing conditions that result in territoriality and promote size differences in the population:
   a. stock at optimum density = too low stocking densities promote territoriality
   b. Adopt feeding techniques that promote uniform and rapid consumption of feed by fish (Module 6)
3. To promote wound healing and prevent infection of/through wounds becoming infected, give affected salt bath/dip (1 - 3 ppm salt) to fish with physical injuries as soon as possible

8.5.1.4 *Genetic Conditions*

Genetic conditions are inherited from the parents.

They commonly present as:

- Physical abnormalities (body anomalies such as of the skeleton, body organs or skin pigmentation)
- Level of susceptibility to diseases
- Growth potential
- Will normally affect one or a few fish in the cohort rather than the entire population

Prevention and Control

- Avoid inbreeding in broodstock

8.5.1.5. *Tumours*

Invasive and non-invasive cancers occur in fish. Common non-invasive tumours include papillomas caused by the papilloma virus.

8.5.2 Infectious Diseases

The commonest stress-mediated infections in fish are bacterial and parasitic infections (section 8.3.3.).

8.5.2.1 *Bacterial Infections*

The symptoms of different bacterial infections tend to be similar depending on whether the infection presents as:

a. Acute bacterial septicaemia
b. Skin and gill infections
c. Chronic disease (table 46).

Table 46: Bacterial Infections

Type of Infection	Common Causes	Remarks
Bacterial Septicaemia	• Aeromonas salmonicida • Vibrio anguillarium • Flavobacterium columnaris	• Infection with primary pathogenic bacteria or sero-types that spread rapidly throughout the body • May or not not be bleeding/haemorrhages
Skin and gill infections	• Aeromonas hydrophilla • Flavobacterium columnaris	• Affect the body system along with skill and gill lesions • Prevalence of external lesions is closely linked with husbandry practices especially water quality, injury, • Presence of other bacteria, fungi or parasites • Show signs of respiratory distress – gasping, puffed out gills, gather towards inlets or stack at water surface, • Fin or gill rot

a. ***Columnaris disease (Flavobacterium columnaris infection)***

Clinical signs

- Frayed fins
- Fish become lighter in colour especially around abdomen
- Open lesions may develop
- Yellowish growths may develop around mouth giving a ***'cigar-mouth'*** or ***'saddle-back'*** appearance.

Diagnosis

- Clinical signs and history
- Microscopy - wet smears
- Confirmatory diagnosis from laboratory cultures

Treatment and Control

1. Reduce stressors: improve water quality, minimise stress during handling, improved nutrition
2. Treatment options:
    - Bath treatment in tanks or indefinite pond treatment of 2 to 4 ppm potassium permanganate.
    - Salt bath of 1 – 2 ppt

NB: Once a full outbreak occurs it is very difficult to control and treat. It is better to prevent the disease with good management than wait to get to the scepticemic stage when antibiotics may be required and its often not economical to treat.

In African catfish tank-based hatcheries, Columnaris disease often appears after there has been power-shut down and consequently moments of limited/no water exchange and aeration in tanks. During such moments salt the water in the tank at rate of 1ppt to stimulate mucus secretion and prevent the ***F. columnaris*** bacteria attaching onto the fish. When power returns, reduce half the water in the tank, add fresh water with aeration and make a 2 ppm potassium permanganate dip bath a minute. After which follow normal water flow rate/exchange regiment.

b. Aeromonas hydrophila infection

Clinical signs

- Ulcerations of the skin
- Signs of fin rot of the fins
- Open lesions may develop
- Reduced appetite
- Lethargy
- Mortalities

Diagnosis

- Clinical signs and history
- Laboratory bacterial isolation from lesions

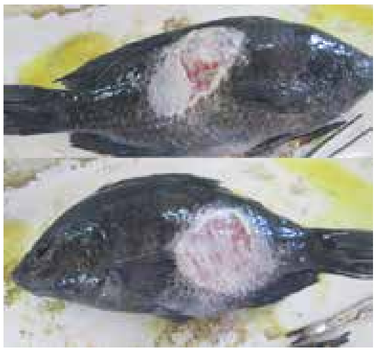
Treatment and Control

1. Identify and reduce stressors: improve water quality, minimise stress during handling, improved nutrition

2. Observe sanitation and hygiene e.g. disinfection of nets, isolation of affected cohorts and proper disposal of dead fish.
3. Treatment options:
    - Prescription based on culture and sensitivity laboratory results.
    - Salt bath of 1 – 2 ppt

c). Streptococouss sp. (Strep)

Bacterial infection caused by ***S. iniae*** and often complicated with other bacterial cocci such as *Enterococcus* and *Lactococcus*



Clinical signs

- Acute to chronic diseases
- Fish look dark
- Frayed fins
- Haemorrhages on skin
- Popeye sometimes

Diagnosis

- Clinical history and signs
- Post-mortem lesions - white nodules in spleen, kidney and other viscera, cavitation's in muscle
- Laboratory for confirmatory diagnosis

(NB: external clinical signs look very similar to Aeromonas hydrophila above. Pictures courtesy of B. Mudenda)

Treatment and control

- Sanitation and biosecurity
- Antibiotics upon prescription and evaluation of prognosis
- Vaccination in endemic areas where recurrences are high
- Use pathogen-free stock
- Adopt good husbandry practices

d) Mycobacterium sp. (fish tuberculosis)

Clinical signs

- Usually chronic condition
- Nonhealing shallow deep skin ulcers
- Pale colouration
- Loss of weight
- Ulcers on the cornea
- White nodules on viscera
- Ornamental fish more predisposed

Diagnosis

- Clinical history and signs
- Post-mortem signs
- Laboratory diagnosis

Treatment and Control

- Disinfection and quarantine

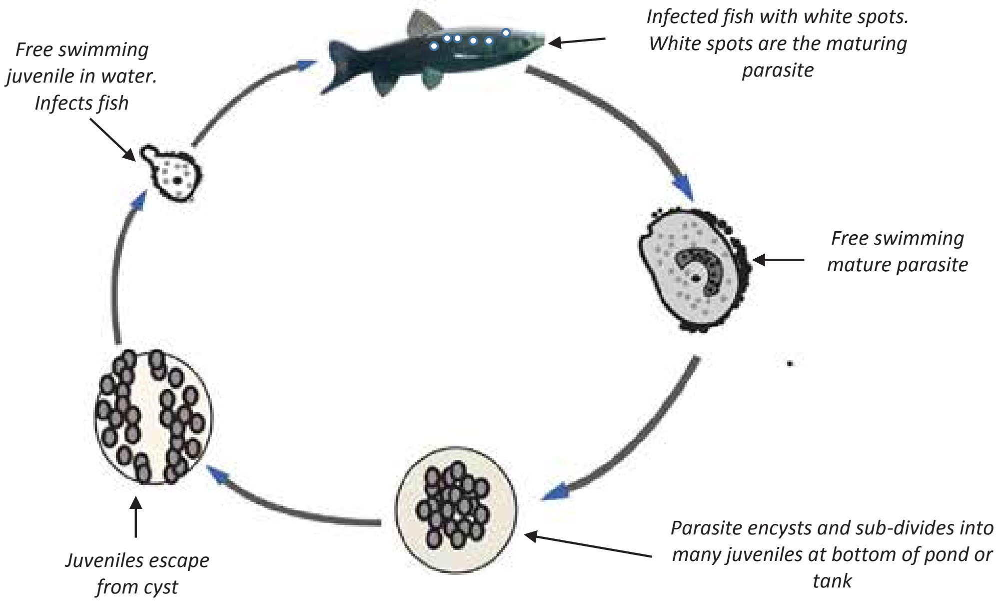
8.5.2.2 Parasitic Infections

The commonest fish parasites in Ugandan fish farms belong to the following broad groups:

1. Protozoa: Myxosporidia, Icthyobodo (Costiasis), Icthyophithrirus, Trichodina, Chilodonella
2. Metazoa:
   - Crustacea: Argulus (fish louse), Lernaea (anchor worms)
   - Trematodes (flukes): Monogenic and digenic trematodes
   - Cestodes (tape worms)
   - Nematodes (round worms)
   - Leeches

Parasites gain access to fish via an intermediate host (figure 100).

Figure 100: Life Cycle of *I. Mulitifillis.* It takes three to five days for the parasite to complete this cycle when water temperatures are about 20^{o}C



a) Parasites of Gills, Fins and Skin

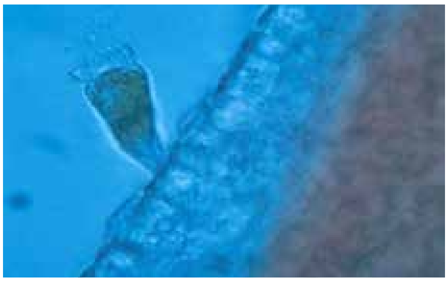
Most of the parasites that affect the gills, fins and skin are opportunistic organisms. Their ability of cause infection and the severity of disease depends on the immune status of the fish. Fish that are stressed, poorly fed, raised under sub-optimal environmental conditions (poor water quality), have a disease condition, injured and juveniles are more susceptible to parasitic infestations.

Clinical Signs and Symptoms

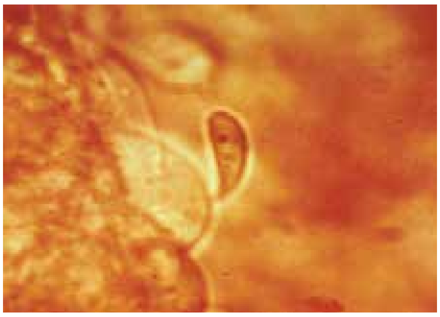
Parasites attach and cause damage to the lining of the gills, fins or skin. This causes irritation and points of entry for other pathogens such as bacteria and fungi. The affected area becomes inflamed, excess mucus secretion and sometimes there is bleeding. When the gills are affected, ability to take up oxygen is impaired and fish show signs of anoxia (section 8.5.1.1.). On the skin and fins, there is often a change in pigmentation and fin erosion at the affected area. Irritation of these tissues causes discomfort to the fish and causes them to loose appetite, swim erratically, congregating at the surface or inlets where water quality is often better and become lethargic and anaemic.

Figure 101: Common Fish Parasites

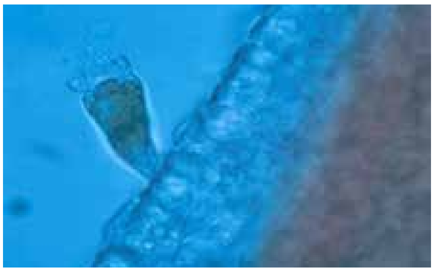

Trichodina sp. | *Capriniana (Tricophrya)*

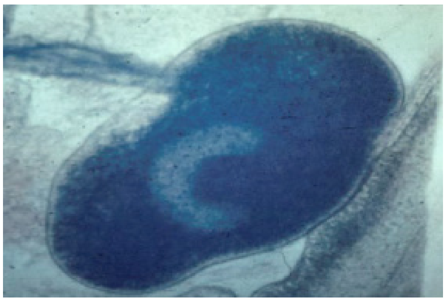
Ambiphrya (Scyphidia) | *Apiosoma (Glossatella)*



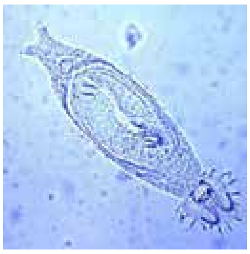

Icthyobodo



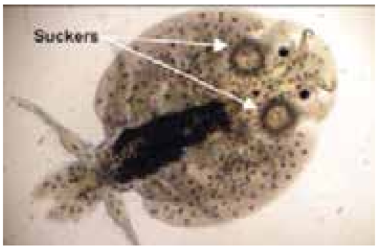

Epistilis sp. | *Leeches*



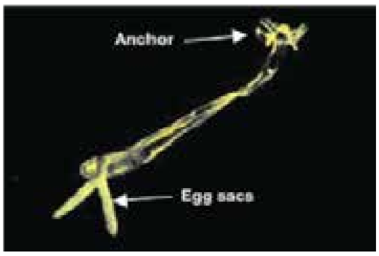

Ich or White Spot (Icthyophthirius multifillis)

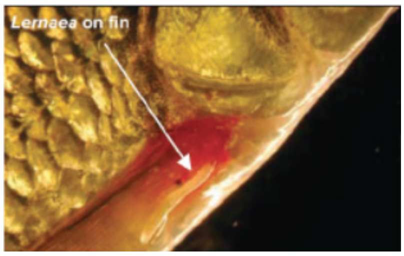


Grypdactylus	Dactylogyrus



Argulus sp.





Anchor Worms	Lernaea sp.

Diagnosis

- Clinical signs
- Gross pathology for large parasites
- Microscopy
- Laboratory diagnostics

Prevention and Control

- Adopt best management practices paying attention to water quality, nutrition, stocking density and handling practices.
- Sanitation and hygiene focusing at interrupting the life cycle of the pathogen and on preventing re-infection. For example, slashing around to control snails, proper disposal of rubbish, dead fish to control of predators and minimize birds visiting or settling around the farm and control accumulation organic matter in rearing facilities.

Treatment

- Indefinite treatment
  - 15 ppm formalin
  - 2 ppm potassium permanganate
  - 0.25 ppm copper sulfate
- Bath
  - 166 to 250 ppm up to 1 hour - formalin

For Ich, use acidified copper sulphate applied twice, once every 7 to 10 days.

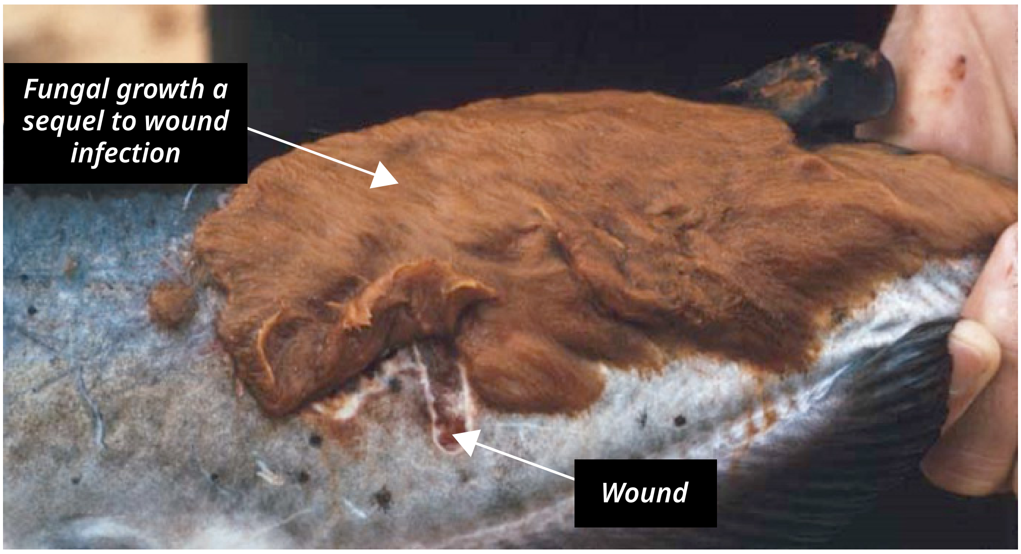
b. Internal Parasites

Internal parasites may affect the eyes, muscle tissue, intestines and other internal organs. As in (a) above, their ability to affect the fish dispends on the fish's health status and management conditions on the farm.

8.5.2.3 Fungal Infections

The commonest fungal infection on farms is caused by ***Saprolgenia*** sp. It is an opportunistic organism that is often associated with secondary infections. A cotton-like growth is observed on the fish or dead fish eggs in hatcheries. Heavy infections develop when the fish's immunity low due to other running bacterial or parasitic infections (figure 102)..

Figure 102: Saprolgenia infection



Prevention and Treatment

- Ensure good growing conditions
- Treat all injuries with salt immediately
- Formalin

8.5.2.4 Viral Diseases

Endemic viral conditions in fish have not yet been confirmed in Uganda.

8.5.3 Notifiable Diseases of Concern

The following highly infectious diseases, though not endemic to Uganda, must be reported to the Fisheries Officer and/or Veterinary Officer if one comes across them or suspects a case. They are caused by obligate pathogens to which commonly farmed species in Uganda are susceptible.

a. *Tilapia Lake Virus*

The tilapia lake Virus has been identified in Uganda, but no clinical outbreaks have so far been reported.

Clinical Signs (figure 103)

Figure 103: Symptoms of TiLV. *(a) discolouration, loss of scales and skin lesions, (b) naturally diseased red tilapia showing skin haemorrhages, (c and d) experimentally diseased Nile tilapia showing exopthalmia, abdominal swelling and scale protrusion.*

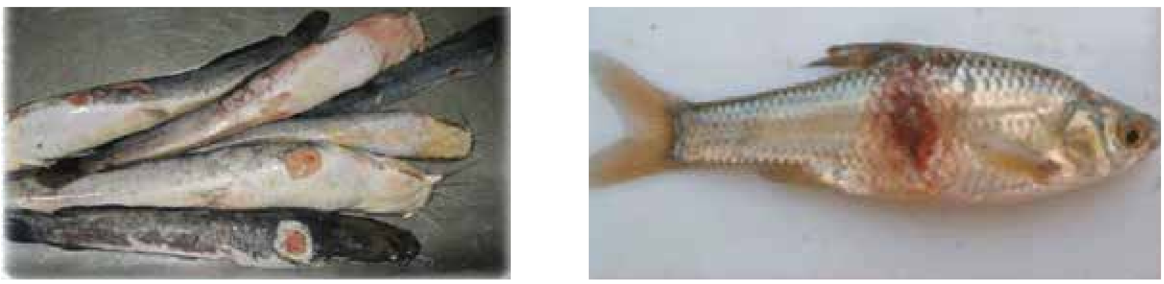
b. *Epizootic Ulcerative Syndrome (EUS)*

This is a fungus infection caused by ***Aphanomyces invadans*** that affects fin fishes.

Clinical Signs

Necrotic skin lesions that progress into congregation and proliferation of blood and epithelial cells in affected tissues that have been invaded by the fungus (figure 104).

Figure 104: Signs of EUS infection in African catfish (left) and *Barbus* sp. (right).



Occurrence of the disease is associated with seasonal weather patterns (onset of rains and flooding of plains) In geographical regions where the disease has been reported. High fish mortality rates are typical in outbreaks.

c. Koi Herpes Virus (KHV) Diseases

KHV Disease is notifiable infectious viral disease that affects carp, more commonly associated with the ornamental Koi carp.

Figure 105: Gill lesions in KHV Disease

Clinical Signs

Gill lesions, red and white patches on the gills. Fish may have sunken eyes and pale patches on the skin or a notched nose (figure 105). This may be complicated with signs of secondary bacterial and parasitic infections.

d. Diagnosis and Control of all Notifiable Diseases

- Immediately report suspected cases to your local Veterinary and/or Fisheries Officer for on-ward reporting to National authorities.
- Sample collection and identification procedures based on:
  - Laboratory standards
  - OIE ***Manual of Diagnostic tests for Aquatic Animals – use latest versions***
- Implement management plan that has been predetermined before outbreak occurs

8.6 Predator Control

Predators are a major source of stress to fish. Predators cause stress and eventually losses because they:

1. Consume the fish in the pond,
2. Consume the fish's feed,
3. May transmit parasites and other infections to fish,
4. scare the fish when they are chasing them up,
5. Mause physical injury to several fish in the process of hunting, and
6. Reduce pond carrying capacity.

Wounded fish left in the pond cannot get to the feed as well as the other normal fish. This is because, their eyes might be injured, or their open wounds might get infected. Consequently, their growth rate slows, and chance of survival drop. Controlling predators is therefore important in commercial production.

The most common predators are:

1. **Humans Beings**

   Provide security to your premises by fencing off and keeping the place active.

2. **Frogs and Snakes.**

   The populations of frogs and snakes can be controlled by keeping premises around clean and clear. Do not allow bushes to grow around the ponds. Water channels should also be kept clean and clear. Screen the ponds as recommended. Screens within the water channels also help reduce frogs' access to the ponds. Frogs tend to come into pond areas via the water channels.

3. **Birds**

   a. Wading birds (such as the heron, marabou stock, hamakop) walk into the pond to catch fish. To control wading birds, ensure pond average water depths of 1 meter so that the birds are unable to stand in the pond (figure 105).

   b. Diving birds (such as the king fishers, ducks) fly over or swim on the water surface then dive down to pick the fish. Tying string at close intervals over the pond prevents them from being able to fly away once they have come down or dive through the strings.

   c. Avoid setting your ponds near places where birds can perch, such as under telephone or electricity wires/poles, trees, etc. These provide a spot for birds of prey to sit, watch the fish and time when best to hunt them.

   d. Scarecrows or sudden loud noises may be used to scare away birds. However, if this option is used, change the tactics at least every two weeks. This is because the birds learn fairly fast that the object is not life threatening and will eventually ignore the scarecrow or noise.

   e. Learn at what time birds come to hunt fish. Most times, birds come down to get fish soon after feeding, early in the mornings or late in the evening. Be around at such times to scare away the birds. Human activity helps to keep birds away.

   f. Do not leave any dead animals or feed, etc. lying around ponds because birds may come to feed upon them. Dispose of all rubbish and carcasses by burying them away from the pond area.

   g. String may be tied across the pond or specifically around the feeding area to prevent diving and wading birds predating upon the fish (figure …).

   h. One may also train dogs on the farm to scare away birds.

4. **Monitor Lizards and Otters.**

   Clear the bush around so that they have no nesting close by. Set traps to catch monitor lizards and otters.

Use non-lethal means to control predators. The common 'predators' other than man, are wildlife and these are protected by law. In the event that birds, otters, monitor lizards, snakes become uncontrollable then, report to the Uganda Wildlife Authority who will then have these animals captured and translocated.

Figure 106: Common Predatory Wading Birds

a. Marabou Stork

b. Yellow Bill Stork

c. The Grey Heron

d. The Jacana

e. The Hammerkop

f. Goliath heron

8.7 Biosecurity Control

The essence of biosecurity control is to prevent the entry, exposure and spread of fish pathogens, particularly those that are infectious and have economic, public health or negative environmental consequences.

The extension agents should be aware of requirements to implement biosecurity control at national level and support producers implement at farm level.

8.7.1 National Level

- Be aware of regulations concerning the control of animal1 (specifically aquatic) animal diseases.
- Diseases of concern to the country both notifiable and endemic as well as recommendations for their reporting and control.
- Establish the private and public sector stakeholders in your local area who may be concerned with maintaining biosecurity (i.e. movement, production, processing and trade of farmed and wild fish). Obtain their contacts, interact and build relationships with them
- Identity and prioritise the critical control points for disease entry and exit into the aquaculture and/or fish establishments in your working area (farms inclusive)
- Keep records of events
- Ensure compliance to local and national regulations
- Create and maintain awareness within local community within which one is working.

8.7.2 Farm Level

Ensuring biosecurity on an aquaculture establishment, entails developing and implementing a biosecurity plan based upon risks of pathogen entry and spread associated with the establishment (Tables 47).

Table 47: Basic Elements of a Biosecurity Plan

1. Farm location and farm facilities *(What are the risks of entry?)*	As much as possible ensure the establishment and its facilities are isolated from potential pathogens. The risks to consider • Farm location e.g. water or land-based, not next to public road, not too close to other farms, industrial areas, watershed, agro-ecological zone, etc. • Limit access onto premises for vehicles and personnel. Disinfection upon entry and clothing • Access of vermin, wild animals • Wind • Water sources
2. Physical attributes of the aquaculture establishment *(What are the risks of spread?)*	• Farm layout • Peri-meter fencing • Water reticulation and drainage • Design of respective production and other holding units • On-site movement plan for vehicles, fish, equipment, personnel • Delivery and storage of inputs (notably feed) and equipment • Public conveniences
3. Management facilities and establishment *(What are the risks of infection and control options?)*	• Instituting routine procedures for preventing introduction and spread of pathogens (i.e. Standard Operating Procedures (SOPs) • Awareness and ability of personnel to effectively implement SOPs • Regular review to improve effectiveness of SOPs • Quick response to emergencies and corrective action against issues that may arise • Record keeping

1 Some are general and would apply to both.

The specific details of a farm-level biosecurity plan depend on identified risks associated with the farm's operations, namely:

(i) species

(i) Production objectives

(ii) Targeted markets

(iii) Disease causing agent(s) of key concern

(iv) Production systems and management practices used

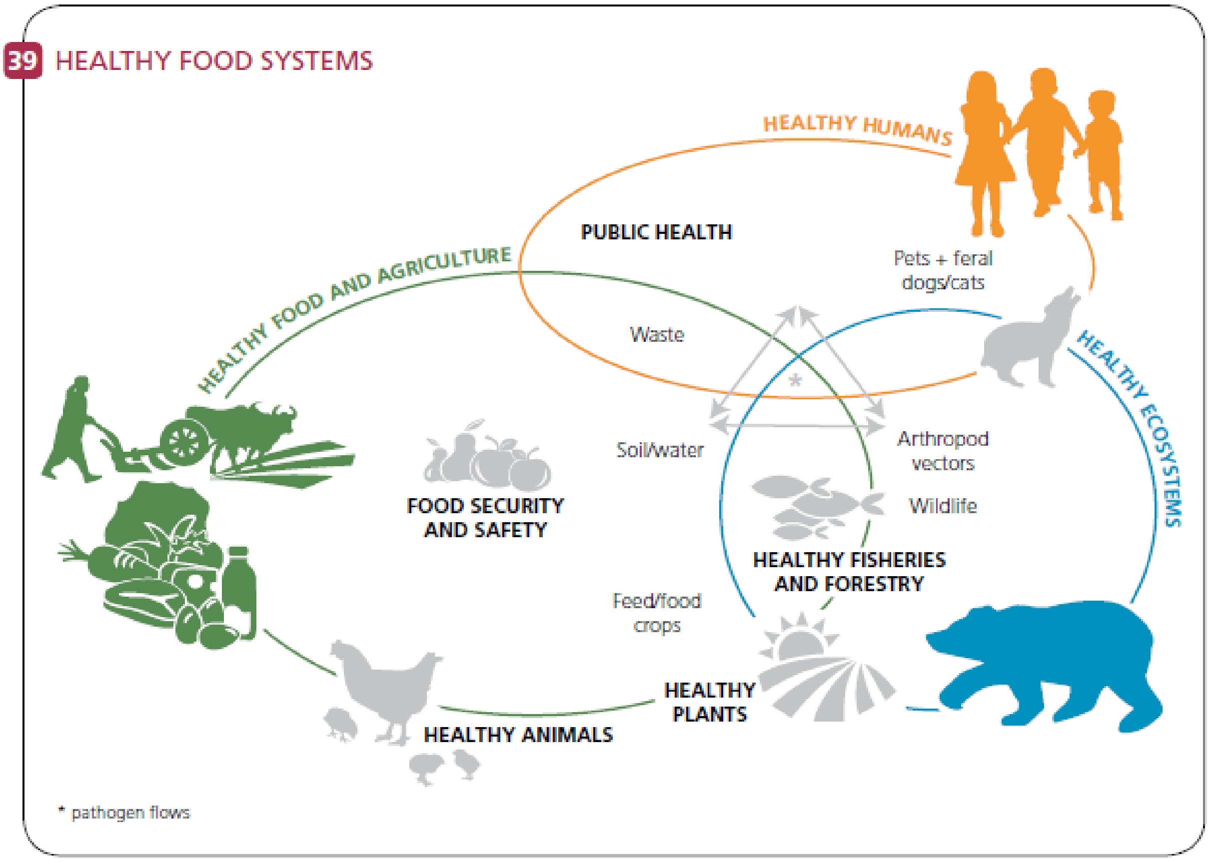
(v) Environmental characteristics

(vi) National and/or regional biosecurity plans

8.8 Public Health and Safety (One Health)

The figure 107. .below illustrates how terrestrial and aquatic food production systems are intertwined. Ensuring food safety and public health are consequently important parameters for the aquaculture producer. It includes occupational safety for farm personnel and those handling farmed aquatic animals.

Figure 107: Ecosystem interactions for healthy food production



8.8.1 Zoonotic Diseases

Zoonotic diseases are those that affect both man and animals. These are a potential hazard for farm workers and those handling farmed aquatic animals along value chain.

- Streptococcus sp.
- Mycobacterium,
- Escheria coli
- Leeches

8.8.2 Anti-Microbial Resistance

Figure 107 above shows how aquatic animal production is affected by activities on land. Anti-microbial substances used as medications for terrestrial animals, plants and humans end up in water and build-up in aquatic flora and fauna. Likewise, so do medications administered to fish.

Inappropriate use of anti-microbial agents affects the entire ecosystem and food-chain. This leads to indirect consumption of anti-microbials by non-targeted species that subsequently leads to resistance. For this reason, the use of anti-microbials in aquatic animals, particularly in food animals is discouraged. When their use becomes necessary, it should be based only on confirmatory diagnosis and prescription by veterinarian. The proper implementation of best management practices to great extent reduces the need for anti-microbial use.

8.8.3 Other Potential Communicable and Non-Communicable Health Hazards Associated with the Aquaculture Environment

a. Non-Communicable Diseases

- Physical injury due to falls on slippery wet surfaces
- Drowning
- New breeding sites for vectors such as malaria, schistosomiasis and dracunculiasis
- Contamination of water with farm waste from the farm including human, dead fish, chemicals and other waste
- Transmission of amoebic and bacillary dysentery, intestinal worms and cholera
- Conflict with livestock, agriculture or forestry activities
- Accumulation of heavy metals where fish farms are located close to telecommunication masts, roads, fuel stations, etc.

b. Communicable Diseases

- Enteric pathogens (***e.g. Salmonella, E. coli***) particularly where there's poor sanitation or farms are located close to sewage facilities or run-off (e.g. pit latrines).

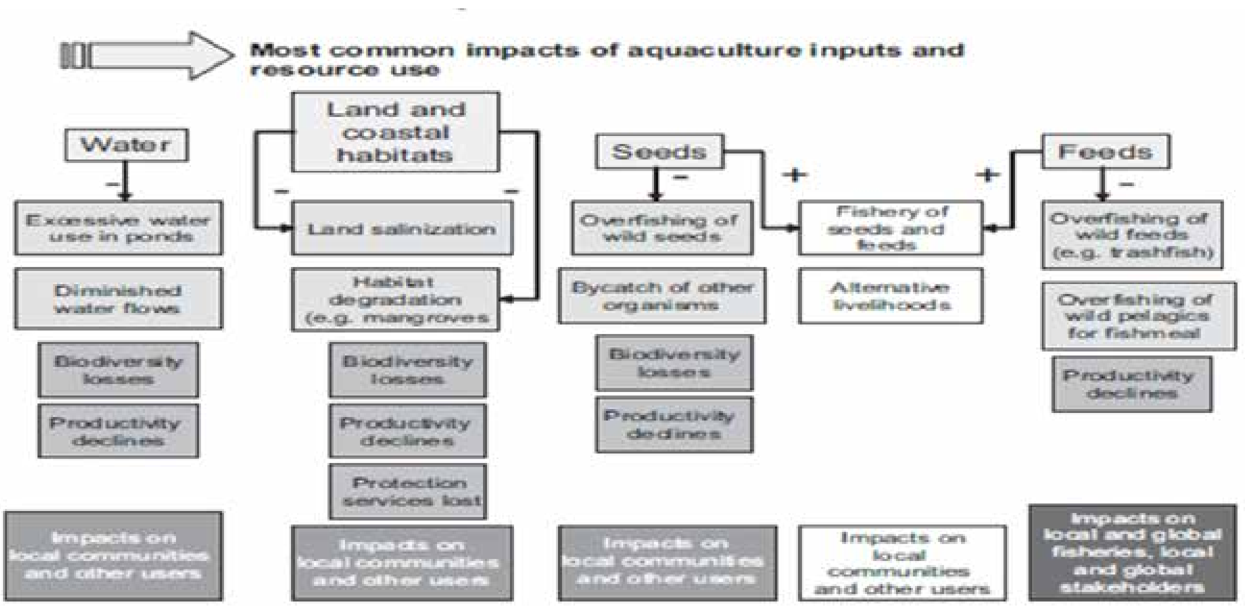
Mitigation Measures

- Avoid such sites and fish should be well cooked.
- Follow sanitary practices on the farm and when handling fish
- Monitor health status of personnel, water quality, fish and environment.

8.9 Environmental Impacts of Aquaculture

Aquaculture can have both positive and negative environmental impacts as illustrated in figure 108 Below.

Figure 108: Examples of positive (+) and negative (-) impacts related to aquaculture inputs and resource use (FAO, 2010)



Note: Positive (+) and negative impacts (-).

The following are the potential negative impacts of aquaculture culture and suggestions on how they can be mitigated against.

Table 48: Potential Negative Environment Impacts from Aquaculture

Environmental Risk	Suggested Mitigation Measures
Biodiversity losses	• Screening of inlets and outlets • Farm indigenous species
Excessive water use and diminished water flows	• Improve water use efficiency e.g. adopt reuse water systems where applicable, good quality feed and aeration • Integrated systems
Degradation of aquatic habitats	• Avoid establishing farms in sensitive aquatic habitats e.g. in wetlands, fish breeding areas
Overfishing for seed and fish meal	• Produce seed for aquaculture in hatcheries • Use plant-based proteins and/or fish by-products as source of protein for diets as much as possible

Environmental Risk	Suggested Mitigation Measures
Spread of diseases and AMR	• Observe biosecurity recommendations • Adopt best management practices for welfare of fish • Farm disease free stock • Prudent and judicious use of antimicrobials
Effluent/pollution	• Treat all farm effluent before release • Proper disposal of chemicals and medications used on farm

MODULE NINE:

POST HARVEST HANDLING AND PROCESSING OF FARMED FISH

This module provides guidance on how farmed fish should be handled from harvest to market.

9.1 Introduction

Once fish have been harvested, they are considered a 'product' and become a commodity for trade. The fish can be processed into different products based on consumer preferences, to add-value and improve the shelf-life. The most important thing during this phase is to reduce spoilage and ensure the product does is not contaminated so that the consumer receives a safe high-quality food product.

9.2 Fish Quality

Fish quality is a combination of:

- Fish food safety
- Degree of spoilage
- Consumer (market) preferences

9.2.1 Fish Food Safety

Safe foods do not cause illness to the consumer. The factors that may cause illness from the consumption of a foodstuff are termed **'food-safety hazards'**. The likelihood for food-safety hazards getting into contact with fish and fish products should be minimised right from production to the point of sale. The tools used to monitor, and control food-safety is the Hazard Analysis and Critical Control Points (HACCP) process.

The HACCP is a systematic approach for the identification, evaluation, and control of food safety hazards. Its objective is to prevent and control potential food safety hazards rather than inspect and address food-safety problems after they have occurred.

The concepts of the HACCP are:

1. Identifying food safety hazards (may be physical, chemical or biological substances)
2. Controlling these hazards,
3. Documenting the system.

Table 49 summarises the principals of the HACCP and what it entails.

Table 49: Principles of the HACCP

Steps in the HACCP	Description of Activity
Preliminary Steps	• The focus is on **food safety only** and not all the attributes that constitute food quality such as consumer preferences. • Apply right from production and on preventing food-safety hazards coming into contact with the fish and fish products. If food-safety hazard do come into contact with the fish or fish products, they should be contained within the segment of the operation line. • Identify and describe the specific value-chain and the stakeholders in the chain (e.g. tilapia from cages to restaurant, etc). Draw a flow diagram • As much as possible quantitative practical measurable parameters and occasionally control in lab to ascertain for effectiveness for monitoring.
Principle 1 – Conduct a Hazard Analysis	• Based on the flow diagram, list of all the processes, points where significant hazards are likely to occur, likelihood of occurrence, severity of effects from hazard and describe corresponding control measures (e.g. placing fish in clean containers to prevent contamination from dirt). • Liaise with MAAIF and local public health inspectors for further guidance.
Principle 2 – Identify Critical Control Points (CCP)	• These are the points at which the hazard can be controlled, and action taken. For example, a CCP to reduce flying insects entering the facility would be screening all windows and doors connecting to the outdoors.
Principle 3 – Determine Critical Limits (CL)	• Establish the safe and unsafe levels. For example, what is the maximum temperature beyond which the display fridge should not be set.
Principle 4 – Determine Monitoring Procedures	• Regularly monitor the CCP's and CL based on the agreed monitoring plan. Make the required observations, measurements and record them. Evaluate the information.
Principle 5 – Determine Corrective Actions	• Once a fault has been identified, determine the necessary corrective action and implement corrective actions as soon as possible • Record all corrective actions taken.
Principle 6 – Determine Verification Procedures	• Verify the procedures used in the HACCP in liaison with the competent authority* • Refer to government guidelines (Module 2)
Principle 7 – Record-Keeping Procedures	• Keep all records up-to-date as recommended in the HACCP plan

***NOTE:** If you are supplying your local market or restaurant, contact the local fisheries and public health officer for guidance. When supply and distributing fish to larger markets and plants (including for export) the Fisheries Resources Department (MAAIF) will need to be contacted for additional guidance.

9.2.2 Level of spoilage

Most consumers like fresh fish. In addition, for all fish products, the best quality is obtained when the freshest fish is used as raw material. It is therefore important to keep fish as fresh as possible (alive until it is required by the market if possible).

The ability to assess the level of spoilage is important for all fish products

Table 50: Freshness Grading Scheme for Fish

Grade	Extra	A	B	C (unfit)
Skin and scales	Bright, shinning	Waxy, slight loss of bloom	dull	Dully, dry, gritty
Outer Slime	transparent	milky	Yellowish-gray, some clotting	Yellowish and clotted
Eyes	Convex black pupil, translucent cornea	Plane, slightly opaque, opalescent cornea	Slightly concave, graying pupil, opaque cornea	Completely sunken, gray pupil, opaque discoloured cornea
Gills	Bright red, mucus translucent	Pink, mucus slightly opaque	Gray-white, mucus thick and opaque	Brownish, mucus yellowish gray and clotted.
Peritoneum	Glossy, brilliant, difficult to tear from flesh	Slightly dull, difficult to tear from flesh	Gritty, fairly easy to tear from flesh	Gritty, easily torn from flesh
Gill and internal odours	Fresh, smell of pond water	Neutral odour,	Musty odour	Fruity and/or sulphide smell

Adapted from Connell, 1995.

The common signs of spoilage in smoked, dried and frozen fish are listed in tables 51 and 52 below.

Table 51: Signs of Spoilage in Smoked and Dried Fish

Common signs of Spoilage	Prevention Measures
• Fragmentation (flesh easily breaks and crumbles) • Change from normal colour • unpleasant smell (e.g. rancid, ammonia) • Mould growth • Insect and maggot infestation • Bacterial deterioration • Unpleasant taste	• Dry and smoke from fresh • Prevent blowflies getting onto fish during processing and storage • Avoid bruising of fish • Dry and store off the floor • Store in secure well-ventilated screened room • Don't use prohibited substances during processing and storage such as insecticides • Keep rodents and other animals out/off the fish • Hygiene during processing and handling

Table 52: Signs of Spoilage in Frozen Fish

Common signs of Spoilage	Prevention Measures
• Freezer burn (flesh turns whitish or grayish-brown dry, flakes or patches) • Lighter weight • Slimy film • Smells bad	• Freeze cleaned fish from fresh as rapidly as possible • Maintain recommended temperatures • Hygiene during processing and handling

9.2.3 Consumer Preferences

Consumers have different tastes and preferences and hence assess quality differently. What one regard may regard as poor quality another might prefer. It is important to identify the quality criteria of your clients. For example:

- Size of fish
- Type of product (e.g. live, whole, fried or smoked from slices or chuncks, with or without bones)
- Colour of the fish (e.g. white flesh, golden brown or slightly brown when smoked)
- Taste (salted or spiced)
- Texture of the product

9.3 Fish Processing

The following are the major aquaculture products:

- Live fish
- Fresh fish (whole or filleted)
- Chilled
- Frozen
- Smoked
- Dried

9.3.1 Fish Hygiene

Irrespective of the product, the principals of fish hygiene must be applied:

- Use only portable water that is free from contaminants in all post-harvest processing.
- Non-corrosive easy to clean worktops that don't absorb water (preferably stainless steel, plastic or tiled surfaces).
- Do not mix raw and processed products. The lay-out of the facility no matter how simple should have unidirectional flow from raw-material to product. This is to avoid cross-contamination.
- Prevent rodents, insects and other unwanted substances from coming onto the raw material and work area.
- Wear clean protective clothing each time to ensure no hair ormucus from processor gets onto fish.
- All processors should have 'public health certificates for food handlers'. These can be obtained from your local public health office.
- Keep the area around clean and dispose of waste hygienically.
- Keep production records for each batch of fish produced up-to-date.
- Ensure you have the necessary permits where applicable (see Module 2)

9.3.2 Processing

Different Ugandan aquaculture products are illustrated in figure 109. Processing helps add value to products. By-products such as pet-mince are also produced from the filleting of fish.

Figure 109: Aquaculture Products

a) Live, Fresh and Chilled Whole Fish

Live tilapia

Live catfish being delivered to local market

Chilled tilapia from cages

b) Smoked Fish Products

Smoking catfish and tilapia on a farm

Packaged smoked catfish fillets and whole fish

c) Value-Added Products

Fillets

Fish sausages

Salted tilapia

Product from tilapia ponds is also deep fried as a ready to eat snack.

9.4 Packaging

Different food-grade packaging materials are available on the market. The choice of packaging depends on:

- Wholesale or retail market
- Type of product (e.g. better to pack fatty smoked products in silver foil rather than sealed plastic as the former reflects heat whereas the latter contains heat – especially where cold storage may not be available).
- Consumer preference for pack sizes
- Storage facilities (e.g. fridge, freezers, outdoors)
- Availability

In addition, the choice packaging influences the value attributed to the product by the customer (figure 110.).

Figure 110: Examples of Packaging Used for Aquaculture Products

Crates for bulk fresh or dry. The packaging may go straight to a restaurant, school or hotel where bulk cooking is done.

Well labelled attractive packaging is preferable for retail outlets

Smoked fish (suitable for use in facilities where cold storage is available)

Salted and dried products in paper boxes

9.5 Transportation of Fish Products to Market

- Use clean container – preferably insulated. These can be ferried by bicycle, boda-boda or any vehicles. Transport vehicles should be clean.
- Refrigerated tanks
- Live fish transportation units for live fish (**Module 7**)

MODULE TEN:

MARKETING OF FARMED FISH

The final step in commercial fish production is selling the fish produce and products profitably. This involves identifying the best market opportunities and meeting market demand as the market requires. This module provides an insight into the options for marketing farmed fish and developing a marketing strategy.

10.1 What is marketing

Marketing is a management process responsible for finding out what customers need and supplying them as efficiently and as profitably as possible. It is generally defined as the as "the process of **creating, distributing**, and **pricing** goods, services, and ideas to facilitate a satisfying value exchange".

The functions of marketing can be summarised as follows (see also figure 111):

1. Provide a forum for the exchange of goods and services through:
   a. Buying (including assembling) of fish or fish products
   b. Selling
2. Physical functions:
   a. Storage of fish and fish products
   b. Transportation
   c. Handling and processing
3. Facilitate the exchange of goods and services through:
   a. Standardisation
   b. Labelling

c. Financing
d. Risk-bearing
e. Market intelligence

Consequently, aquaculture marketing involves the above set of activities to enable the flow of aquaculture goods and services form **the farm to the fork** (figure 111 and 112.

The above functions are accomplished during marketing by:

- Getting the attention of your customers.
- Creating **awareness** about the products.
- **Motivating** customer to make the **buying decision**.
- Convincing them to **buy and use** the product
- Convincing them to **buy again**.

Figure 111: Components of the Aquaculture Marketing Chain

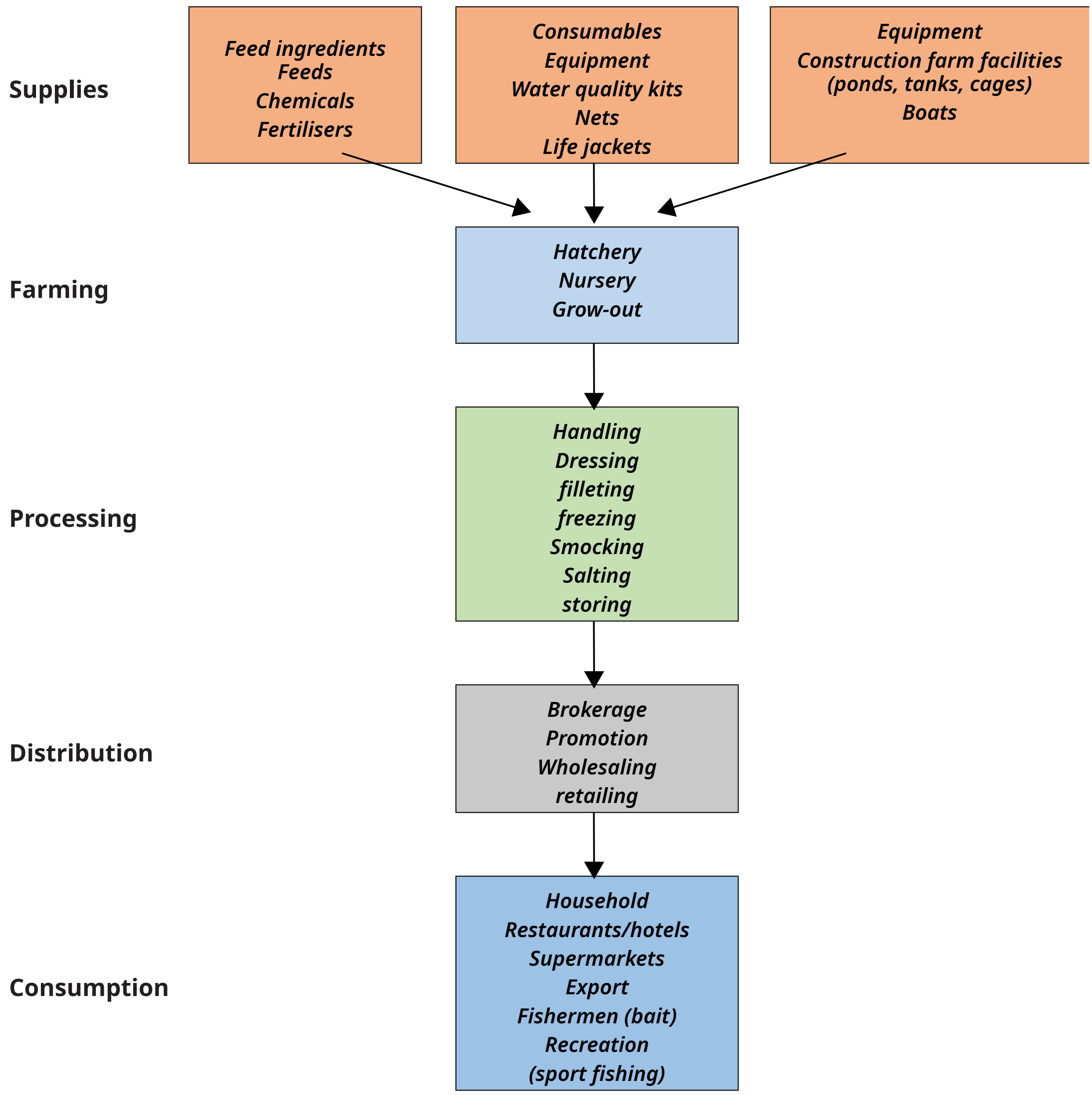
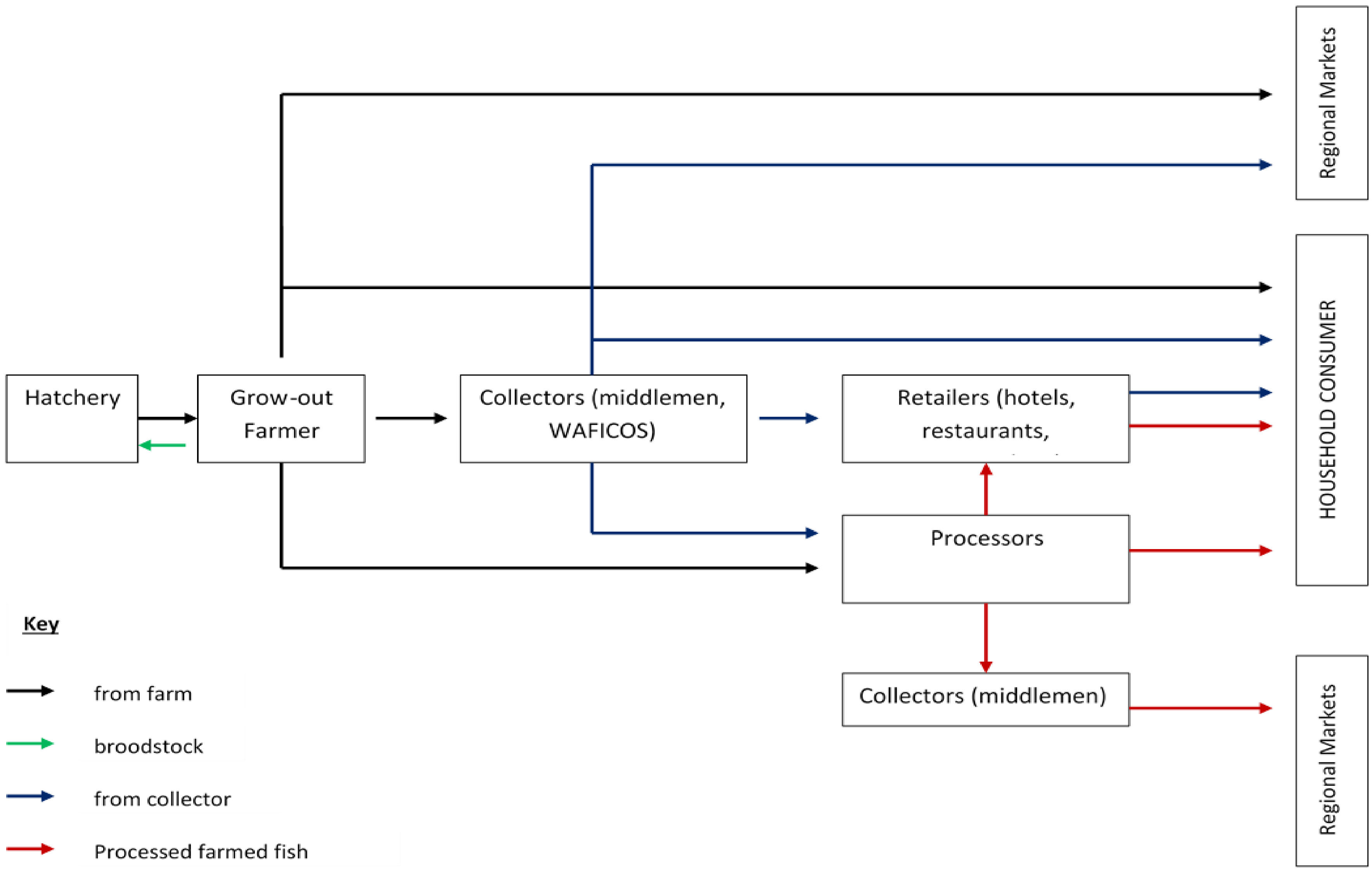


Figure 112: Description of the Farmed Fish Value Chain



10.1.1 Why Marketing is Important

The customer does not always know what products may be available in the market. Marketing therefore helps one:

1. Stimulate demand and build a customer base for selling the products produced to accomplish one's enterprise objectives.
2. Promotes the utilisation of products for consumers by creating or opening channels through which products can be sold and received by customers.
3. Promotes the enterprise's unique products features by building upon its comparative advantages against the competition from similar products or other products that may substitute one's product.
4. Enables the produce to interact and obtain feedback on products from customers which enhances competitiveness.
5. Increases the opportunity for higher turnovers and thus improves the likelihood for growth and sustainability of the enterprise.

10.1.2 What is a market?

Markets create an arena that enable the producer answer the following key questions when developing market-oriented production and business plans.

1. What to produce? This includes the species, size, the quantity, quality and the price the consumer is willing to pay for the product.
2. How much to produce? How much of each species? What size and quality to produce at different periods?
3. How to distribute production? What mechanisms will be used for distribution? What type of networks will be used?

10.1.3 Types of Markets

Markets are described based upon their:

- Location e.g. Nakasero market, Kajjansi fish market,
- Product e.g. catfish market, tilapia market
- Time e.g. September to October catfish or tilapia market.
- Level e.g. retail market, wholesale market etc.
- Targeted clients, e.g. niche or luxury markets.

10.2 Developing a Marketing Strategy

Even where there is a perceived demand, one must market. The assumption that consumers will purchase fish just because it is there, is not absolutely true.

Every farmer, producer or trader in farmed fish products must have a strategy of ensuring that:

- The produce is bought at the right time,
- In quantities that permit one benefit from higher turnovers,

- At a price that is profitable, and
- In quantities that do not hinder one's production objectives and business plan

It is important to really understand your own business. Every aquaculture operation is different. Answers to the following questions would enable the one assess their marketing opportunities and develop a marketing strategy:

- **What is the fundamental business problem your company solves?** Several aquaculture products and services are generated along its value-chain. These include produce fish, transport fish, process, value addition, linking producers to markets, supplying inputs. An entrepreneur may be involved in one or more of these.
- **What is the competitive advantage your enterprise as a company?** Who are your competitors? What causes you to be outcompeted? For example, are you dedicated to supply the quantity and quality of fish your market demands on time? If you have shortfalls in supply, do you belong to a network of producers from whom you could source fish to offset such shortfalls?
- **What are the benefits of your product to your market?** Are my volumes and quality large and stable enough to attract distributors or should I focus on retail? Supplying food service providers? Is it what consumer want?
- **What is your position in the market?** Beginner, trend-setter, large or small producer, contacts and networks?
- **Build good relationships** with customers, including potential ones, service providers and other producers.
- **What are the characteristics of your product?** The quality of your product and quality of your services (even for farmers) is important. What species, product type, unit size are your selling? Do you deliver on time? Consistency in quality is what builds customer loyalty (figure 113).
- **How can you communicate your product?** Work out how you can publicise and promote the use of your product? It's presentation, labelling, branding, publicity
- **What are your marketing options?** Fish can be sold at the farm, retailed in markets or sold in bulk to wholesalers or through farmer's cooperative. Farmed fish and products in Uganda is sold on-farm, local markets, restaurants, to schools and processing plants. It is also sold within the region to the neighbouring countries.
- What distribution channels can you use? (figure 112)
- **Right these down on paper** and remember to build upon your strengths and opportunities.

Figure 113: Some Aspects of Marketing Aquaculture Products and Services in Uganda

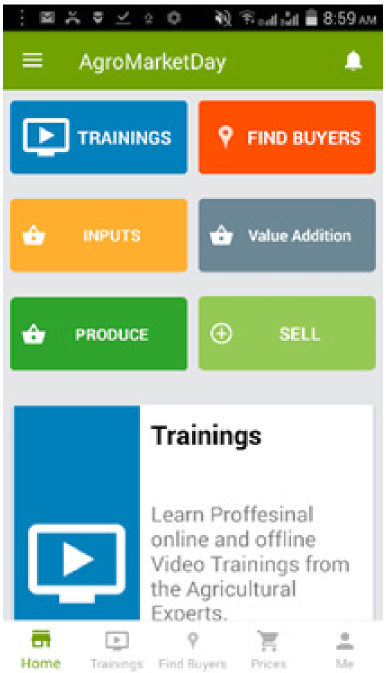
a) Grading, weighing and icing to ensure right quality get to the market.

b) Different distribution channels and market opportunities exist both in rural and urban areas.

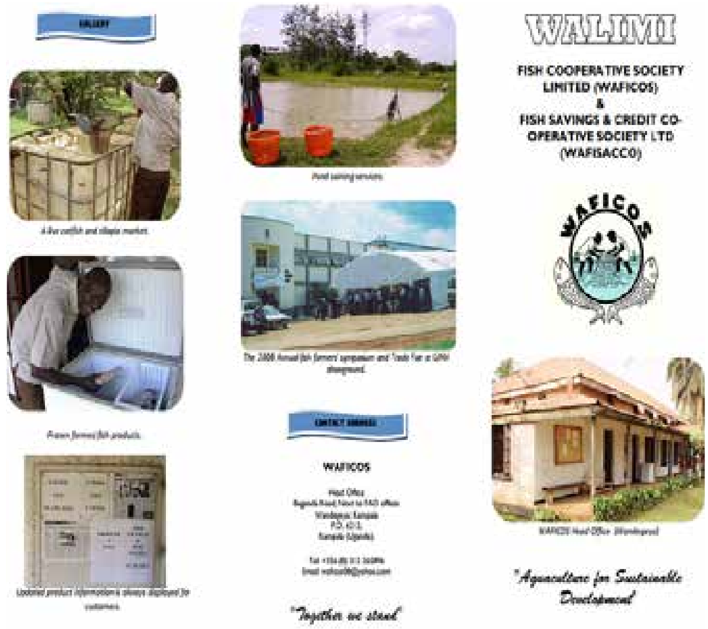
c) Temporary fish holding on-farm help ensure ordered consignment are available on-time.

d) Labelling and branding facilitate standardisation and recognition of products.

(e) Storage of frozen catfish fillets in a freezer



(f) Aquaculture information on my smart-phone. This AgroMarket Day



(g) Brochures to disseminate information.

Answers to the above question can help you develop your image, able and approach promoting your products. Below is a simple outline of basic things to include in a marketing strategy:

1. Define your goals, direction and values
2. The status of the business -What are your strengths, weaknesses, opportunities and strengths? These should take into account the product you are producing, your intended markets, your previous market experiences, nature of your business and products including information
3. Identify and describe the targeted market. Its location, what consumers want and so on.
4. Marketing goals - How much would you like to distribute and sell each time? How frequently?
5. Marketing communication – what is the best way to communicate with the market.
6. Marketing action plan -develop short- and long-term action plans
7. Marketing budget - Consider phone expenses, publications (hand outs, product literature), transport, display materials, participating in shows and other marketing events among others.
8. Review your progress - Keep and review your records to ensure you are on track and or need to change strategy.

10.3 Collective Marketing

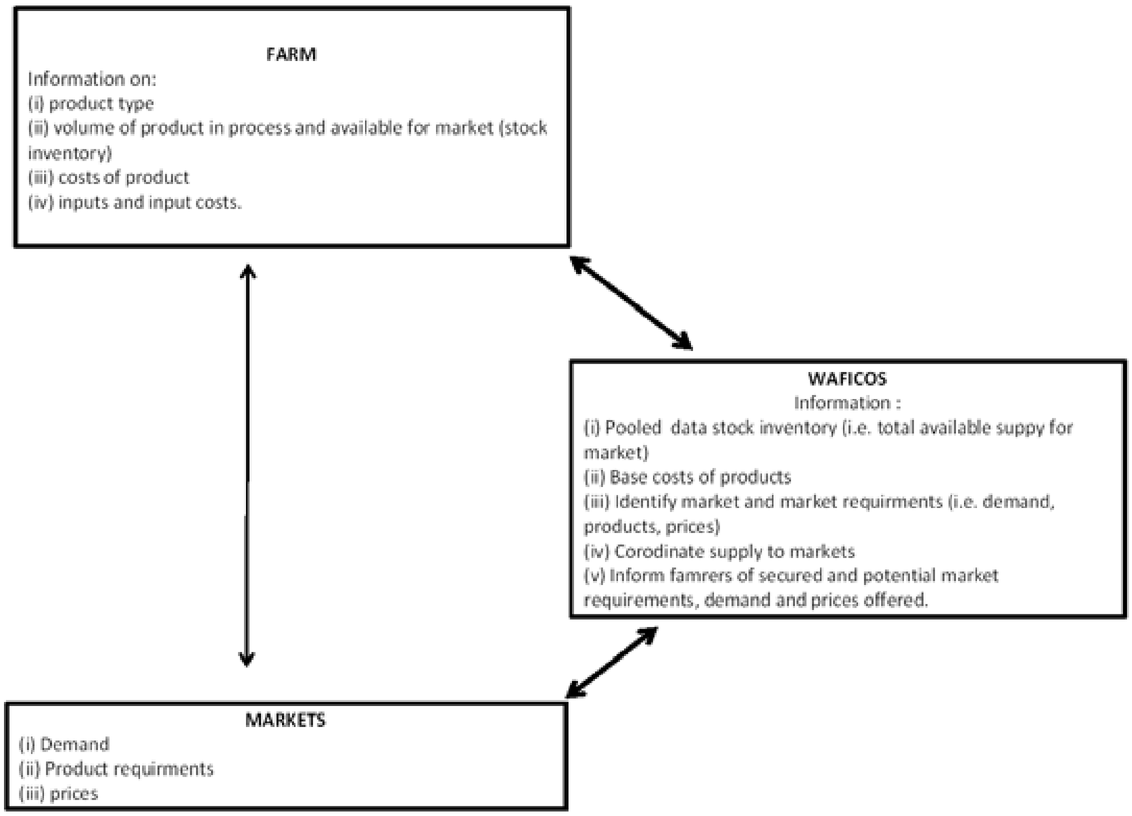
Independent small-holder farmers can secure large markets and obtain economics of scale if they form clusters and associations. Such an arrangement enables them:

- Synchronise their production to ensure that market receives the quantities it demands consistently throughout the year. This helps avoid the problem of too much production coming into the market at the same time with a consequent fall in fish prices or post-harvest losses.
- Producer groups can also set and maintain standards among themselves to improve the

assurance of their products. This provides competitive advantage and access to more selective markets.

- Bulk purchase inputs which improves profit margins
- Obtain collateral thus improving access to finance
- Access and procure technical services (figure 114)

Figure 114: Local Example of Collective Marketing Approach



MODULE ELEVEN:

AQUACULTURE AS A BUSINESS

11.1 Introduction

The objective of running a business is to make a profit. To profit one must gain both materially and financially from one's investment, inputs and effort. Achieving this continuous monitoring of the enterprise and planning to overcome the many challenges and risks that would otherwise cause the business to fail.

Businesses tend to fail because:

- Things do not add up - production, demand and sales do not tally.
- Inability of owners or managers to honestly accept and act to address mistakes pragmatically.
- Over-expansion particularly borrowing too much money to start-up or grow. Start small then progressively grow.
- Poor accounting. Every owner or manager should be able to keep their financial flows and balances in check even when a trained account is hired.
- Lack of cash cushions in the event of an eventuality (e.g. floods). Insurance, membership to associations or other fall-backs can be helpful.
- Operational mediocrity. Repeat and referral business is critical for successful business.

- Production and operational inefficiencies. For example, paying too much for services and rent.
- Dysfunctional management. Lack of focus, vision, planning, standards and everything else that goes into good management.
- Falls and changes in market.

The ability to monitor and control the flow and utilisation of inputs against production and sales is therefore important. This cannot be done without record keeping.

11.2 Record to Keep and their Evaluation

Keeping and analysing records to make production and business decisions make it possible to execute production objectives within the cost-structure of the enterprise. Through records the evidence of what is at stake (your stock), changes that have occurred during production and marketing, impending challenges and opportunities becomes available.

The basic aquaculture records to keep are:

a. Production records (feeding, management, stock, growth, diseases and survival)
b. Marketing (market requirements, prices)
c. Financial records (costs of expenses, sales, revenue and expenses)

11.2.1 Production Records

As opposed to terrestrial animals, fish are always under water during the production cycle. The only time a farmer sees them is at feeding, if they feed by response, or at sampling (Module 6). Keeping records of inputs, water quality, management actions, average weights at sampling and mortalities up-to-date provides a lot of insight on the status of operations.

Appendices 6 and 7 provide examples of feeding and production management records and of how these records can be used to make management decisions.

11.2.2. Marketing Records

Records of purchases and sales from the various markets, turnover, promotion and communication costs and results and market profiles are important.

11.2.3. Financial Management

The information on costs of inputs, expenses, revenue enables one control the use of inputs and production management decision to ensure optimum productivity and positive returns. They attach a financial value to the inputs, production process, goods produced and sold.

Once this is done, the following business management tools become possible (see appenidx 8).

11.3 Enterprise Analysis and Business Decision Making

11.3.1 Enterprise Budgets

if the overall farm operation is to remain profitable, each production cycle must be profitable. Analysing the production and financial performance of each production cycle concurrently is therefore an important tool (table 53).

Table 53: Example Enterprise Budget for Single Pond Cycle for Static-Water Tilapia Monoculture Ponds Fed Nutritionally Complete Commercial Sinking Pellets

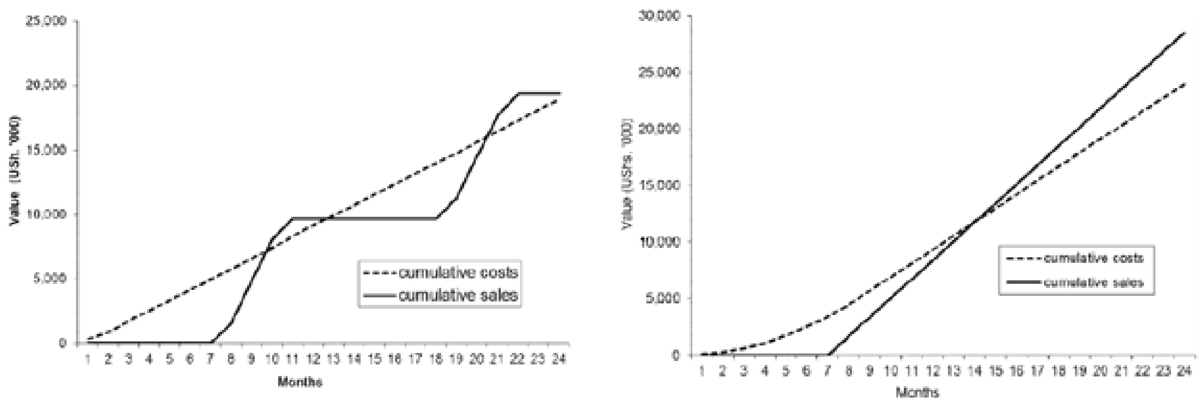
Item	Amount	Unit Cost (USh)	Total Cost (USh)
Production Targets			
Pond	1,000 m^2		
Carrying capacity	800 kg		
Targeted average size at harvest	350 g		
Survival at harvest	90%		
FCR obtained	1.7		
Major Variable Costs			
Tilapia (monosex) fingerlings	2,286	40	91,429
Catfish	227	180	40,860
Feed (type)	1,360 kg	1,000	1,360,000
Fertiliser	110 kg	500	500
Labour			0
Interest on Loans			
Total Variable Costs			**1,492,789**
Production			
Number of fish (tilapia) of marketable size*	2,085		
Total weight of fish available for sale	748 kg		
Sales			
Total Revenue	**748 kg**	**3,000**	**2,244,000**
Income above variable costs			**751,211**
Net income if amortized over 10 years			
Proportion of Total Variable Costs	**%**		
Fingerlings	9		
Feed	91		

As a rule of thumb in commercial fish farming, the cost of fingerlings should not exceed 10-15% of variable costs.

11.3.2 Cash flow analysis

To run an enterprise efficiently, one must have all the necessary inputs and be in position to deliver the produced demanded by the market on time at the most economical cost. The ability to project expense requirements helps on plan and budget to ensure resources are available on time (figure.115.).

Figure 115: Cash Flow Analysis of Two Tilapia Farms. ***(a)*** *Sales done when pond is ready to harvest, and such ponds maintained until all fish are bought* ***(b)*** *Several small ponds sized to market demand and an all-in-all out-production system.*



a) Three large ponds ***b) Several small ponds***

Analysis of production and sales to assess cash flows make it possible to choose or improve investment, business and production plans.

11.3.3 Risk Analysis

Once the above records are well kept and monitored, it becomes possible to identify the factors that cause loss to the enterprise and address them as soon as possible (table 54).

Table 54: Risk Analysis

Period	JUNE			JULY			AUGUST		
Products	Target Number to produce	Actual Number Produced	VARIANCE	Target Number to produce	Actual Number Produced	VARIANCE	Target Number to produce	Actual Number Produced	VARIANCE

Remarks		
Month	Performance	Reason for Variance

11.3 Production and Business Planning

When making a production and business for farming fish, one should endeavour to answer the following questions beforehand.

- Where is the market? – its location, what category of people are likely to buy the fish I produce, etc.
- What does the market want? – type of fish, how much, what size, how frequently, fresh or processed, etc.
- What resources do I have? – number of pond(s), size of pond(s), water for production (quantity, quality, flow rates), feeds, labour, seed, etc.
- From where and when should I source my seed and feed?
- What is the quality of feed I intend to use? This is important because it limits possible FCRs, water quality and carrying capacity.
- How much feed and seed shall I require?
- What technology do I have at my disposal and which would be the best to adopt?
- How frequently do I need to harvest for the market? (complete harvest/partial harvests)
- How do I get my fish to the market?
- What returns can I expect from the above?

Table 55: Template for Developing an Aquaculture Business Plan

Chapter	Objective	Content
1. Background	Define business vision, goals and objectives	• Justification for proposed aquaculture enterprise • Objectives • Summary of proposed approach • Expected output
2. Situation Analysis	Establish the current status of what is that you would like to do, take stock of the resources you have in relation to what you propose to do	• History of the project (if on-going) • Description of enterprise • Assessment of resources for the proposed enterprise (land, water, climate, farm infrastructure, services, personnel, socio-economic and environmental assessment, compliance requirements, administrative system, financial structure, market overview, technical support) • Current financial performance for on-going businesses
3. Needs Assessment	Based on the situation analysis, identify what gaps and opportunities there are in relation your proposed business	• Identify the strengths weaknesses opportunities and threats to your proposed and/or on-going operation

Chapter	Objective	Content
4. Business Analysis	Review of the business environment, both internal and external	• Assessment of external and internal business environment • Industry outlook • Competitors • SWOT of the above factors • GAP analysis • Strategy formulation
5. Production Planning	Tailor production to meet market needs	• What to produce • Evaluate how best to streamline production to meet market needs • Production projections
6. Marketing Plan	Identify market opportunities and	• Determine the market opportunities • Identify actions you would need to take to penetrate, be competitive and sustain your identified market (e.g. join an association) • Plan with milestones for implementation
7. Investment Strategy	Capital budget to invest into what you will need to execute your business	• Capital requirements (e.g. buildings, production units, machinery equipment) • Operational requirements • Plan with milestones for implementation
8. Enterprise and Financial Assessment		• Calculate product prices based on above • Attach costs and run scenarios (e.g. enterprise budget of one tank using your assumptions or if in operation comparing proposed changes with what you are actually getting) • Cost benefit analysis • Cash flow projections • Sensitivity analysis • Risk analysis
9. Conclusions and Recommendations		• Establish best options
10.Monitoring and Evaluation		• Implementation plan with milestones • Records

11.4 Maintaining Farm Income

Times change. In order to increase farm income and maintain productivity and competitiveness must be among the key attributes of the enterprise. To do this:

1. Innovative. Create secondary businesses from the farm
2. Continuously re-assess performance and make the necessary adjustments to production and marketing in order to remain competitive, notably:
   a. Satisfy the Market's Needs.
   b. **Production Efficiency.** When running a fish farm commercially, the overall aim is to mini-

mize production costs and optimize efficiency as well as returns. Practically this means:

- **Lowering FCRs to optimum levels.**
- **Lowering labour costs.** For example, sample all your ponds on the same day if extra labour is required.
- **Improving returns to land**. It should be profitable to use the land for fish farming. Use your space as efficiently as possible because land costs money and has a value as the major capital investment cost. Aim at getting the best production per unit area for the technology being applied.
- **Making and adopting the appropriate investment and management decisions.** A farmer should be in position to decide whether or not to increase the levels of production, when to do so and by what level production should be increased. The farmer should also be in position to examine whether or not it will be possible to achieve the desired level(s) production practically and profitably, with the resources available to him/her. For example, should production be increased by building more ponds, improving management, or simply deepening ponds to recommended levels?

QUESTIONS FREQUENTLY ASKED BY FARMERS

PRODUCTION

- Where can I buy from simple water quality equipment and other aquaculture equipment?
- How much money can one begin with?
- How do you select an area for pond construction?
- How does a pond look like?
- What is the maximum depth one can dig?
- How many pieces to stock per square meter?
- How do you transport fish?
- Do you just pour the fingerlings into the pond water?
- Where does one sell the table fish?
- Can fish be fed on an formulated feed/food stuff?
- How can one access a permit/license?
- Is It payable annually or monthly?
- Who should a farmer contact?
- Is contacting NEMA very important before starting fish farming?
- What is the recommended water depth for ponds and cage farming?
- How many fish to stock per square meter/cubic meter in ponds, tanks, cages?
- Where does get ready catfish mkt?
- How can one describe Oreochromis niloticus or Tilapia?
- What is the type of water used for fish farming?
- How much feed can one fish take up to sell?
- Why do we need to flash water in ponds and tanks?
- Do fish diseases have similar signs?
- At what level can one be regarded as a commercial farmer?
- How do I tell that my fish is sick?
- What is the difference between a female and male fish?

- How does one prepare a pond in a water logged area?
- What is the importance of lime in ponds?
- What water quality parameters does one have to check in fish farming?
- The difference between concrete ponds/tanks and dam lined ones?
- How can recirculated water be used in fish farming?
- What is the difference between metallic and plastic cage frames?
- Describe the correct anchoring for cages?
- Is fish farming a profitable business?
- What is the cost of constructing ponds?
- What is the cost of constructing cages?
- Can I set up a farm in a swamp?
- Which is the best fish species to culture?
- Can I culture both tilapia and catfish at the same time?
- How many fish can I stock per pond?
- How many fish should I stock per cage?
- Where can I get from good quality and affordable seed?
- What is the cost of seed?
- Do I have to continuously buy the seed or I can reproduce seed using my production facility?
- What is the biggest cost of production?
- Where can I find a good manager for my farm?
- Where can I buy from the fish seed?
- How much fish feed shall I use throughout the production cycle?
- What is the cost of feed?
- Is there an alternative feed to commercial feed?
- Can I manufacture my own fish feed on farm?
- How long do the fish take to reach marketable size?
- Which is the best size at which I should sell my fish?
- What is the minimum amount of money to invest so that I can make profit?
- Can I grow fish uphill or in a place without a natural source of water?
- Do fish fall sick, If yes; how do we control or treat the diseases?
- Are there any legal requirements like licenses needed to establish a farm?
- What other challenges exist in the fish farming business?

MARKETING

- Where can I sell my fish when its ready?
- How much is a kilo of fish?
- Do you pick the fish from the farm when its ready?

IMPORTANT PLACES

- Where is the Ministry of Agriculture Animal Industries and Fisheries located?
- Where is the Directorate of Water Development?
- Where do we find NaFIIRI?

List of Appendices

Appendix 1: Description of the Species

*1. **Nile Tilapia** (Oreochromis Niloticus)*

Physical Appearance	• Silver grey in colour with distinct vertical bands across the body and tail. Variations in intensity of colour may occur depending on the specific environmental (water) characteristics of the growing environment. • Males generally larger than females of same age • Laterally compressed body covered with relatively large scales that don't dislodge easily (advantageous for aquaculture as scales protects against injury when stocked at high densities)
Natural Habitat	• Slow-moving rivers, pools, swamps and lakes • Shallow areas of these water bodies where risks of water quality fluctuations are less adverse, are warmer, higher levels dissolved oxygen and food availability • Their seasonal and daily distribution within the water body shifts towards areas with optimal conditions to enable them optimise energy use. • Are aquatic air breathers. During moments of oxygen stress (below 3 mg/l oxygen) can gulp water through their mouths to extract oxygen *(piping)*. Prolonged exposure to such conditions is however stressful and suppresses growth and reproduction. • Are social and school.
Feeding	• Are herbivorous and feed predominantly on phytoplankton. Also feed on some macrophytes, detritus and decomposing organic matter, aquatic invertebrates • Can digest 30 – 60% of the protein in algae • Juvenile stages consume require 50% animal protein, so consume zooplankton and larvae of other fishes as part of their normal diet. • Feed during the day, normally twice a day (am and pm) • Have small stomachs for feed more frequently

Reproduction	• Year round regular spawners in equatorial regions • Territorial behaviour by males and courtship are characteristic. • Males build and guard nests into which the female lays her eggs. Eggs laid are proportional to female's body weight. A 100 g female will produce about 100 eggs per spawn, while a female weighing 600-1 000 g can produce 1 000 to 1 500 eggs. • Male fertilises the eggs after they have been laid. • The male remains in his territory, guarding the nest, and is able to fertilize eggs from a succession of females. • Breeding males develop a distinct reddish hue. • Females incubate eggs and nurse larvae within their mouths (brooding). Brooding lasts up to 12 days or until such a time fry can escape predation. • During brooding females do not feed and will only develop another batch of eggs after they stop nursing their fry.  ***Nile tilapia nests at bottom of pond***
Attributes for aquaculture	• Hardy and fast growing • Can withstand high stocking densities in grow-out units due to protection of scales and schooling behaviour • Accept a wide array of diets and can be raised using different production strategies • Reproduce easily under captivity • High quality white flesh • Marketable in Uganda and globally

2. African Catfish *(Clarias gapriepinus)*

Physical Appearance	• Uniform greyish brown with whitish belly. Some have a bit of marbling. • No scales • Elongated and its cross-section is oval shaped • large flat-shaped head with flattened mouth • Have barbels to enable them sense the presence of food when visibility is poor • Relatively small eyes • Dorsal fin extends over most of the back with about 60 - 80 soft rays and no spine • Tail is rounded with 9 – 12 soft rays and no spine • Pectoral fin 9 – 12 soft rays and no spine • Pelvic fin located behind abdomen and has about soft rays
Habitat	• Swampy areas that are muddy with low levels of oxygen • Are air breathers • Burrow into mud when swamps start drying up to keep moist and cool.
Diets and feeding	• Omnivorous – eat anything – fish, insects or other forms of aquatic animals • Feed off the bottom substrate • Fast growers and can get to above 20 kg

Reproduction	• Don't' become sexually mature until a year old • Reproduce during the rainy season when environmental conditions for juveniles whose air-breathing apparatus is not fully developed can get dissolved oxygen, zoo-plankton, etc. • Small sticky greenish-brown eggs that stick onto substrate (aquatic plants, etc.) • No parental care
Distribution	• Native to Uganda
Aquaculture	• Hardy adaptable fish • Consumes all foods • Marketable in Uganda • Perform better in fish ponds and tanks. • In ponds monoculture and polyculture with tilapia • Challenges administering feed uniformly and obtaining uniform growth in cages • Burrow into pond walls making harvesting by seining more challenging. Where pond walls not well compacted, can burrow through walls resulting into leaking and loss of fish.

3. Mirror Carp *(Cyprinus carpio)*

Physical appearance	• Can reach up to 1 meter and above 30 kg in the wild. Long lifespan. • Leathery greyish-yello brown skin with large scales on uppder body or line of scales along body that have a 'mirror' image.
Habitat	• mainly bottom dwellers • optimum water temperature 20 – 25 ^{o}C • The fish can survive cold winter periods. Salinity up to about 5‰ is tolerated. The optimal pH range is 6.5-9.0. The species can survive low oxygen concentration (0.3-0.5 mg/litre) as well as super saturation
Diet and Feeding	• Omnivorous with • Search for food in the middle and upper layers of the water body • High tendency to animal foodstuffs notably aquatic insects, worms, molluscs and zooplankton • Also feed off stalks, leaves and seeds of aquatic and terrestrial plants, decayed aquatic plants • Fish gulp in mud from which digestible matter is sifted and spit out what is rest rejected making pond water turbid. • Dig and burrow into pond embankments and sides in search of organic matter.
Reproduction	• Don't' become sexually mature until a year old • Reproduce during the rainy season. • Females lay 100 to 230 g/kg body weight. • Male fertilises eggs after they have been laid • Small white eggs whose egg shell becomes sticky and attach to substrate such as aquatic plants after contacting water. • Small sticky whitish eggs that stick onto substrate (aquatic plants, etc.) • No parental care
Distribution	• Foreign fish species

Aquaculture	• Can be grown in fish ponds or tanks • Fast growth of 2 to 4% body weight per day. Can reach 600 g to 1 kg in one growing cycle • Can be raised at high stocking densities in ponds and/or tanks

4. Ningu (Labeo victorianus)

Belongs to the family of Cyprinids

Physical Appearance	• Fusiform shaped (tapers at both ends) • Lateral line running along middle of the flank and the caudal peduncle. • Flap of skin in front of upper lip. • Jaws with horny cutting ridges. • Barbels hidden. • Yellowish-green on upper body and abdominal area light creamy in colour • Dorsal, anal and pelvic fins often coloured yellow- orange at the tips
Habitat	• Dwell at the bottom of the lake
Diet and Feeding	• Diverse diet of detritus, plant parts, zooplankton, diatoms, and insect parts • Adults Specialized feeder on epilithic and epiphytic algae • Also feed on rotifers growing on the body of other fishes
Reproduction	• Migrates from lake up into river leaving the lake to breed at the start of the rainy season • Eggs laid, fertilised outside female and are semi-buoyant • No parental care
Distribution	• Lake Victoria and its affluent rivers • Indigenous to Uganda
Aquaculture	• Success trials on induced breeding, tank and pond culture of juveniles. • Pond and cage culture grow-out trials have been done • Can be raised on periphyton

5. Angara, Pebble Fish (Alestes baremoze)

Physical Appearance	• Fusiform shape typical of fast moving fish • Relatively large scales. • Relatively large, typical of characins. • Fleshy-lipped terminal small mouth with a soft textured tongue • Obvious teeth that include large molars (Figure 3b) arranged in one row (Figure 3c) and premaxilla had two teeth rows, one composed of conical teeth with the other composed of molars (Figure 3d). • Forked tail • Maximum length about 43 cm
Habitat	• Rivers • Optimum temperature range 15 to 35 °C.
Diet and Feeding	• Flexible diet constituting mainly aquatic animals notable insects, molluscs, crustaceans and zooplankton. Phytoplankton also consumed sometimes.

Reproduction	• female during rainy season when environmental conditions optimum for juvenile growth • Undergo short spawning periods.
Distribution	• Lake Albert and the Albert Nile. • Indigenous to Uganda but
Aquaculture	• Success trials on induced breeding, tank and pond culture of juveniles.

6. Mamba/Marbled Lung Fish *(Protopterus aethiopicus)*

Physical Appearance	• Smooth, slimy, cylindrical body • Dark slate-grey above, yellowish-grey or pinkish below; often with numerous dark spots or flecks on the fins and body (some specimens bright yellow ventrally) • Deeply embedded scales. 55-70 scales in a longitudinal series from immediately behind the head to above the vent; 40-50 scales around body • Tail pointed and confluent • Long dorsal and anal fins; dorsal fin originating at an equal distance from the eye and the vent, or nearer to the latter; • Slender and filamentous pectoral and pelvic fins slender • Upper and lower tooth-plates in the form of sharp cutting ridges • Have lungs • Young fishes with true external gills, but usually absent in specimens greater than 15 cm • Max total length recorded 200 cm and weight up to 17 kg
Habitat	• Rivers and edges of lakes, swamps and floodplains • Juveniles are found in the matted roots of papyrus • Adults can survive in dry streams and swamps for long periods by • They withstand desiccation on floodplains by staying dormant in cocoons until the next rains. They breath air while in cocoon from small passage leading to the outside • Mature individuals breed during flood season. One or several females spawn in burrows which are dug and cleaned by the male, who later guards the eggs and the young.
Diet and Feeding	• Adults feed on molluscs, small fishes and insects • Juveniles less than 35 cm feed mainly on insects
Reproduction	• Breed during flood season • Males burrow nests in mud • More than one female may lay eggs in a nest. • Once the eggs are laid, the female leaves the nest and does not return. • Males aerate the water in the nest, guards the eggs and young for nearly eight weeks.
Distribution	• Nile basin and Lakes Albert, Edward, Victoria, Nabugabo, Tanganyika, Kyoga, Indigenous to Uganda but
Aquaculture	• Success trials on induced breeding, tank and pond culture of juveniles.

Appendix 2: Steps to Follow in Preliminary Evaluation of Cage Sites

Estimating the number of cages per site

To sustain the aquatic environment to provide a suitable environment for the cage farm, a balance to be needs to be maintained between production of by-products from operations and the ability of the site to assimilate or disperse these.

The optimum number of cages that can be placed per site depends therefore depends on the carrying ***capacity*** (see module 4.8. for more details).

Once the sites carrying capacity has been estimated, then the management requirements determines the number of cages (see table ….)

The steps below illustrates how site characteristics and production objectives influence age farm size in small bays close to shore

STEP ONE: Assess Site Suitability

	Criteria	Score	Given Score
Distance to nearest to obvious source of pollution	**More than 1,000 m** **Between 500 to1,000 m** **Less than 500m**	**3** **2** **1**	
Transparency (secchi disk visibility)	**More than 200 cm** **Between 100 to 200 cm** **Less than 100cm**	**3** **2** **1**	
Dissolved oxygen levels (mg/l) before 08.00 am in the morning	More than 6 mg/l surface to mid depth and more than 5 mg/l at bottom More than 5mg/l surface to mid depth and more than 4 mg/l at bottom More than 5mg/L surface to mid depth and more than 3mg/L at bottom	3 2 1	
Water depth at proposed position for cages	More than 8 m Between 4 and 8 m Less than 4 m	3 2 1	
The connection of the bay to open water of the lake	More than 1,000 m Between 500 to 1,000 m Less than 500m	3 2 1	
Characteristics of the long axis of the bay	Parallel to prevailing wind Oblique to prevailing wind Perpendicular to prevailing wind	3 2 1	
Currents between bay and lake	Not obstructed by islands, peninsulas, or aquatic weed infestations Less than 50% obstructed More than 50% obstructed	3 2 1	
TOTAL SCORE			
Interpretation of the Total Score	**1 to <7** **7 to 10** **11 to 17** **18 to 21**	**Unacceptable** Poor Fair Good	

STEP TWO: ***Estimate Site Carrying Capacity*** *(in this case based on feed quality and environmental water quality)*

The site profiles above have the following implications for management and consequently sizing of the farm in lieu of environmental considerations. (see sections...)

Overall site rating	Max allowable daily feed input(kg/ha)	Max. Standing crop
Poor	2.5	<250
Fair	5.0	250 to 500
Good	7.5	>500

c.f.

STEP THREE: ***Proposed Management for Site***

Key Parameters	Input Levels		
	Small-holder	**Medium Scale**	**Large-Scale**
Size of Cage (m^3)	2.5 x 2.5 x 2.5 m deep	4 x 2 x 3 m deep	12 m-D x 10 m deep
System	LVHD[1]	LVHD	HVLD[2]
cage carrying capacity is equal to optimum maximum stocking density per cage	150 – 200 kg/m^3	150 - 200 kg/m^3	12.5 kg/m^3
Water Quality management	Water depth +6m	Water depth + 8 m	Water depth+25 m
	Net depth 2.5 m	Net depth 3 m	Net depth 10 m
	Current1 – 10 m/min (Optimum 5 m/min)	Current + 5 m/min	Current+ 5 m/min
	Water transparency + 1m	Water depth + 1.5m	Water transparency + 2m
Feed	High quality extruded, min 30% CP, 5 kg/ha	High quality extruded, min 30% CP, 5 kg/ha	High quality extruded, min 30% CP, 5-7 Kg/ha
Expected FCR	1.7	1.7	1.7
Yield	800 - 1000 kg/per cage	3,600 kg/per cage	12 to 15 tons/cage

Average data obtained from farm trials in Uganda and Philippines ***Source:*** *EU/ MAAIF (2013).*

Note: LVHD[1] – Low Volume High Density; HVLD[2] – High Volume Low Density

STEP FOUR: ***ESTIMATED NUMBER OF CAGES FOR THE DIFFERENT MANAGEMENT CONDITIONS PER SITE CATEGORY***

- If feed only

A) Overall Site Rating Poor

B) Overall Site Ratting Fair

C) Overall Site Rating Good

Appendix 3: Feeding Charts

TILAIPA FEEDING CHART

Weeks in Production	Size (g)	Growth (g/ day)	Daily Feed (% BW)	Daily Feed/ Fish (g)	Type of feed Protein %CP - size (mm)	Number of Feedings/ Day
*Recommended Size at Stocking						
1	10	0.4	5.0	0.5	36 - 3	4
2	13	0.6	4.8	0.6	36 - 3	2
3	17	0.7	4.8	0.8	36 - 3	2
4	22	1.0	4.6	1.0	36 - 3	2
5	29	1.1	4.5	1.3	36 - 3	2
6	37	1.3	4.5	1.7	36 - 3	2
7	46	1.4	3.8	1.7	36 - 3	2
8	56	1.9	3.7	2.1	36 - 3	2
9	69	2.0	3.5	2.4	36 - 3	2
10	83	2.1	3.4	2.8	32 - 3	2
11	98	2.4	3.4	3.3	32 - 3	2
12	115	2.4	3.2	3.7	32 - 3	2
13	132	2.4	3.2	4.2	32 - 5	2
14	149	2.6	3.0	4.5	32 - 5	2
15	167	2.6	3.0	5.0	32 - 5	2
16	185	2.7	2.9	5.4	32 - 5	2
17	204	2.7	2.8	5.7	32 - 5	2
18	223	2.9	2.6	5.8	32 - 5	2
19	243	2.9	2.5	6.1	32 - 5	2
20	263	3.0	2.4	6.3	32 - 5	2
21	284	3.0	2.3	6.5	32 - 5	2
22	305	3.0	2.3	7.0	32 - 5	2
23	326	3.0	2	6.5	32 - 5	2
24	347	3.0	2	6.9	32 - 5	2
25	368	3.0	2	7.4	32 - 5	2
26	389	3.0	2	7.8	32 - 5	2
27	410	3.0	2	8.2	32 - 5	2
28	431	3.0	1.8	7.8	32 - 5	2
29	452	3.0	1.8	8.1	32 - 5	2
30	473	3.0	1.8	8.5	32 - 5	2
31	494	3.0	1.7	8.4	32 - 5	2
32	515	3.0	1.7	8.8	32 - 5	2
33	536	3.0	1.4	7.5	32 - 5	2

CATFISH FEEDING CHART

Weeks in production	Fish Size (g)	Growth (g/day)	Daily Feed (% BW)	Daily Feed/ Fish (g)	est FCR	Type of feed Protein %CP - size (mm)	Number of Feedings/ Day
***Recommended Size at Stocking**							
***1**	**10**	0.5	5.0	0.5	1.0	36-3	4
2	14	0.6	4.7	0.7	1.1	36-3	4
3	23	1.2	4.6	1.0	0.9	36-3	4
4	33	1.4	4.0	1.3	0.9	36-3	4
5	45	1.7	3.8	1.7	1.0	36-3	3
6	59	2.0	3.6	2.1	1.0	36-3	3
7	77	2.6	3.4	2.6	1.0	36-3	2
8	97	2.8	3.0	2.9	1.0	32-3	2
9	122	3.7	3.0	3.7	1.0	32-3	2
10	150	4.0	2.7	4.1	1.0	32-3	2
11	182	4.6	2.5	4.6	1.0	32-5	2
12	217	4.9	2.4	5.2	1.1	32-5	2
13	252	5.0	2.4	6.0	1.2	32-5	2
14	288	5.1	2.0	5.8	1.1	32-5	2
15	323	5.1	1.8	5.8	1.1	32-5	2
16	359	5.1	1.8	6.5	1.3	32-5	2
17	395	5.1	1.8	7.1	1.4	32-5	1
18	430	5.1	1.5	6.5	1.3	32-5	1
19	466	5.1	1.5	7.0	1.4	32-5	1
20	502	5.1	1.5	7.5	1.5	32-5	1
21	537	5.1	1.4	7.5	1.5	32-5	1
22	573	5.1	1.4	8.0	1.6	32-5	1
23	609	5.1	1.3	7.9	1.6	32-5	1
24	645	5.1	1.3	8.4	1.6	32-5	1
25	680	5.1	1.2	8.2	1.6	32-5	1
26	716	5.1	1.2	8.6	1.7	32-5	1
27	752	5.1	1.2	9.0	1.8	32-5	1
28	787	5.1	1.1	8.7	1.7	32-5	1
29	823	5.1	1.1	9.1	1.8	32-5	1
30	859	5.1	1.1	9.4	1.9	32-5	1
31	894	5.1	1.1	9.8	1.9	32-5	1
32	930	5.1	1.0	9.3	1.8	32-5	1
33	966	5.1	1.0	9.7	1.9	32-5	1
34	1002	5.1	1.0	10.0	2.0	32-5	1
35	1037	5.1	1.0	10.4	2.0	32-5	1
36	1073	5.1	1.0	10.7	2.1	32-5	1

Appendix 4: How to Use Feeding Chart

Catfish Feeding Chart for Pond Grow-Out

Weeks in production	Fish Size (g)	Growth (g/day)	Daily Feed (% BW)	Daily Feed/Fish (g)	est FCR	Type of feed Protein %CP - size (mm)	Number of Feedings/Day
*Recommended Size at Stocking							
*1	10	0.5	5.0	0.5	1.0	36-3	4
2	14	0.6	4.7	0.7	1.1	36-3	4

STEP 1

If on average, each fish weighs 10 g

STEP 2

The feeding chart shows that the total amount of feed a 10 g fish requires per day, is equivalent to 5% of its body weight.

STEP 3

Therefore, the total amount of feed a 10 g fish requires per day is:

$\frac{5}{100} \times 10g = \mathbf{0.5g}$ **feed per day**

STEP 4

A 10 g fish eats four times a day. Therefore, the estimated amount to feed at each meal is:

$\frac{0.5}{4} g = \mathbf{0.125g}$ **feed per meal**

Appendix 5: Examples of formulations for on-farm fish feeds.

Source FAO Aquaculture Feed and Fertilizer Resources Information System

TILAPIA DIETS

Ingredient/proximate composition	Life stages/size class			
Ingredient composition (%)	Early fry	Fingerling	Grower (in cage)	Grower (in pond)
Cassava starch	15	0	0	0
Cassava meal	0	23	23	22
Coconut meal	0	0	0	30
Rice bran	30	15	20	0
Soybean meal	0	30	25	25
Fish meal	47	25	25	20
Fish oil	5	4	4	0
Dicalcium phosphate	1	1	1	1
Vitamin and mineral premix*	2	2	2	2
Proximate composition (%)				
Dry matter	8.3	9.0	9.0	9.1
Crude protein	30.0	31.0	30.0	29.9
Crude lipid	10.0	7.4	7.5	4.1
Ash	16.3	12.6	12.8	10.7
Crude fibre	3.8	4.2	4.4	6.0
NFE	31.6	35.8	36.3	40.2
Gross energy (kcal/kg feed)	2,800	2,700	2,700	2,500

Source online: http://www.fao.org/fileadmin/user_upload/affris/docs/tilapiaT14.pdf

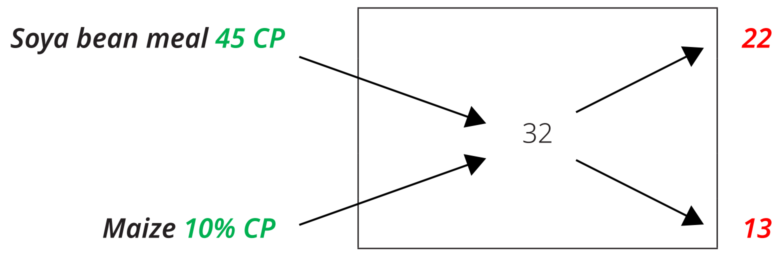
CATFISH DIETS

Feed formulations	**L1**	**L2**	**L3**	**F&B1**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**
Ingredient compostion	%	%	%	%	%	%	%	%	%	%	%	%	%
Fishmeal	43	50	50	30	20	55	25		10	10	24.7	20	2
Blood meal				5			10					5	48
Carcass meal		12.5		15					50.2	22.7	10.5	15	
Bone meal						4							
Poultry by-product meal										10	10		
Milk powder (full fat)		10											
Lake shrimp meal								34					
Torula yeast	50												
Soya meal (full fat)			30	15			35					22	
Soya oilcake					15	5				10	10		
Cotton oilcake[1]					15	5			9				2
Groundnut oilcake					5	4							
Sunflower oilcake[1]													
Brewery waste					15	10							
Rice/wheat bran					15	2		66					
Maize bran				11.5								13.5	48
Maize�			20		8	3	15		15				
Wheat		25		22					15	14		22	
Lucern meal											30		
Tomato waste meal										20			
Molasses powder									9.8	10	8		
Palm oil					2	5							
Sunflower oil	3						4						
Fish oil	3						6			3.3	6.8		
Starch/binder						2	2						
Vitamin & mineral premix	1	2.5		1.5	5	5	3					2.5	
Eggs (fresh)			5										
Proximate analysis													
Crude protein (%)	55.4				34.5	43.3	40		38	38	38		
Total lipid (%)	9				9	11			8.1	12.5	13.5		
Carbohydrate	21												
Gross energy (kJ/g)					19.2	20.4							
Digestible energy (kJ/g)									12	12	12		
Protein/energy ratio (mg/kJ)	30.4												
Feed Conversion Ratio									1.2	1.1	1.1		

Source: http://www.fao.org/fileadmin/user_upload/affris/docs/North_African_Catfish/English/table_7.htm

Appendix 6: How to use the Pearson's square to formulate feeds

A farmer would like to make 100 kg feed of 32% crude protein using soya bean meal and ground maize. The protein content of the soya bean meal is 45% crude protein and of the maize 10% crude protein. How much of each should be mix?



Steps

Write the 32% in the center of the box

On the left of the box write down each ingredient at the corner (green)

Subtract the Crude Protein percentage from the figure in the centre.

45 – 32 = 13

10 – 32 = -22

Add the top red and bottom red figures. Ignore the negative signs

13 + 22 = 35

Divide each of the red top numbers

Soyabean - 22/35 = 0.629

Maize = 13/35 = 0.371

The answers give the proportions to mix. So for 100 kg of feed:

Soyabean = 100 kg x 0.629 = 62.9 kg to be added

Maize = 100 kg x 0.371= 37.1 kg to be added

Appendix 7: How to prepare pituitary extract.

The pituitary gland can be collected from a freshly killed fish in two ways: by cutting open the head or by removing the pituitary gland (figure 23a) with a drill. It is easier to work on the head of a fish if you have a wooden frame to hold it firmly in place when cutting or drilling.

Collecting pituitary glands by cutting open the head

To cut open the head, proceed as follows:

a) remove the top part of the skull with a strong sharp knife

b) locate the pituitary gland in the brain mass

c) remove it carefully with forceps.

You may either use this gland immediately or store it for later use.

Extraction of pituitary gland

Preserving pituitary glands

a) As you collect the fresh gland from the fish, place it in a small bottle containing acetone. This chemical will start removing water and fat from the gland. It will harden and preserve the gland and the hormones it contains.

b) Collect together, in the same bottle, all glands obtained on the same day.

c) About every eight hours replace this acetone with new acetone, over a total period of 24 hours. Then drain out all acetone.

d) Dry the hardened glands on blotting paper.

e) Put the dry glands in small glass containers and press them down with a ball of fine cotton wool.

Cork the container tightly and seal it with wax or other sealing material such as paraffin. Label it, indicating the origin of the glands and the date of their collection.

f) Keep these sealed containers either in a plastic bag or in a desiccator or air tight storage jar, in the presence of a desiccating chemical such as silica or calcium chloride.

Acetone-dried pituitary glands can be safely stored this way for several years, without the need for refrigeration, as long as they are kept free from moisture. You may also keep fresh glands in a freezer.

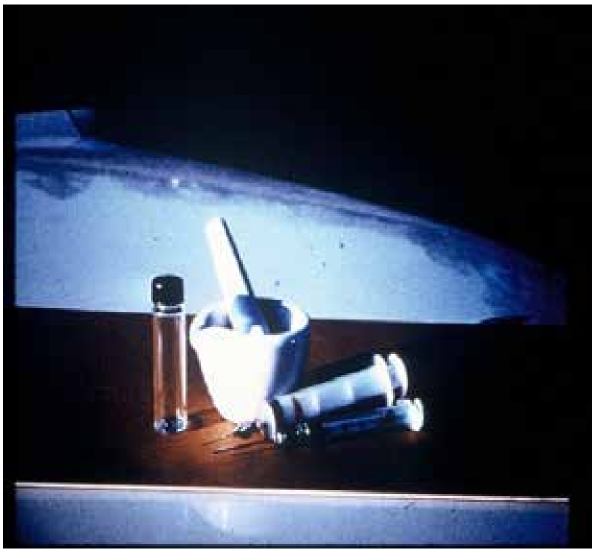
Extracting gonadotropic hormones from pituitary glands

The gonadotropic hormones which are injected to induce ovulation and/or spawning are extracted from the pituitary glands, either immediately on collection or after a certain storage period. The required quantity of powdered acetone dried pituitary material or the required number of whole pituitaries are crushed/pounded/ground/powdered in a porcelain mortar, mixed with the required quantity of physiological salt solution (9gm of common salt/litre of water). A syringe is filled with the suspension and the injection can be given.

The most common method of administering injection into the dorsal muscle.

- Cover the head of the breeder with a wet towel to keep it quiet during injection of hormones. In general most fish keep still if their eyes are covered.
- Normally the females are injected in the afternoon/evening and are kept (separated from the males) in holding facilities. The holding facility can be a concrete basin inside a hatchery, a happa in a pond or even a simple plastic bucket or a half oil drum will do. Of major importance is that the breeders can be caught easily the morning after injection so as to avoid spoilage of eggs.
- Fill the syringe, insert the needle on it and empty the syringe again into the mortar, when this is possible you can start to inject the fish. This procedure has to be followed always, as the needle often gets blocked if the pituitary material is not completely crushed and it is unpleasant for the fish and annoying for the operator to resolve this problem once the needle is inserted into the fish.

Pituitary extract of fish



Equipment for crushing pituitary gland

Appendix 8: Record Sheets and their Interpretation

FEED SHEET: week of

Pond	Type feed	Amt to feed	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Tot kgs	Observations

Feeding Response: E - excellent G - good F - fair P - poor

Pond: **Size:** ______________________ . **Function:**

Date	Stock	Treat	Sample	Harvest	Drain	Description (species, numbers, weights, sizes, where from, where to)	Total #	Total Weight

Interpretation of Tilapia Pond Management Records

Pond Record	Possible Causes	What Should I do?
A) Not much positive gain in between samplings in total pond biomass	- Pond is approaching carrying capacity or feeding the wrong feed	The options include: 1. Reduce the fish biomass in the pond. 2. If the pond water smells foul and with frequent low D.Os, it is time to start exchanging at least 50% of the water in the pond daily. This should only be a short-term solution (e.g., 1 week). 3. Check that you are not putting beyond the maximum amount of feed into the pond that it can assimilate. Improve the quality of feed used to pellets if using powders. 4. Adjust your pond depth at the next cycle if the water depth in the pond is less than a meter.
B) Sudden Mortalities and Fish Floating on Water Surface with Opercula Open	- Sudden deterioration in water quality most probably due to low dissolved oxygen. Opercula open indicates fish may have been gasping.	1. Stop feeding. 2. Note whether or not there are any changes in water colour and smell. 3. Flush water through the pond.
C) Three to four fish dying every day	- build up of a parasite problem	1. Control the situation to prevent it from worsening by: - ensure good water quality within pond, - identify and remove possible sources of entry (e.g. check screens are in good condition, minimise organic build-up in pond, keep area around pond clean so that there is no refuge for animals that may be transmitters of such parasites. - ensure fish are fed adequately, both in terms of quality and quantity. - identify and remove potential stressors. 2. It is often not economical or practical to treat grow-out fish at such a stage. 3. Minimise handling, e.g. do not sample until the situation is under control. If one has access to diagnostic facilities, then one can send a sample to be checked in order to confirm it is a parasite load and what sort of parasite is affecting the fish.
	- if it is a couple of days after stocking or sample, due to procedural stress. In this case mortalities should stop within a week at the most. - Fish may have been scared or frightened. If this was due to a predator, there may additionally be signs of injury on affected fish.	1. Maintain good pond condition 2. If due to predation, work at controlling it. 3. Minimise sharp sudden noises or activity in/around ponds.

Pond Record	Possible Causes	What Should I do?
D) Polluted waters, pond still below carrying capacity compounded with high FCR for the size of fish in the pond.	- overfeeding. Feeding response is also likely to be poor.	1. Stop feeding. 2. If water quality is really bad (smelling), flush the pond. 3. Re-adjust ration with aide of feeding chart. Cut estimated ration by half, train fish to feed by response, and add more feed based on their response and desire for more feed.
E) Add recommended amounts fertiliser to pond but it never turns green	1. Pond water is acidic, less than 6.	1. Where pond is acidic, lime the pond first. Dissolve the lime first in water and sprinkle over the pond. Add small amounts over a couple a days until the alkalinity and/or pH picks up. 2. Phosphorous is likely to be the limiting factor in this case. If you fertilise, then add small amounts of phosphorous only till it turns green.
	2. Alkalinity of water is less than 20 mg/l	2. Lime with agricultural lime. Ensure there is no seepage. Dissolve the lime first in water and sprinkle over the pond. Add small amounts over a couple a days until the alkalinity and/or pH picks up.
	3. May be a lot of seepage (water loss) through the pond requiring that it is constantly refilled.	3. Repair the leaking points you can. If you cannot, and there is still a lot of water loss, might be better to drain and fix pond first. Fish can be sold as stockers to another farmer or stocked into another pond. Weigh the consequences of drainage first, ***vis-a-vis***, the economic effect of possible increased FCRs, reduced growth rates and low survival from escapes.
F) Pond too green, foul smell, fish up piping most mornings, poor growth	1. High organic loading.	1. Do not add any more fertiliser to the pond. 2. Stop feeding 3. Flush pond to dilute wastes
	2. Pond at carrying capacity	1. Do not add any more fertiliser to the pond. 2. Stop feeding 3. Flush pond to dilute wastes 4. If pond has exceeded carrying capacity, reduce stocking rates.

Interpretation of Trends in Feeding Response and FCR

FCR Trend	Possible Causes	What Should I do?
A) FCR is much lower than what is suggested by the feeding chart while at the same time the feeding response is continuously excellent	1. Underfeeding	a. Increase the feed ration. Determine the increase in amount to feed by feeding until the fish appear to lose interest in consuming more food.
	2. Loss of fish/ Mortalities – there may be fewer fish in the pond than what one actually thinks. This is only true for the estimated interval FCR. If this is the case, then at draining, the ***real*** FCR will be much higher.	a. Do a complete inventory, if possible, to ascertain exactly how many fish are in the pond and what size they are. This requires draining the pond and transferring fish to another pond. This should be a last resort because the stress of moving the fish will add to the mortality. b. Determine the feeding ration based on response rather than the feed chart directly. c. Make sure ponds are stocked with fingerlings that are actually 'alive' and of the recommended size (5 g for grow-out ponds). Watch the way fish are handled and packed from the hatchery. Fish should be packed in bags with oxygen for transportation or transported in properly aerated or oxygenated tanks in adequate amounts of water.
B) Increase (high) in FCR and reduced feeding response	1. Overfeeding. (Overfeeding can arise when there is a lot of natural food in the pond or few numbers of fish in the pond).	a. Reduce the amount of feed being given to the fish based on feed response. b. Cut ration for about two to three days to get fish really hungry then give amounts based upon response c. Check pond bottom under feeding area for leftover feed.
	2. Poor Feeding technique- trickling in feed and feeding more frequently than is required.	a. Cut ration for about two to three days to get fish really hungry then give amounts based on response b. The number of feedings to be given depends on the size of fish and ration size that fish is to get based on its percent body weight. Each ration should be about 1% of the fish's body weight. c. The amount fed should be slightly less than the daily feed requirement (i.e. about 80 -90% of the full ration)
	3. Poor quality feed (both qualitative and quantitative) – e.g. Pellet size may be too big or small (feeding powder when fish are big), pellets disintegrating in water too soon, pellets too hard, rancid feed.	a. Buy the correct type of feed for the fish being raised (i.e. protein levels, size of pellet) b. Check the pellets at purchase. c. Do not purchase and stock too much feed over a long period on the farm. Purchase enough to last about 4 – 6 weeks to ensure that fresh feed is used as much as possible. d. Store your feed correctly to prevent it getting wet, mouldy or rancid. Feed should be stored off direct floors and levees on pallets, in a well-ventilated room that does not leak, and has provision to prevent pest entering (e.g., rats and bats).

C) Increase in FCR while feeding response remains fairly good	1. Pond may be attaining its carrying capacity-i.e., grow slowing down	a. Check inventory trends from pond records b. Reduce stocking densities
	2. Feeding technique – dumping of feed.	a. Feed by response
D) Drop in feeding response	1. Changes in Water Quality causing the culture environment to become less favourable (e.g., drop in water temperature on cool days, reduced oxygen levels)	a. Do not increase feed at the next ration to compensate for the period when it was cold. b. Feed based on response – give the right amount for the ration.
	2. Fish Falling Sick	a. Identify the cause
	3. Cold weather	a. Reduce feed amount (cut the ration in half if the temperature drops from 28oC to 22oC for example).
	4. A sudden but unseen loss of fish (e.g. theft).	a. Adjust feed amount by feeding by response.
E) Low feeding response but fish growth good in well fertilised ponds	1. Tilapia, especially if they are juvenile obtaining enough to eat from plankton	a. Continue maintaining optimum levels of pond fertility. b. May reduce feeding frequency to once a day, preferably in the afternoon. c. Ration can be reduced by half based on the fishes actual feeding response.

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Other NARO and MAAIF aquaculture and other sector-related production guidelines, permitting and certifying requirements (e.g. postharvest, value-addition, phyto-sanitation, marketing, environmental and water resource management, biosecurity, etc). 11.   Other regional a guidelines on aquaculture production and marketing The above list is not exclusive.

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