A COMPANION FOR FISHFARMERS IN KENYA

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1 FISH FARMING IN KENYA

What is aquaculture?

The term ***Aquaculture*** is used to refer to the farming of water dwelling organisms in controlled or semi controlled environments to enhance productivity. The organisms are farmed or grown because they have value to man. These organisms include fishes, molluscs, crustaceans, aquatic plants etc. The farming activities may include stocking, feeding, protection from diseases and predators and harvesting.

Compared to conventional livestock and crop farming, aquaculture is much more diverse and varied. There are many diverse species cultured. The different species have different biology and therefore different ecological requirements. They therefore have different feeding, breeding and water quality requirements.

A brief history of fish farming in Kenya

Aquaculture industry in Kenya has greatly grown over the last few decades. Promotion of aquaculture started in the early 1920s as a subsistence means of supplementing protein sources in the rural areas. This was a non-commercial approach and it was promoted only as a family subsistence activity. This has however changed over the years with the government putting a lot of effort and resources in promoting aquaculture as a business. Many entrepreneurs s have now invested in commercial aquaculture ventures.

Aquaculture activities in Kenya involve the production tilapia (mainly *Oreochromis niloticus*), the African catfish (*Clarias gariepinus*) and the Rainbow trout. The tilapines and catfish production is mainly done as mono or polyculture of the two under semi intensive systems using earthen ponds while the Rainbow trout production is done in intensive raceways and tank systems. The Tilapine species constitute the largest portion of aquaculture production in Kenya. Although most of the productions target the food fish market, there has been an increasing demand for baitfish for the Nile Perch capture of Lake Victoria. Several entrepreneurs have started producing the catfish juveniles for this market. Ornamental fish production is also gaining interest and several producers are engaged in the production of gold fish and koi carp among other ornamental species.

Aquaculture in Kenya can be divided into two broad divisions, i.e.

- Marine aquaculture and
- Fresh water culture.

Although Kenya has a long coastline along bordering the Indian Ocean, and therefore great potential for marine aquaculture, this is yet to realise any meaningful development and the resources remain largely un used.

Fresh water aquaculture dominates fish farming in Kenya and can be divided into:

- Cold water culture involving culture of rainbow trout (*Oncorhynchus mykiss*) in highland areas and
- Warm water culture involving the culture of Tilapine fishes, the African catfish, common carp and a variety of ornamental fishes in low land regions of the country

Aquaculture investment opportunities in Kenya

Some potential areas of investment in commercial aquaculture in Kenya include:

i). **Integrated aquaculture**
Aquaculture can easily be integrated with conventional crop and livestock farming. The management techniques and inputs employed are similar to those that crop and livestock farmers are familiar with. Integration has a lot of benefits for farmers. In addition to the production of fish for consumption or sale, it increases efficiency in use of available production resources by allowing for recirculation of nutrients among different production units. This provides opportunities for diversification on crop and livestock farming and can put to productive use otherwise idle land resources

ii). **Cage culture**
This can be done in rivers, water reservoirs, lakes and the ocean. The advantage here is that more benefits can be generated from such water bodies and yet the technology and the capital input do not have to be demanding.

iii). **Bait culture**
There exists a very big market for bait fish (juvenile *Clarias gariepinus* and *Chanos chanos*) for the Nile perch capture industry in Lake Victoria and Tuna fisheries of the Indian Ocean. The technology for the culture of the bait fish exists locally among aquaculture experts and many farmers in the Lake Victoria region are already doing it.

iv). **Ornamental fish culture**
There are only a handful of ornamental fish producers in Kenya. Resources for culture of both marine and fresh water species are available in Kenya. Potential markets for the ornamental fishes include local cities, the Africa countries, Europe and Asia.

v). **Integration with livestock farming in ASAL**

Fish could be stocked in water pans meant for livestock watering. This will increase the benefits accrued form such water bodies by diversifying sources of income and increasing security for quality food for livestock farmers in such areas.

vi). **Capture-based Aquaculture**

This can be done in the many water reservoirs in the country. These include domestic water reservoirs, irrigation reservoirs and the hydro electricity reservoirs. Capture-based Aquaculture involves stocking of such reservoirs with appropriate fish species of commercial value which is later harvested when mature. This can have an overall effect of increasing the fisheries resource base and therefore food security and incomes to fishers.

Any or a combination of the above can lead to attractive profits if well planned and thought out. For an investor to opt for any of these enterprises, it is important for the decision to be based on proven facts. This calls for thorough prior planning.

2 CONSIDERATIONS BEFORE INVESTING IN FISH FARMING

Introduction

When starting aquaculture, thorough planning before any investment is made is very important. Planning will involve a detailed evaluation of both the **biological** and **socio-economic**, aspects of the venture. The technical requirements for fish production must be satisfied for the fish farmer to harvest a crop that meets both his economic and social goals.

It is therefore essential to ascertain that your aquaculture business idea is realistic.

Ask whether:

- There are adequate and profitable markets for proposed product(s)
- You have a suitable site for the proposed production
- You have enough resources to meet the projected targets
- Your financial projections are realistic, robust and consistent
- You have the expertise to produce
- You can access adequate essential support services
- Your proposed undertaking meets all the environmental, social and requirements as required by the government

All these should be answered in a well thought out **BUSINESS PLAN** and will provide you with a written document to serve as your reference for your business.

Business Planning Process

Business planning is important to both new and established aquaculture enterprises. It enhances the chances for success by helping you identify and go over avoidable mistakes. The plan will be helpful when looking for financing, because many financial institutions require a workable **business plan** before providing the financing. For your aquaculture business to succeed, you need a **business plan**. This will provide you with bench marks for your business. It will be your working document and it will need to be reviewed and updated at least on yearly basis.

A **business** plan is analysis of **production**, **market** and **financial** aspects of your proposed aquaculture enterprise. It consists of:

- A thought out description of production technologies and strategies
- A well researched and thought out marketing strategy
- Financial analysis of the proposed venture

A business plan will:

- Be very instrumental when soliciting for financing

- Explain to potential financiers that aquaculture is viable investment worth funding
- Help the investor to keep on track during the course of the business
- Help minimize risks associated with the market, production and financing

Basics Components Of A Good Aquaculture Business Plan:

1. **Marketing plan**

Where will I sell my fish? This is a question you should ask well before you go into fish production. Surprisingly , many fish farmers ask this question deep into their production cycle. Others will ask this question after they have harvested their fish. As a serious producer, you should ask and get answers to this question well before you go into production.

Many aquaculture entrepreneurs in Kenya overlook markets/marketing for their produce yet this is the essence their business. This is where profit should come from. They fail to take notice of the fact that for any enterprise to succeed, it must target specific and well thought out market/markets.

Any serious entrepreneur will produce goods which match the needs and wants of the customers they wish to serve. Therefore, one must make a decision on what to produce based on what the market wants.
Therefore, to avoid uncertainties and eminent failure, the first questions that an investor must ask and get answers to, are:

- What products does the market demand?
- What quantities does the market demand?
- What production resources do I have?
- Can the resources meet the proposed production?
- Which fish products am I capable of producing?
- What quantities can I realistically supply?
- When does the market want them supplied?
- What quality does the market require?
- Can I meet these standards?
- Is it possible to get a bulk buyer?
- Does the demand in the market justify the intended production?
- What prices is the market ready to pay?
- Is it cost effective to produce at the offered prices?
- What competition exists in this field and how do I deal with it?
- Are the existing physical infrastructure (roads, power telecommunication etc) sufficient to meet the marketing needs for the produce?

After answering these, the entrepreneur should be able to make a decision on whether to continue or abandon the proposed production. If the entrepreneur decided to go on, then, it is time to develop a **marketing strategy**.

2. Marketing strategy

A marketing strategy is a plan to achieve the financial goals of the entrepreneur. The strategy should address; the products, product prices, advertisement and where to sell as regards marketing. Ideally, the products must be sold for more than the production cost and quantities that allow the producer to make gains and remain in business.

Marketing strategy involves:

i. Analyzing the market situation
ii. Formulating marketing goals
iii. Evaluating and selecting suitable marketing alternatives

i. Analyzing market situation

To do this, the entrepreneur should have a good knowledge of:

- Potential customer
- Modes of marketing (e.g. do you need to draw agreements, do you have to go through brokers etc)
- Product prices and their seasonality
- Product forms acceptable by the market
- Product quality requirements including regulation governing this
- Consumer preferences
- Quantity requirements
- Modes of payments and frequency
- All costs involved
- All competing products
- Alternative markets
- History regarding prices, demand, supply, product spoilage, product rejection etc

ii. Marketing goals

In formulating marketing goals, the producer must ask and be able to answer the following:

- What is the targeted production?
- Is this achievable?
- What is the size of the target market in terms of geographical extent and consumer number?
- Is it possible to reach this market?

The goals must be realistic and achievable; otherwise the producer will be groping in darkness without purpose.

iii. Marketing alternatives

It is important to consider marketing alternatives to avoid disappointment where a target markets collapse. For the marketing alternatives chosen or considered, product volumes and size preferences, costs associated with the marketing, and relevant legislations should be considered very carefully.

Markets for aquaculture products in Kenya include:

- Hotels, restaurants, retail markets and fish shops including supermarkets: These could be out of reach of most small scale producers because they might not meet the frequency and quantity requirement of such outlets. However they can easily overcome this by forming marketing groups.

- Farm Gate Sales: Where local demand for fish is high, this offers a very good option. It removes the problems associated with taking the produce to distant markets. However it necessitates for proper storage facilities like deep freezers or cold rooms and some degree of processing and packaging.

- Sales to whole sellers, fish processors and large institutions: The advantage here is that large quantities can be disposed off at once and terms of supply and payment are normally stipulated in a legal contract. But this is only suitable for large scale producers.

3. Production techniques/strategy

When planning for commercial aquaculture, the following aspects of production must be considered very critically:

i. Fish to be produced
ii. Production site
iii. Production technology

I. Fish to be produced

The choice of what to produce will be guided by:

a) Market preference
b) Ecological requirements of the fish
c) Production technology of the fish
d) Resources available to produce

The fish to be produced must not only be marketable but also suited for the climate and be produced cost effectively. Different fish require different climatic conditions to perform optimally. For example:

- Nile tilapia and African catfish require warm water of more than 25°C.
- Growth of these fish is quite slow at elevations greater than 1600 meters because the water temperatures are very low
- For best performance, average water temperatures of about 28°C are best
- In Kenya, such regions are to be found in low land areas
- In areas where temperatures are lower than this, a larger pond surface area can compensate
- High sunlight intensity is also preferred for tilapia culture under semi intensive production.
- Trout require cold water of less than 18°C for grow out and below 10°C for hatchery production. Such conditions in Kenya are to be found in high altitudes areas. The water must be adequate, clean and fast flowing.

It is also important to know whether the species selected for production is adaptable to intended culture conditions and there is adequate knowledge of the reproductive biology, nutritional requirements, common diseases and parasites of the species. Also important is to ascertain that the species proposed for production is being profitably produced at commercial levels by other producers.

Other issues to consider, which are equally important are:

- Is there a reliable supply of good quality juveniles at a reasonable price, for stocking?
- Are you capable of establishing your own seeds (juveniles or ova) production capacity?
- Is there quality feed for the species and are the prices cost effective?
- Do you have a reliable and affordable source for specialized production supplies and equipment?

A good species should have the following characteristics:

- Adaptable to culture conditions
- Fast growth rate, from egg to market size
- Simple and inexpensive dietary requirements
- Hardiness and resistance to diseases and parasites
- Producer can have full control over the life cycle processes in captivity
- Easy market acceptability
- Availability of advanced and proven production technology

II. Production site

The proposed site should have the following characteristics:

- Be located in a region suitable and allowed for aquaculture production
- Have a climate suitable for the species intended for production (preferably indigenous to the area)
- Be well drained and protected from floods
- The topography and the soils should be suitable for the construction of the proposed production system
- Have adequate and preferably free flowing good quality water supply. This is the life line of aquaculture and is a must.
  - Water is the key to a good site
  - Water should be available throughout the year
  - Water must be free from pollution e.g. pesticides & other detrimental chemicals
- Accessible throughout the whole production cycle and have easy access to services and technical assistance
- Have adequate space for intended function and possible future expansion
- Located on site acceptable under local and environmental management legislations
- Have good Infrastructure like:
  - Roads to bring supplies to the farm and take the products to the market?

    - Air or water transport where export markets are the targeted
    - Power where intensive production systems are proposed
    - Telephone service may be needed to run the enterprise efficiently
- Have good security

III. Production technology

Aquaculture, compared to crop and animal farming, is much more diverse and varied. There are many different species that are cultured each with different ecological requirements. They therefore have different feeding and breeding requirements as well water quality. Aquaculture production is done at different management and intensity levels. Production systems have therefore been developed to meet both the economic needs of the producer and the requirements of the species to be cultured.

The choice of the production level will depend on:

- The species of choice
- Availability of the needed technology
- Prevailing prices of fish
- Available capital
- Availability of essential inputs for example feeds, power, skilled labour, professional expertise etc.

Depending on the planned level of production and the resources available, the producer will make a choice from the following:

i). Extensive systems

In these systems little or no input is used in the production. Fish are stocked in cages, still water earthen ponds and other water impoundments (for example reservoirs) and left to fend for themselves. Low stocking densities and thus low yields characterize the systems. The main cultured species are Tilapines (e.g. *Oreochromis niloticus)*, *Clarias gariepinus* and *Cyprinus carpio*. These are low input–low-output production systems. Majority of the small scale, subsistence fish farmers in rural Kenya fall in this category.

Production in these systems ranges between 500 and 1500 Kg/Ha/year.

ii). Semi-intensive systems

These systems form the bulk of aquaculture production in Kenya. In these systems still water earthen ponds and cages are used as holding units for fish culture. Still water pond culture uses the natural productivity of the water to sustain the species under culture. However to enhance productivity, the ponds are fertilized using both chemical and organic fertilizers at varying proportions to enhance natural productivity. Exogenous feeding using cereals bran and other locally available feeds is done to supplement pond productivity. Polyculture of *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* is practiced with various combinations of species.

Commercial production in these systems ranges between 1 to 3 Kg/m^2/year depending on the management levels individual farmers employ.

There are Tilapia/Catfish producers in Western Kenya who have achieved productions between 6-10Kgs/m^2/year

iii). Intensive systems

In these systems water flows in and out continuously (flow through). This allows higher stocking densities. The systems require good supply of good quality water. Less land is required to produce the same quantity of fish as compared to extensive and semi intensive systems.

The systems employ mainly raceways, various types of tanks and floating cages as holding units. In these systems, more fish are produced per unit area by complementing or substituting the natural productivity in the culture units by exogenous feeding using complete feeds (the feeds are specifically manufactured for the species under culture) and water aeration. Such operations require high initial capital investment and high operational cost. They are mainly suited for high value fish. There are very few such operations in Kenya and most of them produce Rainbow trout.

Production in such systems in Kenya range from 10-50Kg/m^2/year. This depends on the management levels employed by individual producers. This production can go higher with better management and quality feeds.

3 EVALUATING VIABILITY OF A NEW FISH FARMING BUSINESS

Introduction

The reason for starting any business is to make profit/gains. This applies to all kinds of business including aquaculture. In aquaculture business, proper management of **BIOLOGICAL** aspects of production is very important, so are the **FINANCIAL** aspects of the enterprise. An entrepreneur must beforehand evaluate the new business to know whether it is **viable** and continue to monitor its **financial health** during the whole period of operation.

How do you make decisions on investments?
One way of evaluating whether a business idea such as a new aquaculture investment will make profit in the long-term, or to chose between aquaculture opportunities which vary in size, is by use of **capital budgeting**. The most used methods of capital budgeting include the use of net present value (**NPV**), and internal rate of return (**IRR**). Pay-back period (**PBP**) and the breakeven point (**BEP**) are also used as indicators of viability of investments.

Net Present Value (NPV) is used in the analysis of the profitability of an investment. It gives indication of the today's value of what will be earned by the business in future. Remember that KShs 1,000 earned five years to come does not have the same value as KShs 1,000 earned today. To get the present value of KShs 1,000 that will be earned five years to come, we discount it to its value today. This will give the NPV value.

If NPV is	What does the value show	What does it mean
Greater than zero (0)	The investment will be profitable The higher the NPV value the better is the investment	the project may be accepted
NPV < 0	The investment is likely to have a negative Net cash flow	the project should be rejected

What potential investors need to know is that NPV can be calculated easily using tables, and even much easier by use of computer soft ware like the Microsoft Excel spread sheet.

However, the best way is to contact an aquaculture economics expert from the Ministry of Fisheries development to do these for you.

Internal Rate Of Return (IRR) indicates the estimated rate of return that a project is expected to generate to an investment. This can be viewed as the efficiency of an investment to bring in profit.

IRR can be calculated easily by use of computer software like the Microsoft Excel spread sheet.

Pay Back Period (PBP) is the time required to recover the money invested in a project through the profits the project makes. It is calculated by dividing what was invested by the annual profits. This method has limitations and should only be used as a first step at the initial stages of evaluation to give an indication of how long it will take to recover what was invested and may not be relied upon to rank investments on basis of profitability. PBP is calculated as:

PBP= I/E

Where:
PBP = payback period in years
I= Initial investment
E= Annual accumulated profits

Breakeven Point (BEP) describes how much a business must produce to cover for the total cost of production. At the BEP, the revenue generated by a project equals the total cost incurred. An investor will need to know this to weigh this against production possibilities available. However, this method like the PBP should only be used as a first approach before proper evaluation is conducted because it does not show profitability of projects.

For aquaculture investment, BEP can be derived for **production quantities** and **produce prices**. BEP analysis for production quantities is derived by calculating how much farmer should produce per hectare, considering the prevailing market prices of fish, to be able to cover for the total production cost.

It is calculated as:

$$\textbf{BEP} = \frac{\textbf{Estimated total production cost}}{\textbf{Estimated price per unit of produce}}$$

In Table 1, the BEP for production quantity (Kg/Ha/Year) is calculated by dividing the total production cost (TC) KShs 1736000 by the prevailing price of fish KShs 250 per Kg.

<u>KShs 1,736,000</u>
KShs/Kg 250

This will give 6,944 Kg which is for the 0.5 Ha farm. Therefore, for a 1 Ha farm, it will be 13,888 Kg or 13.9 Mt/Ha/year.

This means that the farmer must aim to produce above this so as to make profit.

The BEP for the produce prices is calculated by deriving the price at which the produce must be sold to cover the total cost of production.

BEP for produce price is given as:

$$\textbf{BEP} = \frac{\textbf{Estimated total production cost}}{\textbf{Estimated total production}}$$

This will give a farmer an indication of how must he needs to sell his fish to recover his production cost. For the farmer to make profit, he must sell his fish above this price. In the case given in table 1, the farmer must sell the fish above KShs 115 to make profit.

Sensitivity of an investment to aspects of production is very important. Some of these aspects can be very volatile and their changes might have enormous effects on the profitability of projects. For investors to be able to make choices on where and how to invest, they need to know how likely variations on production output, cost of inputs or even changes in the market prices for the products will affect their future cash flows and net incomes.

To be able to carry out a proper sensitivity analysis, an entrepreneur needs the following information for each of the investment type:

Capital investment costs estimates:
a) Cost of land
b) Cost of construction of buildings and fish production facilities
c) Cost of acquisition of equipment and machinery

Operational investment that included the cost incurred during production. These included:
a) Quantities of inputs used in production
b) Cost of inputs of production
c) Payment of salaries and wages
d) Costs of taxes, depreciation, permits and licences
e) Cost of acquisition of financing

Operational incomes that included:
a) Products and production quantities
b) Market price of products per unit value of product

For aquaculture investments, sensitivity can be analysed by simulating changes (but not limited to) in:
a) Produce prices
b) Cost of feeds
c) Production quantities
d) Food conversion ratios and

e) Survival rates of fish species under culture

It is important to point out that there are experts in aquaculture economics in Kenya who can do these analyses for potential investors. Unless the investors are themselves conversant with the analysis, they need not struggle to do them but consult the experts.

Enterprise budgeting

Commercial aquaculture can result in good profits but it can also result in meaningless gains or huge losses. The reasons for failure are diverse but include:

- Over-capitalization
- Improper practices
- Poor planning
- Lack of foresight
- Lack of hindsight

There is no need to start something that you do not know whether it will make intended gains. It is therefore important to find out in general terms, the costs and returns of the proposed aquaculture venture before investment is done. To do this, you need to do a **budget** of your **enterprise** to see how it will operate. An **enterprise budget** provides information on annual cost, annual returns and capital investment requirements for a particular enterprise. Many farmers budget in their heads and end up making wrong decisions. Good budgets should be written so that they can be reviewed as times goes by. Most of the information needed for a good budget is available locally e.g. past experience, farm plan, agricultural input dealers for input costs, aquaculture product dealers for fish prices etc.

Uses of an enterprise budget;

- It is used by Farm manger as a plan of operation before production
- Can be used as reference during production or after marketing
- It forms basis of a comparison of what really happened versus what was planned so as to inform on improvement
- Aid in cash flow planning, in controlling production costs and in determining the Break Even Prices and Yields

The basic structure of an Enterprise Budget consists of:

i). Gross Receipts

This refers to gross returns or total sales from the farm. It is the income generated from the sale of farm produce e.g. fish, fingerlings etc. They are estimated by multiplying the total expected harvest weight (quantity) with the expected price per unit weight (Kg)

ii). Variable costs

This is also referred to as operating costs. These are costs that vary with production or expenses related directly to the quantity of fish produced for market.

All production costs/expenses are itemized and they include; Cost of fingerlings, feeds, labour, interest on operating capital etc.

Interest on operating capital is a variable cost and is a charged for a loan required to purchase production inputs

Total Variable costs (TVC) is the sum of all variable costs

iii). Fixed costs

These are costs that are incurred regardless of the level of production (operation). A good example of this is the cost of ponds, buildings, equipment and machinery. Whether the farm is on production or not, the farmer will continue to incur cost on these items.

TOTAL FIXED COSTS is the sum of all fixed costs.

Summing the **TOTAL VARIABLE COST** and the **TOTAL FIXED COST** gives the **TOTAL COST.**

NET RETURNS*:* This is the difference between **GROSS RECEIPTS** and **TOTAL COSTS** which is the indication of the amount of profit earned.

Returns above variable costs

- This is the difference between the GROSS RETURNS and the TOTAL VARIABLE COSTS.
- If this figure is positive, it means that all variable expenditures are covered and the enterprise is profitable at least in the short run.
- If they are negative, it is advisable to close the business if you cannot reduce on the variable costs

Net returns

- This is the difference between the TOTAL COSTS and the GROSS RETURNS.
- Positive returns indicate that the enterprise is profitable even in the long term while negative returns indicate that the enterprise is not viable and should be abandoned if you cannot reduce on the costs

Table 1: An enterprise budget for a hypothetical fully operational tilapia /catfish farm

Total area of ponds 0.5 Ha
Productivity 3kg/m^2/year
Av price of fish in KES/Kg 250

Item	Description	Unit	Unit price (KES)	Quantity	Total Amount
Gross Receipts					
Tilapia	Whole fish	Kgs	200	12,000	2,400,000
Catfish	Fillet	Kgs	300	3,000	900,000
Gross Receipts					**3,300,000**
Variable Costs (VC)					
Tilapia fingerlings	1 month old	No.	3	30,000	90,000
Catfish fingerlings	1 month old	No.	5	10,000	50,000
Wheat bran		Kgs	30	35,000	1,050,000
Fertilisers	DAP	Kgs	50	130	6,500
	CAN	Kgs	50	270	13,500
Lime		Kgs	20	1,300	26,000
Labour	Pond repairs and harvesting	KES/day	2000	150	300,000
Interest on operation loan		KES	12%	500,000	60,000
Total Variable Costs (TVC)		KES			**1,596,000**
Net returns above TVC		KES			**1,704,000**
Fixed Costs (FC)		KES			
Depreciation	Ponds	KES			40,000
	Equipment	KES			10,000
	Machinery	KES			30,000
	Buildings	KES			10,000
	Water supply system	KES			20,000
Interest on capital investment		KES			30,000
Total Fixed Costs (TFC)		KES			**140,000**
TOTAL COSTS		KES			**1,736,000**
Net returns above TC		KES			**1,564,000**
Net returns/Ha		KES/Ha			**3,128,000**
Break Even Price					
Above TVC		KES/Kg			106.4
Above TC		KES/Kg			115.7
Break Even Yield					
Above TVC		Kg/Ha/Year			12,768
Above TC		Kg/Ha/Year			13,888

These calculations are based on the 2009 input costs

Cash flow budget

One useful tool for planning the use of money in an aquaculture enterprise is a cash flow budget. A cash flow budget is an estimate of all cash receipts and all cash expenditures during a certain time period. Estimates are made monthly, bimonthly, quarterly or annually. Estimates can include non-farm income and expenditures as well as farm items. Cash flow budgeting looks only at money movement, not at profitability. Non-cash revenue or non-cash expenses e.g. depreciation, are not considered.

A cash flow budget is a useful management tool because it:

- Makes you to think through your production and marketing plans for the year.
- Tests farming plans: will it be possible to produce enough income to meet all cash needs?
- Projects need for operating credit and ability to repay borrowed funds.
- Projects when to borrow money and when to repay
- Helps in control of finances. By comparing the budget to actual cash flow, one can spot developing problems due to an unexpected drop in income or unplanned expenses, and opportunities to save or invest funds if net cash flow is higher than expected
- Helps communicate farming plans and credit needs to lenders

Items to be included in a cash flow budget include:

- Receipts from sales
- Operating cash expenses
- Living expenses
- Other expenses e.g. Personal withdrawals
- Debt interests and payments
- Capital sales
- Capital purchases
- Income tax payments

Each type of revenue is charged during the specific period when it is occurred.

Cash flows differ depending on the purpose for which the analysis is being developed. You could have:

- Monthly cash flow budgets – for detailed financial planning
- Quarterly budgets – to develop estimates of cash needs over a several year period
- Annual budgets – used in investment analysis to determine cash flow over the life of the investment

Components (items) of a cash flow budget

- **Beginning Cash Balance (BCB)** – This is the amount of cash at hand at beginning of the production period.

- **Receipts** – Cash revenue generated by sales of the crop or capital assets.

- **Note**: Cash revenue items (receipts) + BCB are summed up to obtain **TOTAL CASH INFLOW** for the time period

- **Operating Cash Expenses** – Expenses related directly to the quantity of fish produced. E.g. Fingerlings, Feeds, Field labour, Security personnel, repairs etc.

Also expenses associated with the purchase of capital assets or breeding stock are included.

- **Living Expenses** – This Includes what the owner of the enterprise spends on the self which can be referred to as nonfarm investments

- **Other Expenses** – not related to actual production

- **Scheduled Debt Payments** – includes principal and interest payments for each separate loan

Note: All expenses are summed to obtain **TOTAL CASH OUTFLOW**

- **Cash Available** – This is the difference between **TOTAL CASH INFLOW** and **TOTAL CASH OUTFLOW**

- **New Borrowing** – If the **CASH AVAILABLE** is **negative**, this means that there is insufficient cash generated during the period to meet all cash obligations and additional borrowing is needed for that time period.

- **Cash Balance** – obtained by adding **Cash Available** to **New Borrowing**. It becomes the **Beginning Cash Balance** at the start of next time period. This must always be positive

- **Debt Outstanding** – An accounting of the debt outstanding for each loan is kept at the bottom of the cash flow budget. Therefore, principal payments in a time can be subtracted out of the balance owed.

Table 2: An annual Cash Flow budget for a hypothetical fully operational tilapia /catfish farm

Farm size 0.5 Ha
Productivity $3kg/m^2/year$
Av price of fish in KES/Kg 250

Item	**Yr 0**	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Yr 6**
Beginning cash Balance		100,000	732,000	1,364,000	1,996,000	2,628,000	3,260,000
Tilapia		2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
Catfish		900,000	900,000	900,000	900,000	900,000	900,000
Total Cash inflow		**3,400,000**	**4,032,000**	**4,664,000**	**5,296,000**	**5,928,000**	**6,560,000**
Operating cash expenses							
Tilapia fingerlings		50,000	50,000	50,000	50,000	50,000	50,000
Catfish fingerlings		900,000	900,000	900,000	900,000	900,000	900,000
Wheat bran		1,050,000	1,050,000	1,050,000	1,050,000	1,050,000	1,050,000
Fertilisers		6,500	6,500	6,500	6,500	6,500	6,500
		13,500	13,500	13,500	13,500	13,500	13,500
Lime		26,000	26,000	26,000	26,000	26,000	26,000
Labour		300,000	300,000	300,000	300,000	300,000	300,000
Interest on operation loan		60,000	60,000	60,000	60,000	60,000	60,000
Total Operating cash expenses		**2,406,000**	**2,406,000**	**2,406,000**	**2,406,000**	**2,406,000**	**2,406,000**
Living expenses		100,000	100,000	100,000	100,000	100,000	100,000
Other expenses		50,000	50,000	50,000	50,000	50,000	50,000
Scheduled debt repayments							
Interest on Investment loan	12%		150,000	120,000	90,000	60,000	30,000
Repayment	5 yrs		250,000	250,000	250,000	250,000	250,000
Operating principle		100,000	100,000	100,000	100,000	100,000	100,000
Interest on operation loan	12%	12,000	12,000	12,000	12,000	12,000	12,000
Total Cash Outflow		**2,668,000**	**2,668,000**	**2,668,000**	**2,668,000**	**2,668,000**	**2,668,000**
Cash available		**732,000**	**1,364,000**	**1,996,000**	**2,628,000**	**3,260,000**	**3,892,000**
New Borrowing							
Cash Balance		**732,000**	**1,364,000**	**1,996,000**	**2,628,000**	**3,260,000**	**3,892,000**
Outstanding debts							
Investment		1,250,000	1,000,000	750,000	500,000	250,000	0.0

4 POND DESIGN AND CONSTRUCTION FOR SEMI-INTENSIVE AQUACULTURE

Introduction

The importance of proper designs, construction and the need for involvement of experts during the process of construction of fish ponds cannot be belittled.

Ideally, production units should be designed in such a way to allow total control of;

- What gets in or out
- When it gets in or out
- How it does this
- How much gets in or out
- Rate of getting in or out

The production site is of great importance. It does not only dictate the fish species to be produced but also, the cost of construction is directly related to the nature and location of the site. A good site should therefore meet the following criteria:

- Have water in quantity and quality needed for the proposed production
- Suitable topography to allow cost effective setting up the proposed production facility
- Have soil suitable for pond construction (if ponds are planned).

> *A Simple test of the suitability of a soil for pond construction:*
> - *Dampen a handful of soil with water. Use only enough water to dampen the sample (do not saturate it).*
> - *Squeeze the sample tightly in your hand.*
> - *Open your hand:*
>   - *If the sample keeps its shape, it is probably good enough for building a pond (sufficient clay present).*
>   - *If the sample collapses and does not keep its shape, it is probably not good enough for building a pond (too much sand present)*

- The site be in a region or area as suitable and allowed for aquaculture production
- Well drained and away from flood-prone areas or at least have potential for flood control
- Allow for acceptable effluent disposal as required by environmental management authorities
- Have a climate suitable for production of the intended species
- Have accessibility to a good and all-weather market
- Have easy access to services and technical assistance
- Have adequate room for intended investment and possible future expansion
- Not in a pollution prone area

The final size of a fish farm is determined by:

- Amount of water available

- The land available and usable for fish culture
- The technology to be employed; Intensive systems require less land compared to semi intensive systems, to produce the same quantity of fish
- The target production
- Capital available for investment

The number, size and the shape of ponds will be determined by:

- Land size
- Topography of the land
- Intended use of the pond
- The species to be produced
- Frequency of harvest
- Target quantity per harvest
- Whether juvenile production is intended etc

For these reasons it is not always possible to give general recommendations on the sizes and shapes of earthen ponds. However, rectangular ponds are easier to manage. Fingerling ponds should be smaller than fattening ponds.

Pond design

Once the site have been identified, surveyed and the producer has made decision on the number and sizes of ponds that will be needed when the farm is fully operational, it is time to make decision on designs of the ponds.

During the process of designing ponds, decisions on the following should be made:

- Total area of the pond water surface needed
- The length and the width of the pond water surface
- The water depth and the total pond depth at both the deep and shallow ends
- The slope of the dykes and the pond bottom
- The size of the free board
- The width of dykes

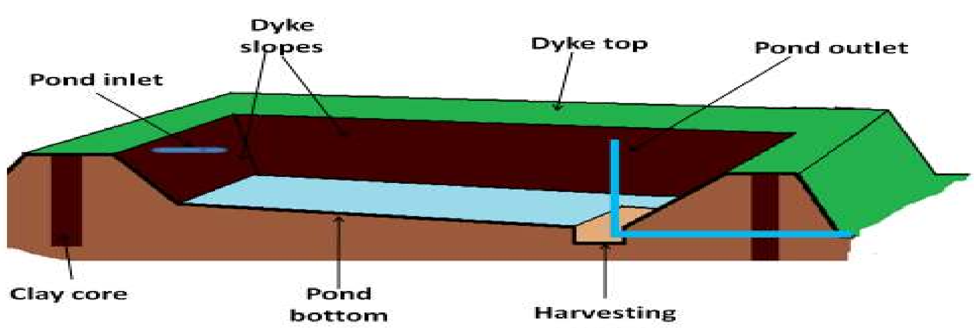
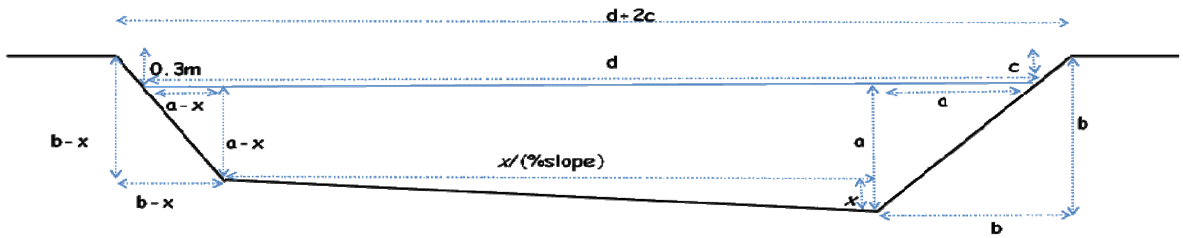


Figure1: A cross section of a typical earthen fish pond showing the pond profile and important features

(Sketch by: Mbugua Mwangi)

Once this is done, all other pond dimensions can be calculated. The diagram below gives the relationships between various pond dimensions based on the assumptions that:

Dyke slope: 1:1
Bottom slope: 1% (0.01)
Free board 30cm



a = Water depth at deep end
b = Total pond depth at the deep end
c = Free board
d = Water surface length

Figure 2: Length wise section of a typical 1:1 fishpond showing the relationship between various measurements

For a 300m² pond measuring 30 by 10 metres at the water surface, and using the relationships given in figure 2, the dimensions will be as follows:

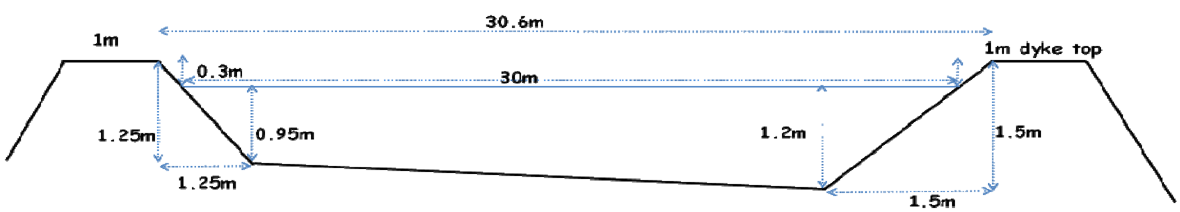


Figure 3: Length wise section of the pond showing the various measurements

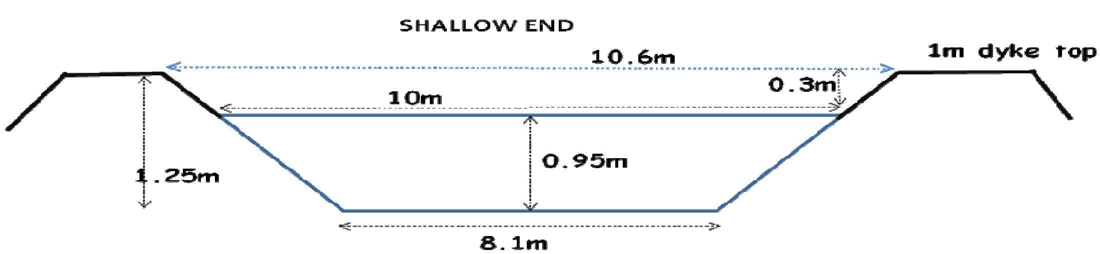


Figure 4: Width wise section of the pond at the shallow end showing the various measurements

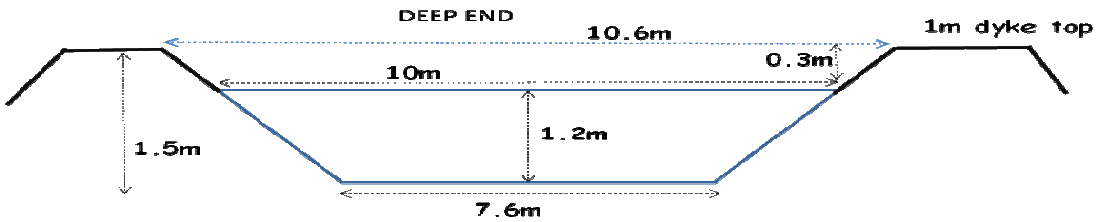


Figure 5: Width wise section of the pond at the deep end showing the various measurements

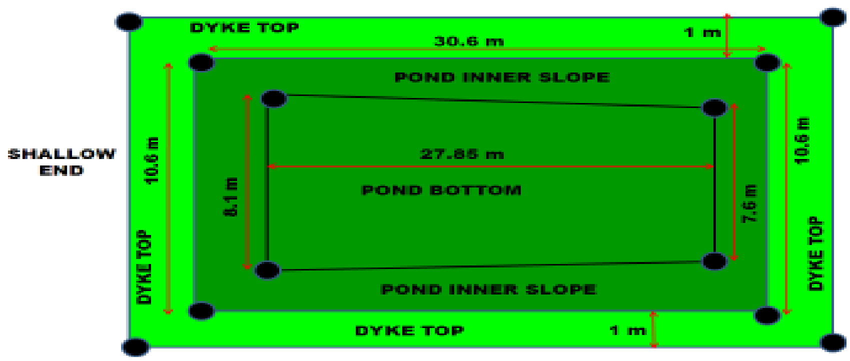


Figure 6: Plan view showing the pegging positions for a 300 m^2 pond measuring 30 by 10 metres at the water surface and inner dyke slope of 1:1.

STEPS IN POND CONSTRUCTION

Mark out the area that the pond will occupy using wooden pegs and strings and then remove all the vegetation.

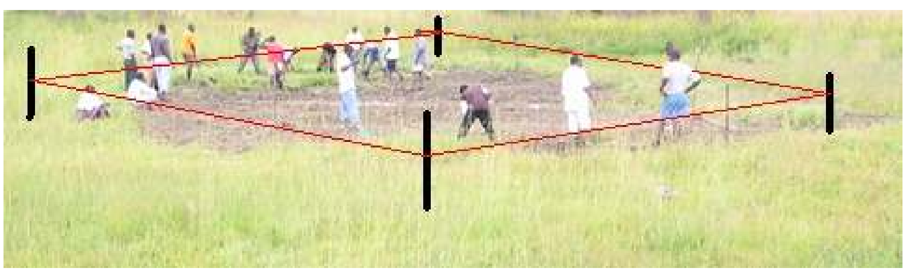


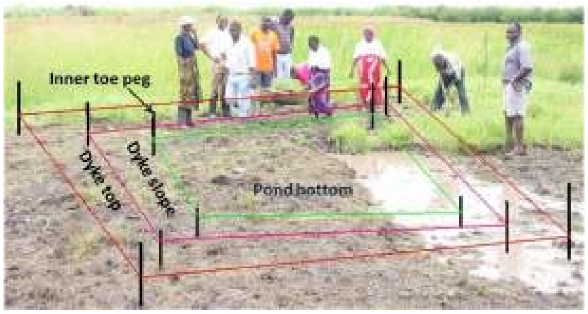
Figure 3: Clearing vegetation from the pond site (*Mbugua H. M.)*

Remove the top soil and keep it in a good location close to the site. It will be used to cover the pond bottom and the dyke tops to enhance fertility. Remember that if the soil is kept far away, this will increase the cost of pond construction since the soil will need to be brought back

Clear the area within the pond limit of all vegetation including the area within 10 m of dykes and pond structures and any access, water supply or drainage area.

Establish a Temporary Bench Mark (TBM). This will allow you to determine and check by use of levelling equipment (e.g. spirit level) the elevations of the dykes, canals and other structures. The TBM should be set and permanently fixed in a protected location during the whole construction period.

- Using level equipments (e.g. spirit level), measuring tape, pegs and strings, mark out:
    - The dykes
    - Dyke slopes
    - Inner and outer toes
    - The pond bottom



4: A site pegged ready for **digging** and **filling** (*Mbugua H. M.)*

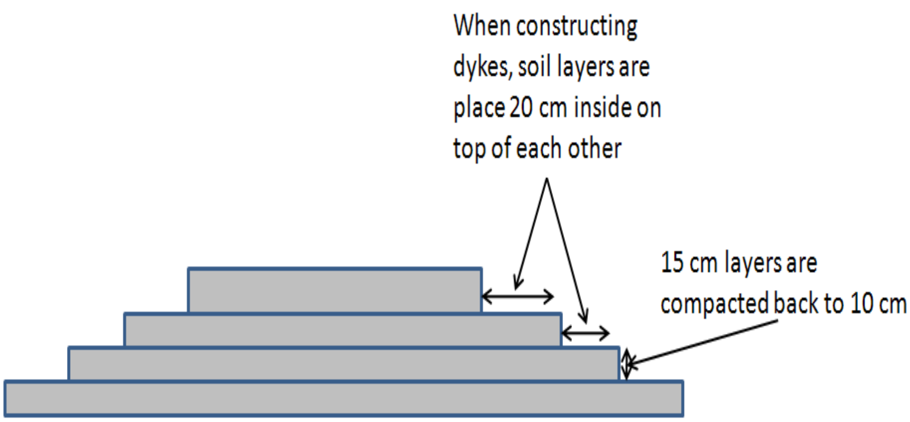
- Using the determined pond depths and the actual elevations of the site, determine which areas need digging and which need filling. This is very important because it eliminates unnecessary movements of soil and thus keeps the construction cost at a minimum.
-
- Dig out the soil from the 'dig' areas and place it on the 'fill' areas. Most of the fill areas will be on the dyke position

5: Dig the soil from the ***dig*** areas and move it to the ***fill*** areas (*Mbugua H. M.)*

6: Make sure that you remove all boulders and tree stumps from the pond area (*Mbugua H. M.)*

- Once the soil is placed on the fill area, make sure that this soil is properly compacted. To achieve good compaction, place soil in layers not exceeding 15 cm in height and compact back to at least 10 cm. When constructing dykes, soil layers are place 20 cm inside on top of each other to reduce amount of work during dyke cutting.

7: Compact the soil properly (*Mbugua H. M.)*



Fifugure 8: When constructing dykes, soil layers are place 20 cm inside on top of each other

8: Where soils are too pervious, dig a trench all round within the dyke position before constructing the dykes *(Ngugi C. N.)*

9: Fill the trench with moist clay and compact thoroughly *(Ngugi C. N.)*

10: Shape the dyke slope and the pond bottom (*Mbugua H. M.)*

11: To get the desired slope and uniformity (*Mbugua H. M.)*

12: Where the soils are too pervious, ponds could be lined with suitable water proof pond liners (*Mbugua H. M.)*

13: Soil can be moved using simple locally assembled equipment e.g. a stretcher made of sticks and old gunny bags locally known as '*machela*'. *(Ngugi C. N.)*

14: A simple and inexpensive soil compactor made from scrap metal (*Mbugua H. M.)*

Good dykes should:
- Be able to resist water pressure resulting from the pond water depth
- Be impervious
- Be high enough to keep the pond water from overflowing

To determine the height of the dyke to be built, take into account:
- The water depth you want in the pond
- The freeboard (upper part of a dyke that is never under water). It varies from 0.25 m for very small ponds to 1 m for very large ponds
- Dyke height that will be lost during soil settlement. This varies from 5 to 20 percent of the construction height of the dyke
- Dyke width depending on the water depth and the role the dyke will play for example transportation in the farm
    - It should be at least equal to the water depth, but not less than 0.60 m in clayey soil or 1 m in somewhat sandy soil
    - It should be wider as the amount of sand in the soil increases

Dyke slopes should be determined bearing in mind that:
- Steeper slopes erode easily

- The more the soil becomes sandy, its strength decreases, and slopes should be more gentle
- The bigger the pond size, the stronger is the erosive power of the water waves
- As the slope ratio increases, the volume of earthwork increases, and the overall construction cost and the land area required for the ponds increases

Note that the more gentle the slope, the more solid the pond, but very gentle slopes make ponds more expensive and make rooted weeds control difficult. A slope of 50% is the minimum recommended

The ability of the dykes to hold water can be enhanced by:

- Using good soil that contains enough clay (about 25% clay is best)
- Building a core trench (clayey core) within the dyke where the soil is pervious
- Building a cut-off trench when the foundation is permeable;
- Proper compacting of the soil
- Ensuring that the thickness of the dyke is appropriate

Newly built dykes should be protected against erosion by planting a grass cover on the crest of the dykes, on outer slope and on the free board.

The pond bottom should be constructed such that water drains towards a harvesting sump at the deepest part of the pond, in front of the outlet, where all the fish can be concentrated during complete draining of the pond.

Water intakes

Main water intakes are used for the overall regulation and transportation of water to the fish farm. They ensure constant supply of water and allow regulation of the amount of water to the farm allowing for diversion of what is not needed.

When setting up Main the intake, consider:

- The levels of the water source (river, stream, etc.) in relation to the elevations of the water supply structure and the ponds themselves and where the water will eventually leave the farm.
- The depth from which you want to take the water (surface, lower levels or the complete depth of the water supply source) at the intake

There are several types of canals depending on their use:

- ***Feeder canals*** *to supply water from the main water intake to the fish ponds*
- ***Drainage canals*** *to take away water from the fish ponds*
- ***Diversion canals*** *to divert excess water away from ponds*
- ***Protection canals*** *to divert water runoff/floods away from the fish farm*

All canals should be well designed to have the required water carrying capacity at the required rate. If the water quantity is low and the rate of delivery is slow, pond will take too long to fill and vegetation will start to grow in the pond.

Several different kinds of structure may be used to transport water to a fish farm. The most common one is the open canal. Others include pipelines and simple siphons.

15: An open water supply canal lined with concrete slabs *(Ngugi C. N.)*

Pond inlets

There are two common types of inlet structures used in Kenya:

- Pipe inlets;
- Open inlets;

When designing and constructing an inlet:

a) Place the inlet at the shallow end of the pond
b) Make sure that the bottom level of the inlet is at the same level as the bottom of the water feeder canal and at least 10 cm above the maximum level of the water in the pond
c) Design the inlet structure to be horizontal, without a slope.
d) Make it wide enough to fill the pond completely in reasonable time
e) Make it such that water splashes and mixes as much as possible when entering the pond.
f) Provide a screen to keep unwanted fish and other organisms out
g) Control mechanism e.g. gate valves

Pond Outlets

1. Pond outlets are built to:

- Keep the water in the pond at its optimum level, which should be the maximum water level designed for the pond
- Allow for the complete draining of the pond and harvesting of the fish when necessary

A good outlet should ensure that:

- The time needed to drain the pond completely is reasonable;
- The flow of the draining water is as uniform as possible to avoid disturbing the fish excessively;
- Fish are not lost even during the draining period;
- Water can be drained from any pond levels
- Allow for overflow of excess water

- Can be cleaned and serviced easily
- Construction and maintenance costs are kept at a minimum

In most cases, outlets have three main elements:

- Water control plugs, valves, control boards, screens or gates
- A collecting sump inside the pond, from which the water drains and into which the fish is harvested
- A conduit through the dyke through which the water flows out without damaging the dykes or the drainage canal

For small rural ponds, investing in elaborate outlets may not be necessary. Complete drainage of the pond can be done by cutting the dyke open at one of the deepest point of the pond. Repairing the dyke should not take more than two hours.

Materials that can be used to construct pond outlets and inlets include bamboo poles, PVC pipes, wood, bricks, cement blocks or concrete.

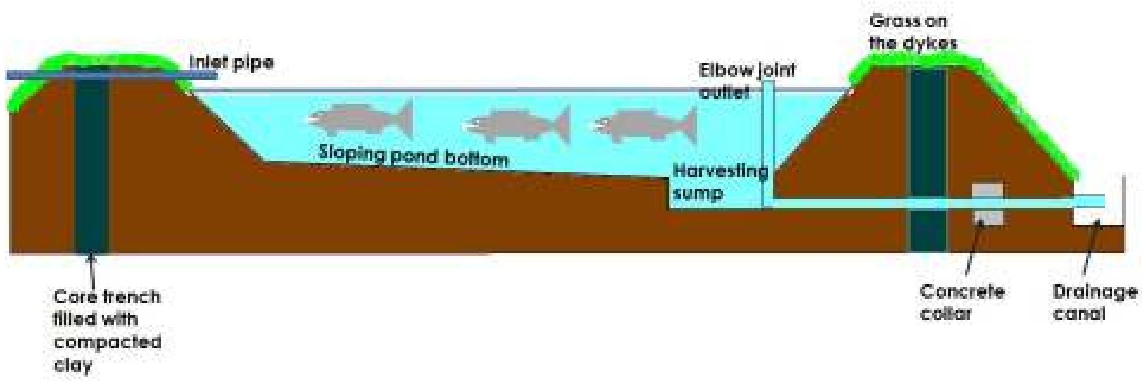


Figure 16: A cross section of a completed pond showing the position of various structures (*Mbugua H. M.)*
(Sketch by: Mbugua Mwangi)

Pond construction costing

Through experience in Kenya, one pond of 100 m^2 will take 15 people about 8 days to complete, working 8 hours a day.

This will cost 15 x 8 x KShs ***X*** (***X*** *= wages per day)*

Inlet canal and outlet canal: Include the cost of cement, sand, pipes, valves etc.

Consider other incidentals costs especially due to the nature of the site and the prevailing weather

Available pond construction contractors in Kenya charge bout KES 150 to 500 per square meter of pond depending on the soil type and weather (2009 rates).

This should give the total cost of constructing one pond but not setting up the fish farm.

Remember that many but small ponds are more expensive to construct as compared to a few but larger ponds. Small ponds also waste a lot of space in comparison. However very large ponds take long to fill and drain and are also difficult to manage.

5 FARMING OF TILAPIA IN PONDS

1. BIOLOGICAL CHARACTERISTICS OF TILAPIA:

I). Introduction

Tilapia is a general name of a group of cichlids endemic to Africa. All tilapia species are nest builders; fertilized eggs are guarded in the nest by a brood parent. The genera *Sarotherodon* and *Oreochromis* are mouth brooders; eggs are fertilized in the nest but parents incubate them in their mouths. For the *Oreochromis*, only females practice mouth brooding, while in *Sarotherodon*, either the male or both male and female mouth brood. The important aquaculture genera in Kenya are; *Oreochromis*, and *Tilapia*.

Tilapias are natives of Africa but have been introduced and produced widely around the world. They are primarily freshwater fishes. They are very tolerant of low water quality and can survive with low dissolved oxygen and even live and breed in saline water. They are hardy, grow well under crowded condition, resist diseases, have a higher fecundity than most fishes and reproduces freely in ponds. They grow well in culture systems, have well established markets around the world and are popular in various product forms.

Mbugua HM

Figure 1: Oreochromis niloticus (Nile tilapia)

Tilapia farming involves the culture of following species

(i) *Oreochromis niloticus*
(ii) *Oreochromis mossambicus*
(iii) *Oreochromis aureus*
(iv) *Oreochromis spilurus*
(v) *Oreochromis andersonii*
(vi) *Tilapia zillii.*
(vii) *Tilapia rendalli*

II). Feeding Habits

Tilapias are heterogeneous in their feeding. They are hardy, have rapid growth, and have ability to consume and efficiently assimilate a wide variety of foods. Various species are omnivorous; others feed on phytoplanktons while others are macrophyte feeders.

(i) *Omnivorous are; 0. mossambicus, O. niloticus, 0. spilurus, 0.andersonii and 0. aureus.*
(ii) *Phytoplankton feeders; O. leucostictus O. Macrochir O. esculentus O. alcalicus grahami and S. galilaeus*
(iii) *Macrophytes (feed on larger plants) feeders; T. rendallii and T. zillii.*

III). Maturation

In natural water bodies, tilapias mature in about two to three years. Under culture they tend to mature early. Sexual features distinguishing males from females are clear when fish mature (about 15 cm in *Tilapia zillii* and 10 cm in *Oreochromis niloticus*). Males have two orifices situated near the ventral (anal) fin, one is the urinogenital aperture and the other is the anus. The females have three orifices, the genital opening the anus and a urinary orifice (difficult to visualize with the naked eyes). Separation of males and females can be made easier by applying dye (India ink, indigo, etc.) to the papilla with a cotton swab to outline the male and female openings.

IV). Fecundity

Fecundity refers to the number of eggs produced by a fish in a spawn. This applies well for monocyclic species, that is, once a year breeders. Tilapias are polycyclic (many times breeders) and their ovary may contain eggs at different stages of maturity.

In substrate brooding tilapias, fecundity is much higher than mouth brooders. Other characteristics that differentiate substrate brooders (*Tilapia*) and mouth brooders (*Oreochromis*) are:

Table 1: Some characteristics that differentiating substrate brooders (*Tilapia*) and mouth brooders (*Oreochromis*)

Characters	***Tilapia***	***Oreochromis***
Fecundity	high	low
Egg diameter (mm)	1-1.5	up to 5.0
Yolk percentage	less than 25%	up to 45%
Yolk colour	pale yellow	orange
Size of fry at feeding	5-6 mm	9-10 mm
Courtship	prolonged (monogamous)	brief (polygamous)
Juvenile mortality	high	low
Longevity	up to 7 years	over 9 years

V). Environmental requirements

a) Optimal Temperature

Temperature affects fish distribution, survival and growth, rate of development, reproduction and even susceptibility to diseases. Various species and strains of tilapia differ in tolerance to low temperatures, but growth is generally limited at water temperatures below 16^{O}C and most become severely stressed at 13^{O}C. Death occur from 12^{O}C with few surviving temperatures below 10^{O}C. Most will not feed or grow at water temperatures below 15^{o}C and will not spawn below 20^{O}C. The normal water temperature should be between 20 to 30^{o}C. Metabolic rate rises at higher temperatures which lead to death.

b) Optimal Dissolved Oxygen (DO)

Tilapias are able to tolerate low levels of ambient oxygen. Usually, well fertilized ponds will have low levels of oxygen early in the morning. Night activities are dominated by respiration and decomposition which reduce DO. Larger fish are less tolerant than juveniles. This could be due to the difference in their metabolic demand. The optimal DO for tilapia culture is 4 mg/litre (50%) and should not go below 2.3 mg/litre

c) Salinity

All tilapia are tolerant to brackish water. The Nile tilapia is the least saline tolerant of the commercially important species, but grows well at salinities up to 15 ppt. The Blue tilapia grows well in brackish water up to 20 ppt salinity, and the Mozambique tilapia grows well at salinities near or at full strength seawater

d) pH

Tilapia can survive in pH ranging from 5 to 10 but do best in a pH range of 6 to 9.

e) Ammonia

Massive tilapia mortality will occur within a few days when the fish are suddenly exposed to water with unionized ammonia concentrations greater than 2 mg/L. Prolonged exposure (several weeks) to un-ionized ammonia concentration greater than 1 mg/L causes deaths, especially among fry and juveniles in water with low DO concentration.

f) Nitrite

Nitrite is toxic to many fish and chloride ions reduce the toxicity. Tilapias are more tolerant to nitrite than many cultured freshwater fish. In general, for freshwater culture the nitrite concentration should be kept below 27 mg/L.

*(For details see **Water Quality Management**)*

2. TILAPIA FARMING

Pond culture is the most popular method of growing tilapia in the world. They are grown in fertilized ponds where the fish utilize natural foods from ponds. Management practices of the systems ranges from extensive; using only organic or inorganic fertilizers, to intensive systems, using high-protein feed, aeration and water exchange. The major problem to overcome in this system is the prolific breeding of the fish that occur in ponds under mixed sex culture. This breeding if not controlled results to overcrowding in the ponds. The end result is stunted growth yielding small size fish (less than 100gms) which may not be of market value. In mixed-sex populations, juveniles can make up to 70 percent of the total harvest weight. Therefore strategies for producing tilapia in ponds should aim at controlling spawning and recruitment.

For easy management and economical operation in Kenya, grow out ponds should be about 1 to 2 meters deep and at least 300 sq meters for semi intensive production of tilapia. A harvesting sump in the pond behind the drainage outlet is needed to concentrate the fish in the final stage of drainage. The pond should drained completely and be allowed to dry to eradicate any fry or fingerlings that may interfere with the next production cycle. This will also kill some parasites, frogs' egg and other unwanted organisms that may be in the ponds.

I). Mixed-sex culture

In mixed-sex culture of tilapia, both males and female are cultured together but harvested before or soon after they reach sexual maturity. This minimizes chances of recruitment and overcrowding. The disadvantage in this is that fish is harvested at a smaller size due to the limited growth period.
In this culture practice, fish are usually stocked at low rates to reduce competition for food and promote rapid growth. One month-old, 1-gram fry are stocked at 1 to 2 per square meter into and grown for about 4 to 5 months. In cold areas where the water temperatures are low and therefore slow growth, tilapia might not reach marketable sizes in that period.

Newly-hatched fry should be used all the time because older ones will reach sexual maturity at a smaller, unmarketable size. They could also be mature fish but stunted. Supplemental feeds with 25 to 32 percent protein are generally used. The average harvest weight is about 250 grams, and total production about 0.25 Kgs/sq m for a stocking rate of 1 fish/m^2. Higher stocking densities can be employed to achieve higher production but must be combined with very good management. Expected survival is about 80 percent.

Species such as *Tilapia zilli*, *T. hornorum*, or *T. mossambica* are not suitable for mixed-sex culture because they reach reproductive maturity at 2 to 3 months at an unmarketable size of about 30 grams. Those that are suitable for this culture are *O. nilotica* and *O. aurea* which reach reproductive maturity at 5 to 6 months

Two to three crops of fish can be produced annually in Kenya depending on the water temperatures.

II). Mono sex culture

To overcome the problem resulting from prolific breeding of tilapia, ponds are stocked with males only because the males grow almost twice as fast as females. Male fingerlings can be obtained by three methods:

- Hybridization

- Sex-reversal and
- Manual sexing.

None of these methods is always 100 percent effective, and a combination of methods is recommended. Hybridization can used to produce better results of males only. The hybrids can then be subjected to hand sexing and/or sex-reversal treatment. Sex-reversal requires obtaining recently hatched fry and rearing them in tanks or hapas where they are subjected to hormone laced feed for about three weeks.

*(For details see **Hatchery Management and Tilapia Fingerling Production**)*

Figure 2: Breeding hapas in a fish pond (Mbugua HM)

Manual sexing (hand sexing) involves separating males from females by visual inspection of the external urinogenital openings. Reliability of manual sexing depends on the skill of the workers, the species to be sorted and fish sizes. Experienced workers can easily sex 20-gram fingerling *T. hornorum* and *T. mossambica*, 30-gram *T. nilotica*, and 50-gram *T. aurea*.

Tilapia males are preferred for culture because they grow faster than females. Females use considerable energy in reproduction and do not eat when they are incubating eggs. All-male culture permits the use of longer culture periods, higher stocking rates and fingerlings of any age. High stocking densities reduce individual growth rates, but yields per unit area are greater. If the growing season can be extended, it should be possible to produce fish of up to 500 grams. Expected survival for all-male culture is 90 percent or greater.

Females included in a male only culture, affects the maximum attainable size of the original stock in grow-out.

A stocking rate of 2fish/m^2 is commonly used in Kenya to achieve yields of 1kg/ m^2. At this stocking rate the daily weight gain will range from 1.5 to 2.0 grams. Culture periods of 6 months or more are needed to produce fish that weigh close to 500 grams. There are cases in Kenya where stocking densities of 6 juveniles/ m^2 is practiced with a production of up to 3kg/ m^2. Higher stocking densities will require water aeration and sub-optimal feeding rates may have to be used to maintain suitable water quality.

III). Polyculture

In Kenya tilapia are frequently cultured with other species, mainly catfish (*Clarias gariepinus*) to take advantage of many natural foods available in ponds and to produce a secondary crop, or to control tilapia breeding. Polyculture uses a combination of species that have different feeding niches to increase overall production without a corresponding increase in the quantity of supplemental feed. Polyculture can improve water quality by creating a better balance among the microbial communities of the pond, resulting in enhanced production.

Other possible polyculture combinations that can be done in Kenya include:
Tilapia and prawns (*Macrobrachium rosenbergii*): In case, survival and growth of tilapia and prawns are independent. Feed is given to meet the requirements of the fish. Prawns, which are unable to compete for the feed, utilize wasted feed and natural foods that result from the breakdown of fish waste.
Tilapia and largemouth bass (*Micropterus salmoides*): The bass which is carnivorous control the breeding of tilapia in mixed sex culture. This allows the original stock to attain a larger market size. Predators must be stocked at a small size and percentage to prevent them from depleting the tilapia stock.

IV). Fertilization and manure application

Where the natural pond productivity is enhanced through water fertilization, reasonable production can be achieved without exogenous feeding. Although yields will be lower that those obtained with exogenous feeding, fertilization will reduce the quantity and expense of feeding. Application of an inorganic fertilizer high in phosphorus should be done prior to stocking fish to create an algal bloom. Tilapia productivity is stimulated mainly by an increase in phosphorus and to a lesser extent by an increase in nitrogen. The inorganic fertilizers used in Kenya are DAP and CAN.

Di Ammonium Phosphate (DAP), Mono Ammonium Phosphate (MAP) and Urea are the cheaper sources of nutrients.

- For Phosphorus; DAP or TSP
- For Nitrogen; UREA

a) Methods of applying chemical fertilizers

Dissolve the fertilizer in a bucket of water by stirring, and then sprinkle the solution at different points of the pond. If you throw the fertilizer in while dry, it will sink and some of the nutrients, especially phosphorus will be absorbed by the mud.

Application Rates for chemical fertilizers recommended in Kenya:

D.A.P.; 2g/m^2 every week i.e. 200g per 100m^2 per week

UREA; 3g/m^2/week i.e. 300g/100m^2/week

Fertilizer application for earthen ponds *(Ngugi C.N.)*

Animal manure is widely used in Kenya in fish production in earthen ponds in. The quality of manure as a fertilizer varies depending on the source animal and the quality of feed fed to the animal. Pig, chicken and duck manures increase fish production more than cow and sheep manure. Animals fed high quality feeds (grains) produce manure that is better as a fertilizer than those fed diets high in crude fibre. Fine manures provide more surface area for the growth of microorganisms and produce better results than large clumps of manure. Manure should be distributed evenly over the pond surface area. Accumulations of manure on the pond bottom produce low oxygen conditions (during decomposition) in the sediment resulting to reduced microbial activity and sometimes result in the sudden release of toxic chemicals into the water.

b) Methods and rates of applying manure

- Crib method: A compost crib constructed using wooden sticks at one or more sides of the pond. It helps fertilize the water gradually. The manure in the crib requires frequent turning to facilitate the release of nutrients.
- Bag method: A bag is filled with manure and tied to the corner of the pond. The bag is shaken weekly or daily to release nutrients.

Manure application rates depend on the size of the pond, which is expressed as surface area of the water in the pond. The recommended rate is 50g of dry matter per m^2 per week i.e. 5Kg/100m^2/week.

The maximum rate depends on the quality of the manure, the oxygen supply in the pond and water temperature. If early morning DO is less than 2 ppm, manuring should be reduced or stopped until DO increases. When water temperatures are less than 18° C, manure application should be discontinued. At low temperatures the rate of decomposition decreases and manure may accumulate on the pond bottom. A subsequent increase in temperature could then result in oxygen depletion.

c) Agricultural lime.

- Used to improve soil quality, which helps the organic and chemical fertilizers to work better. It also helps to clear up muddy water.

- In red soils; about 20kg per 100m2 can be applied. Black cotton soils may require a little more.

Some characteristics of organic and chemical fertilizers

Organic (farm manure)	**Chemical: -** DAP, Urea, MAP, TSP
Contains trace minerals and vitamins.	Contains only what the label says
Uses oxygen to decompose.	Does not use oxygen when dissolving
Is highly variable in composition depending on feeds given to the animals 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 consumed directly by the fish	Not directly consumed by the fish

V). Integrated systems

Manure application can be made easy by placing animal production units adjacent to or over the fish ponds so that fresh manure can easily be delivered to the pond on a continuous basis. This also allows the feed wasted by the animals to fall into the fish pond and utilised by the fish. Effective and safe manure loading rates are maintained by having the correct number of animals per pond surface area.

a) Chicken/fish farming

Maximum tilapia yields are obtained from the manure output of 5,000 to 5,500 chickens/ha, which deliver 100 to 113 Kg (dry weight) of manure/ ha/day. Several crops of chickens can be produced in one fish production cycle.

Tilapia/Catfish farming integrated with poultry farming *(Mbugua HM)*

b) Duck/fish farming

Ducks are grown on ponds at a density of 750 to 1500/ha. The ducks are raised in confinement, fed intensively, and allowed a small portion of the pond where they forage for natural foods and deposit their manure. Ducks reach marketable size in 10 to 11 weeks and therefore staggering production cycles is needed to stabilize manure output.

c) Pig/fish farming

Approximately 60 to 70 pigs/ha are required to produce a suitable quantity of manure (90 to 100 pounds of dry matter/acre/day) for tilapia production. The pigs are usually grown from 44 to 220 pounds over a 6-month period. In cultures and religions where pigs are considered unclean, used of pig manure might reduce the marketability of the fish.

VI). Harvesting

Fish produced for consumption should be harvested when they reach market size. In Kenya, tilapia are ready for harvesting within six to nine months depending on the size at stocking, target harvest size, water temperature and level of management employed. The time of harvesting is determined through regular sampling which should be done monthly.

A day or two before harvesting, feeding and fertilizer application should be stopped. During harvesting:

- Fish should be checked for off flavors
- Fish should be harvested during cool weather
- Harvesting and transportation equipment should be set up well in advance to ensure reduced stress and minimal fish mortality.

Tilapias are best harvested by seining for partial harvesting and complete drainage for complete harvesting.

Harvesting an ornamental fishpond using a seine net *(Mbugua HM)*

Once harvested, fish should be handled with care and transported to the market while still fresh.

VII). Growth and yields

Under proper management and optimal conditions, 1-gram fish are cultured in nursery ponds to 20 to 40 grams in 5 to 8 weeks and then stocked into grow-out ponds. In mono-sex, males can reach 200+ grams in 4 to 5 months, 400 + grams in 5 to 6 months, and 500+ grams in 8 to 9 months.

Dress-out percentage on tilapia is low compared to species such as trout and catfish. Tilapias have a dress-out of 51 to 53 percent of live weight for whole-dressed fish (head-off) and 32 to 35 percent for fillets.

VIII). Diseases

Tilapias are more resistant to viral, bacterial and parasitic diseases than other commonly cultured fishes. Few diseases and mortalities have been reported in semi intensive tilapia farms in Kenya. This could due to low stocking densities in these systems. Lymphocystis, columnaris, whirling disease, and hemorrhagic septicemia may cause high mortality, but these problems occur most frequently at water temperatures below 11^0 C. The most important cause of mortalities is anoxia resulting from blooms of algae. Sudden lowering of temperatures to below the tolerance levels, which can happen during the rainy seasons, can lead to problems including mortalities.

*For further information, see **Fish disease, parasites and predators management and control***

6 HATCHERY MANAGEMENT AND TILAPIA FINGERLING PRODUCTION

Introduction

Although tilapia breed freely in ponds, it is important for farmers (producers) to consider using properly produced fingerlings. They need to invest in hatcheries for fry and fingerling production. Quality fingerlings in tilapia aquaculture are very important. For this reason it is advisable for farmers to generate their own fingerlings if they cannot ascertain the quality of those from other sources. Poor fingerlings result to poor harvests. This will also allow the farmer to have ready fingerlings whenever he needs them. As long as the demand for fingerlings exists, a well-managed hatchery can turn out to be a good business.

Three methods of tilapia fingerlings production are commonly practiced in Kenya. These are; Open ponds (the most commonly used), hapas (net enclosures) placed in ponds, and tanks. For these methods, fry are collected from the spawning units and stocked into fertilized ponds for rearing to the fingerling stage before they are stocked into grow-out ponds.

Open pond method

This is the simplest and most common method of tilapia fingerling production in Kenya. A properly constructed and well fertilised pond serves both for breeding and rearing fry. Brooders are stocked into the ponds and allowed to spawn naturally. The broodfish are stocked at the rate of 100 to 200 kg /ha at a sex ratio of 1:3 or 1:4 (males to females). A female brood fish of 90-300 g produces as much as 500 eggs per spawning. They should produce 6-15 fry/m^2/month. To increase seed production, use larger brooders. Brooders of 1-1.5 kg can produce 45 fry/ m^2/month. For this case, you need to harvest every 17-19 days.

Earthen fish ponds used for fingerlings production in Kenya
(Mbugua HM)

Harvesting for fry from the ponds is done every 15-21 days (More frequently where average water temperatures are above 25°C). The brooders can be used for 3-5 years.

Fry harvesting should be done by hand scoop nets along the edges of the pond to minimise pond disturbance and fry mortality.

The tank method

Tank-based hatcheries are relatively expensive to set up. The tanks should be circular in shape and can be made of concrete, plastic, fibreglass or even metallic.

Hatchery tanks in a fish farm in Kenya *(Mbugua HM)*

When using this method:

- The tanks should be 1-6 m diameter and a water depth of 0.5-1 m.
- Stock 100-200 g brooders at a density of 3-5/m^2 at a sex ratio of 1 male to 2-7 females.
- Feed using a 30-40% crude protein diet at a rate of 1-2% body weight/day.
- Collect fry every 10-14 days

Yields of up to 400-3,000 fry/m^2/month can be realised using this method.

An advantage of using the tank method is that they are easy to manage. On the other hand, tanks are often relatively expensive to set up compared to ponds and hapas.

The "hapa" method
A hapa is a cage like, rectangular or square net impoundment placed in a pond for holding fish for various purposes. They are made of fine mesh netting material. The mesh size is such that the fry or fish inside can not escape.
Hapas sizes varry but the ideal size measures 3 m long, 3 m wide, and 1.5 m deep.


Mbugua HM
Inspecting tilapia breeding hapas

When using hapas to generate fingerlings:

- Stock brooders weighing about 100 to 200 g at a ratio of about 1:5 to 1:7 males to females.
- Stock the brooders at a density of 4-5 brooders / m^2.
- Hapas should be inspected for fry every day
- Remove the fry using a scoop net after two week and stock them into tanks, other hapas, or a rearing ponds.

Production in hapas range from 150 fry/m^2/month to over 880 fry/ m^2/month.

Feeding

- Fry reared in a hapa should be fed 4 times/day on a daily basis until the fry reach the desired size (5 g).
- Use a diet in powder form at the rate of 5-10% of the total body weight per day.

Advantages of using this method are

- Handling of fry and brooders are easily handled
- Production on a per unit area is high.
- Assurance of uniform fry of relatively the same age
- Minimised loos of fry
- Hapas can be set up in ponds stocked with fish

Disadvantages of the hapa method

- Management is more demanding compared with the other methods
- Mortalities may occur due to agressiveness during spawning
- Feeding is a must
- Hapas can be destroyed during stormy weather
- Happa material will degrade in sunlight and need replacing
- Fish may easily escape if the hapa is damaged

- Localised poor water quality is likely due uneated feed and fish waste
- Hapa mesh will get cloged limiting water circulation and need periodic srubbing

Production of all-male fingerlings
Males-only fingerlings can be obtained by three methods:
- Hybridization
- Sex-reversal and
- Manual sexing.

None of these methods is always 100 percent effective, and a combination of methods is recommended. Hybridization can used to produce better results of males only. The hybrids can then be subjected to hand sexing a sex-reversal treatment. Producing sufficient numbers of hybrid fry maybe difficult because of breeding incompatibilities between the parent species. Sex-reversal is more complicated and requires obtaining recently hatched fry and rearing them in tanks or hapas where they are subjected to hormone laced feed for about three weeks.

Manual sexing (hand sexing) involves separating males from females by visual inspection of the external urogenital openings. Secondary sex characteristics may also be used to help distinguish sex. Reliability of sexing depends on the skill of the workers, the species to be sorted and its size. Experienced workers can easily sex 20-gram fingerling *T. hornorum* and *T. mossambica*, 30-gram *T. nilotica*, and 50-gram *T. aurea*.

Hormonal sex reversal
- To do this, you need a tank-based or hapa-based hatchery tha will allow fry to be collected at the yolk sac or first feeding stages (no later than one week after they have been released from the female).
- Transferred healthy fry of uniform size to the tank or hapa where you will feed them with hormone-laced diet for 21-28 days

The sex reversal feed is prepared as follows:
- Mix 30-70 mg of hormone (methyl or ethynyl testosterone) in 700 ml of 95% neutral ethanol
- Add 700 ml of hormone solution to each kg of finely ground feed then mix thoroughly and dry. At this stage you may add any needed supplements
- This feed should be kept under refrigeration if it is not going to be used immediately
- Feed the fry at a rate of 10-30% of body weight per day, at least four times a day for 21-28 days.
- The fry must eat this feed to sex-reverse

Tilapia males are preferred for culture because they grow faster than females. Females use considerable energy in reproduction and do not eat when they are incubating eggs. Males only culture permits the use of longer culture periods, higher stocking rates and fingerlings of any age. High stocking densities reduce individual growth rates, but yields per unit area are greater. If the growing season can be extended, it should be possible to produce fish of up to 500 grams. Expected survival for all-male culture is 90 percent or greater. A disadvantage of male mono-sex culture is that female juveniles are discarded.

Females included in a population of mostly male tilapia affects the maximum attainable size of the original stock in grow-out. A stocking rate of $2/m^2$ is commonly used in Kenya to achieve yields of $1kg/ m^2$. At this stocking rate the daily weight gain will range from 1.5 to 2.0 grams. Culture periods of 6 months or more are needed to produce fish that weigh close to 500 grams. There are cases in Kenya where stocking densities of 6 juveniles/ m^2 is practiced with a production of up to $3kg/ m^2$. Higher stocking densities will require water aeration and sub-optimal feeding rates may have to be used to maintain suitable water quality.

7 WATER QUALITY MANAGEMENT FOR FISH FARMING

Introduction

Fish live, breed and grow in water and therefore is wholly dependent on water where they live. Therefore, water quality is the most important factor affecting fish health and performance. Fish farmers must therefore understand the water quality requirements of the fish under culture very well. Good water quality refers to what the fish wants and not what we think the fish wants. Farmers must understand that different fish species have different and specific range of water quality aspects (temperature, pH, oxygen concentration, salinity, hardness, etc.) within which they can survive, grow, reproduce and perform optimally. Within these **ranges**, each species has its own **optimum range** within which it performs best. It is therefore very important for fish producers to ensure that the physical and chemical conditions of the water remain, as much as possible, within the optimum range of the fish under culture all the time. Outside these optimum ranges, fish will exhibit poor growth, erratic behaviour, and disease symptoms or parasites infestations. Under extreme cases, or where the poor conditions remain for prolonged periods of time, fish mortality may occur.

Pond water contains two major groups of substances:

- Suspended particles made of non-living particles and very small plants and animals, the plankton.
- Dissolved substances made of gases, minerals and organic compounds;

The composition of pond water changes continuously, depending on climatic and seasonal changes, and on how a pond is used. It is the aim of good management to control this composition to yield the best conditions for the fish.

For producers to be able to maintain ideal pond water quality conditions, they must understand the physical and chemical components contributing to good or bad water quality.

Physical Aspects of Water Quality

Temperature

Fish assume the temperature of the water they live in and are referred to as "cold-blooded". Water temperature is therefore a very important physical factor for fish survival and growth. The water temperature and thus the body temperature of the fish, has an effect on level of activity, behaviour, feeding, growth, and reproduction of the fish. Each species has its tolerance limits and optimum range. When water temperatures are outside the optimum range, fish body temperature will either be too high or too low and fish growth will be affected or even the fish die.

Table 1: Tolerance limits and optimum temperature ranges for commonly cultured fish species of Kenya (Nile tilapia, African catfish, common carp and rainbow trout):

Fish species	**Lethal water temperature (^0C)**		**Optimum temperature (^0C) range for adults**	**Temperature range for spawning (^0C)**
	Lower	**Upper**		
Oreochromis nilotica (Nile tilapia)	12	38	27-30	22-32
Clarias gariepinus (African catfish)	-	-	25-27	20-30
Micropterus salmoides (Largemouth bass)	2	35	23-30	17-20
Cyprinus carpio (Common carp)	2	36	23-26 (25)	Above 18
Oncorhynchus mykiss (Rainbow trout)	Close to 0	22	15-17 (16)	4-18

Turbidity

Fine suspended solid particles lead to water turbidity. Turbid Water can be said to be "cloudy". Turbidity can result from suspended solids (clay) or plankton (living organisms in water).

Clay turbidity in pond water (muddy water) can be harmful to fish and limit pond productivity. Clay turbidity in pond can be controlled by:

- Treating affected ponds with animal manures at rates of 2.4 T/ha every three weeks or applying agricultural lime at the recommended rates to improve soil pH and water alkalinity
- Avoiding stocking species that stir up pond bottom mud e.g. the common carp

- Designing water supply system in a way that allow muddy water to sediment or diverted away from the ponds

Plankton are small often microscopic aquatic plants (phytoplankton) and animals (zooplankton) found suspended in the water column. Phytoplankton forms the base of the food chain while zooplankton forms the second link in the chain in aquatic systems such as ponds.

In addition to their role as food for fish in ponds, phytoplankton provides oxygen through photosynthesis during the day. This oxygen dissolves into the water (DO) and therefore becomes available to the fish in the ponds.

Low phytoplankton density in ponds means less food and DO for the fish. On the other hand, too much (algal boom) lead to minimised sunlight penetration causing algal deaths. Less phytoplankton and decomposing plankton also lead to less food and DO for the fish. Good water quality, in relation to plankton therefore means water with just the right bloom. Visibility in a pond with the right plankton density should be about 30 cm.

A simple method of measuring turbidity it to stretch one arm, and immerse it vertically into the water until the hand disappears from sight.

Note the water level along your arm:

- If it Is well below your elbow, plankton turbidity is very high;
- If it reaches to about your elbow, plankton turbidity is right;
- If it reaches well above your elbow, plankton turbidity is low.

Suspended fish wastes are generally not a problem in semi-intensive aquaculture but in intensive systems, especially recirculation systems, they may be a major cause of poor water quality:

NOTE:

- *1 kg of fish waste is produced per kg of fish produced*
- *Fish waste contribute up to 70% of the nitrogen load in the system*
- *Fish waste lead to build-up of ammonia and nitrite*
- *Fish waste lead to reduction in dissolved oxygen*

Chemical Aspects of Water Quality

This is reference to the following parameters:

- pH
- Alkalinity
- Hardness
- Dissolved gases—oxygen, carbon dioxide, nitrogen, ammonia
- Salinity
- Essential nutrients—Nitrogen (N), Phosphorous (P) and Potassium (K)

Soil pH and Acidity

Pond water may be ***acid, alkaline*** or ***neutral***. Depending on this, water will react in different ways with substances dissolved in it. It will also affect in different ways the plants and animals living in the water. The measure of the alkalinity or acidity of water is expressed by its ***pH value***. The pH value ranges from 0 to 14, with pH 7 indicating that the water is neutral. Values smaller than 7 indicate acidity while those greater than 7 indicate alkalinity.

Fish production can be greatly affected by excessively low or high pH. Extreme pH values can even kill your fish. The growth of natural food organisms may also be greatly reduced. The critical pH values vary according to the fish species, the size of individual fish and other environmental conditions. For example, fish are more susceptible to extreme pH during their reproductive seasons, and eggs and juveniles are more sensitive than adults.

Waters ranging in pH from 6.5 to 8.5 (at sunrise) are generally the most suitable for pond fish production. Most cultured fish will die in waters with pH below 4.5 and 11 and above.

Fish reproduction and general performance can be greatly affected at pH below 6.5 and above 8.5, while a pH below 4.5 and above 10 will cause fish death.

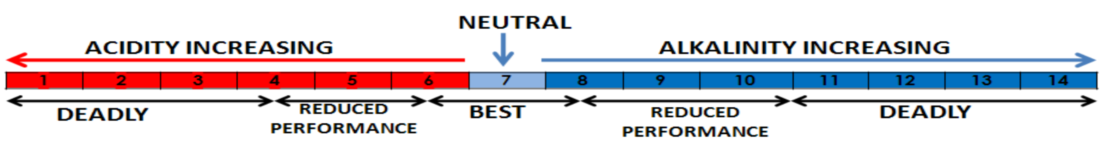


Figure 1: pH ranges showing tolerance limits and optimum range for fish

Pond water with pH unfavourable for fish production can be corrected as follows:

- ***pH is below 6.5 at sunrise:*** use lime and alkaline fertilizers
- ***pH is above 8.5 at sunrise:*** you can use acid fertilizers

Ensuring that soil pH and acidity are within acceptable limits is a necessary part of managing the alkalinity, hardness, and pH of the water, which were discussed above. The key is to keep soil pH at 6.5 or above, which will usually maintain water pH, hardness, and alkalinity at desirable levels. Soil pH can be kept at the right level by:

- Drying the pond for at least two weeks after each harvest before refilling and restocking.
- Applying lime (preferably agricultural limestone) to the pond after each harvest.

Normally lime should be applied to the pond bottom before it is refilled, but if necessary, it can be applied to the water surface after filling the pond. Only recommended liming materials and application rates should be used (***see pond farming of tilapia***)

Pond water pH varies over the course of a 24-hour day. This variation is related to the light intensity which is important in photosynthetic activity of phytoplankton.

- pH is lowest at sunrise and as the light intensity increases, photosynthesis increases causing more and more carbon dioxide to be removed from the water by the plants leading to rise in pH
- A peak pH value is reached in late afternoon.
- As the light intensity starts decreasing toward the evening there will be less photosynthesis and less carbon dioxide is removed from the water. Respiration adds more carbon dioxide to the water and the water pH starts to decrease.
- At sunset, photosynthesis stops, but respiration continues for the rest of the night. More and more carbon dioxide is produced, and pH keeps decreasing until sunrise, when it reaches its minimum.

Dissolved oxygen in fish ponds

The most important gas dissolved in water is oxygen (O2). Dissolved oxygen (DO) is essential for respiration and decomposition.

Dissolved Oxygen in water comes from atmospheric oxygen and photosynthesis.

The atmospheric oxygen diffuses and dissolves into the water. But the diffusion and its subsequent dissolving into water is a slow process. The major source of dissolved oxygen in ponds is photosynthesis. However this process depends on the amount of light available to the aquatic plants in water (Phytoplankton).

Therefore:

- Oxygen production decreases during cloudy days
- It stops at night
- It decreases in increase in water depth the rate of the decrease depends on the water turbidity

Measuring DO

DO can be measured by chemical or electrical methods.

Chemical methods rely on the use of kits which can be bought from shops dealing with laboratory equipment. They contain chemicals and equipment necessary to determine the DO content with sufficient accuracy for pond management purposes.

Electrical methods use an oxygen meter, this too can be bought from laboratory equipment shops but it is expensive. Using this equipment, DO can be measured directly from the pond at any depth.

DO and water temperature should be measured at the same time so as to be able to relate the DO to the temperature.

DO is expressed as mg of oxygen/litre of water (mg/l).

Table 2: DO requirements commonly farmed fishes in Kenya (in mg/l or percent saturation values)

Fish species	Ova and juveniles	Adults	
		Minimum DO level	Preferred DO level at least equal to
Trout	Close to 100%	5 mg/l (50%)	8 mg/l or 70%
Common carp	At least 70%	3 mg/l (30%)	5 mg/l or 50%
Tilapia	At least 70%	2 mg/l	4 mg/l or 50%
African catfish	At least 90%	1 mg/l or less (aerial respiration)	3 mg/l or 35%

Fluctuating oxygen levels
From sunrise to sunset

- *Photosynthesis increases the DO level*
- *DO production is higher in clear sky days than on cloudy days*
- *The higher the phytoplankton population, the higher the DO production.*

At night,

- *Photosynthesis does not take place*
- *Respiration and decomposition which are the main activities taking place, reduces the DO content until sunrise*
- *The higher the plankton population and dead matter, the faster the DO will fall*

There may be very little oxygen left by morning and fish may suffocate if corrective measures are not taken.

In over fertilised ponds, where there is very high plankton density and high turbidity, the bottom water may become anoxic (without oxygen) even during the day. The fish will concentrate at the surface of the pond to survive. This will be much worse at night.

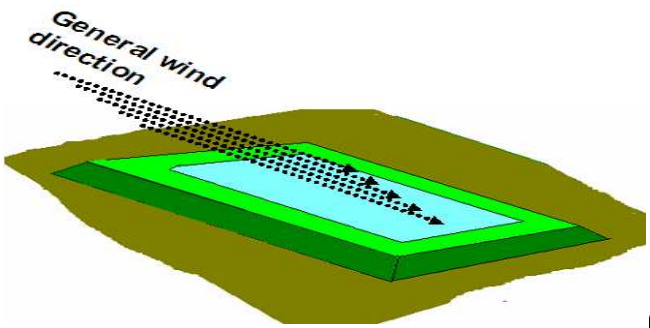
Where DO test equipments are not available, signs indicating reduced DO in pond water include:

- Fish not feeding well or even stopping feeding;
- Fish coming to the water surface to breathe from the better oxygenated surface water (this is called piping).

The DO content of pond water can be increased in several ways:

- Through design and management
- Through structures that cause water to splash e.g. by use of cascades along the inlet canal and raised inlet pipes before the water gets into the ponds
- By use of mechanical aerators for the emergency aeration of pond water

A simple way to ensure a good supply of atmospheric oxygen to fish ponds is in the design of the pond. The ponds should be designed such that they take maximum advantage of the winds. The ponds should be design such that the lengths are parallel to the direction of the important winds.



(Sketch by: Mbugua Mwangi)

Figure 2: Pond designed to take maximum advantage of the winds

Proper pond management can also improve the DO content of the water. The following measures can be taken before any emergency happens:

- Flashing the pond by removing the less oxygenated bottom water and replacing it with better oxygenated water
- Use of water aerators e.g. mushroom blowers or paddle wheels

Alkalinity and Hardness

It is desirable to maintain both alkalinity and hardness at 40-70 mg $CaCO_3$/L. This can be done by:

- Where water is "soft" or acidic and soils are acid, apply lime (agricultural limestone) to the pond soil at recommended rates before to filling the pond
- Lime may also be added after filling by spreading it uniformly over the water surface.
- In areas where soils are alkaline and hardness and alkalinity are high, application of lime is not required.
- Note that proper management of hardness and alkalinity will usually eliminate the need to worry about pH.

(See pond farming of tilapia)

Ammonia

Un-ionized ammonia (NH_3) concentrations in pond water should be kept below 0.5 mg/L. Concentrations of this form of ammonia, which is toxic to fish, are influenced by DO, pH, and alkalinity, therefore it is important to manage this by:

- Maintain water alkalinity at 40 mg $CaCO_3$/L or above
- Keeping pH near neutral, and at least below 9.0
- Keeping DO concentrations high

Toxic Materials

Substances toxic to fish and other organisms (herbicides, insecticides, and other chemicals) should be kept out of the ponds. Ponds should be protected by:

- Not using insecticides, herbicides, or other chemicals (except for recommended inorganic fertilizers) in or near your pond
- Keeping agricultural runoff from the ponds
- Avoiding spraying agricultural crops or animals near ponds on windy days

8 FISH DISEASES, PARASITES AND PREDATORS MANAGEMENT AND CONTROL

Introduction

Occurrence of disease and parasites in farmed fish is mainly as a result of poor husbandry. Disease causing organisms are always in the environment fish live in and they cause few problems. The pathogens naturally exist in a stable "equilibrium" with their hosts until this balance is disturbed through environmental changes and anthropogenic activities. Fish are stressed through inadequate dietary or environmental conditions. The water quality parameters such as pH, temperature, dissolved oxygen may lead to outbreak of disease pathogens and parasites.

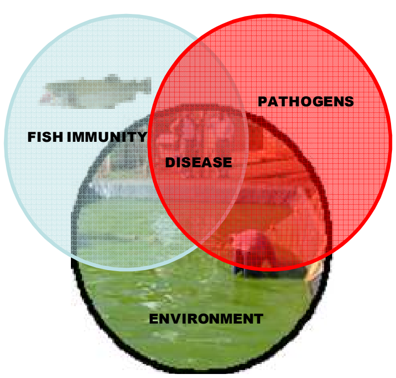


Fig. 1: Pathogens naturally exist in a stable "***equilibrium***" with fish

It is better to try to prevent disease occurrence than to wait to cure them once they start to cause problems. To cure a fish disease is much more difficult and may require the services of a specialist. By the time proper treatment can be sort, the disease may have caused a lot of damage.

Most disease problems in aquaculture result from things that can be avoided. Some fish stressors that lead to diseases that need to be avoided are;

- Poor handling of fish is a major cause of both bacterial and parasitic infections.
- Translocation of fingerlings/fry from one place to another without proper care can spread diseases and parasites.
- Increased nutrient levels due to intensive cage culture promote proliferation of parasites.
- Pollution due to high levels of ammonia predisposes fish to succumb to large numbers of parasites. Human faeces may be a source of gut parasites especially to common carp.
- Damages of fish by predators lead to secondary bacterial or fungi infections. The predators especially birds and mammals play an important role in life cycles of certain parasites.

Disease, parasites or pathogens may enter fish through gills, penetration of egg membrane, ingestion, rupture of skin, wounds or through the digestive tract.

Fish diseases may cause severe losses in fish farms through:

- Reduced fish growth and production;
- Increased feeding cost caused by lack of appetite and waste of uneaten feed;
- Increased vulnerability to predation;
- Increased susceptibility to poor water quality;
- Death of fish.

Main causes of disease in farmed fish

There are several causes of disease that may affect the fish directly or cause disease problems. Any factor which causes stress reduces fish ability to resist diseases and increases chances of problems occurring.

The three main causes of disease are:

1. **Poor feeds and feeding;**
   - When fish are not fed with the right food in the right way, nutritional diseases occur.
   - When fed with poor quality or contaminated feed, they get sick and even die
2. **Exposure to extreme conditions or toxic environments;**
   - Extremes in pH where the water is either too acidic or alkaline
   - Presence of toxic gases such as ammonia

- Lack of dissolved oxygen
- Overcrowding and/or behavioural stresses, for example in storage or transport
- Improper and/or excessive handling
- Toxins in food such as fungal toxins in stored feeds ,pesticide residues etc
- Water pollution by agricultural or industrial effluents, sewage effluents, heavy silt loads.

3. **Actual attack by disease causing organisms;**

Fish like other living organisms, can be attacked by successful disease organisms, either externally (on the skin, gills or fins), or internally (in the blood, digestive tract, nervous system).

Preventing diseases through proper management

Prevention is better than cure, so it is very important to:

1. *Ensure good water quality:* sufficient supply, with adequate dissolved oxygen and free of pollution
2. *Maintain clean pond environment by controlling* silting, plants and proper phytoplankton and zooplankton balance. Regular pond disinfection is recommended.
3. *Keep the fish in stress free conditions by* controlling stocking density, keeping different sizes separate to reduce fighting, providing proper food supply, handling the fish properly etc
4. *Prevent the entry of disease organisms by:*
    - Preventing entry of wild fish by using screens and eradication them from canals and ponds
    - Ensure that all fish got from outside to the farm are clean without parasites or diseases
    - Always using good quality feeds
    - Regular monitoring of the water entering the farm to ensure of its quality
5. *Prevent the spread of disease within the farm by:*
    - Controlling predators, particularly birds and mammals
    - Disinfect ponds regularly to kill both the disease organisms and their intermediate hosts
    - Avoiding water sharing among ponds
    - In case of disease outbreak, remove sick and
    - bury diseased fish with quicklime away from the ponds; carefully treat infected ponds and disinfect all e dead fish from the ponds immediately
    - Always disinfect pond and fish handling equipment

Common disease symptoms in fish

Behavioural signs:

- Decreased feeding
- Weak, lazy or erratic swimming
- Floating on water belly up
- Roughing against hard surfaces
- Crowding/gathering at the inlet

Physical signs

- Gaping mouth
- Open sores, lesions, loss of scales, bloated belly
- Pale, eroded, swollen, bloody or brownish gills
- Abnormally folded or eroded fins
- Cloudy or distended eyes
- Presence of disease organisms on skin, gills, fins

Fish diseases can either be:

(i) **Bacterial** – which causes diseases like fin rot and tail rot

(ii) **Fungal** infections – wooly or cottony patches on the surface of fish, and gill rot causing asphyxia.

(iii) **Parasititic**

- ***Ectoparasites*** **-** Those that occur outside the fish body for example those that cause Black spot, white spot, fish louse and Nematode.
- ***Endoparasites*** – Those that get into the body of the fish like the Contraceacum, and the *Ligula intestinalis*.

(iv) **Dietary** – High carbohydrate levels in trout feeds, lack of proteins and lipids will result to liver tumour.

Some common fish diseases and their prevention

PATHOGEN	SYMPTOM	PREVENTION
Fungus	• Cottony grey-white or brown patches on the skin	• Proper fish handling • Avoid handling fish in cold water. • Low organic matter in water
Trematodes	• Black spots • Yellowish cysts on gills	• Control snails and control predators like birds. • Remove infected fish.
Bacteria	• Loss of appetite. • Fin and tail rot. • Pale gills	• Improved water quality

	• Fluid in abdomen	
Nematode (Contracaecum)	• Round worm in spiral shape near gills	• Not really a problem for fish health but leads to consumer dissatisfaction
Parasitic protozoan	• Fish try to scrap their bodies on hard surfaces (flashing)	• Salt, potassium Permanganate or formalin bath. • Keep water temperature near optimum range for that species of fish.

Nutritional Diseases

CAUSE	SYMPTOM	PREVENTION
1. Lack of proteins	-Poor growth. -Caudal fin erosion. -Loss of appetite.	-Feed protein rich food e.g. soya beans, slaughterhouse by-products, fish meal.
2. Lack of lipids	-Poor growth	-Feed with energy-rich foods

The following points should be followed in treatment of infected ponds.
Ponds with infections should be drained and badly infected fish culled.

- Dry the pond under the sun for about seven days
- Dampen the pond bottom
- Spread Lime (Calcium carbonate) evenly over entire surface of pond bottom at the rate of 1500 kg/Ha
- Wait for 15 days then restock the pond with healthy stocks.

Some common chemicals for use in fish farming

Limes and agro-industrial by-products e.g. rice bran and molasses: Pests control in drained ponds
Organic poisons such as rotenone can control pests in filled ponds
Household bleach is a good disinfectant of *non-metallic equipment* and working areas.
Chlorine bleach liquid and powder can be used as a strong disinfectant for fish handling equipment
Common salt is cheap and easily available. Kills several disease organisms and have positive effects on the fish by stimulating appetite and increasing mucus secretion, improving resistance to handling.
Formalin is toxic to fish particularly in soft water because it lowers dissolved oxygen levels, make sure treatment water is well oxygenated.

Some common fish predators and their control measures

Predator	**Type of fish eaten**	**Control measure**
Insects and insect larvae	Juvenile fish and eggs and fish just hatched.	i). Oil emulsion to prevent aerial breathing. ii). Use of fish that feed on insect larvae especially those that have gills and can remain in the bottom.
Frogs and toads	juveniles of tilapia and catfish	i). Fence with frog proof wire mesh. ii). Clear bush around pond. Screen both in and outlets. iii). Use traps. Adult catfish and bass eat frogs.
Fish	all types of fish	i). Use screen in the inlets and outlets. ii). Do pond draining periodically
Snakes	destroy larval and juvenile fish	i). Clear bush around the pond and fence properly.
Crocodiles, alligators and large lizards.	All types of fish	i). Proper fencing and keeping dense bushes cut down.
Turtles	prey on catfish	Fencing around pond with wire mesh, trapping.
Birds: Wading birds e.g., Herons and egrets Diving birds. Kingfisher, fish eagle cormorants, pelicans	All types of fish and at all stages especially in shallow waters. Cormorants feed on fish just after the fish are fed- when they are most concentrated.	i). Proper fencing all round and then above with netting material or manila ropes/strings on poles with bright coloured cloth or metal crossed over the pond. ii). cover ponds with nets or wire mesh, use flash guns, windmills that revolves and flash brilliantly and bells to scare the birds a way. iii). The birds can also be actively discouraged by destroying their nests
Otters	Prey on large fish at night killing more than they can eat. They burrow and live under the roots of trees near the water. Otters are very clever They can even open latches on gates.	i). Proper fencing around the ponds. ii). The otters can also be trapped using special otter traps set in their passages. iii). Guard by use of trained dogs. iv). Fence the pond half way across giving allowance for fish to pass through but not he otter thus providing hiding places for fish.

Man (theft)	All types of fish. This is also considered among the major predators through which fish are lost.	Extremely difficult to control and is most common in cage culture and other intensive fish farming. Can however be controlled by i). Employing security personnel ii). Use of trained dogs iii). Hidden obstruction to prevent pond seining. iv). Fence the farm and lock securely. v). Burglar alarms or electrified fence

- If the situation is bad, then trapping or shooting can be used as the last resort in cases of birds and otters but in consultation with the relevant authorities for example the Kenya Wildlife Authority

- Be very careful when poisoning predators, humans and non target animals can be affected

9 FISH NUTRITION, FISH FEEDING AND FEED FORMULATION

Introduction

Compared to terrestrial animals, fish have certain specific characteristics in terms of dietary requirements:

- They have lower energy requirement
- Require less lipids in feed (except for cold water species such as trout)
- Can directly absorb certain mineral element from water medium

There are three types of food used in aquaculture:

1. **Natural food** occurs naturally in fish ponds. This includes detritus, bacteria, plankton, worms, insects, snails, aquatic plants and fish. Their occurrence and abundance depends on the water quality and in particular fertilization.

2. **Supplementary feeds** usually consist of feed materials available locally such as terrestrial plants or agricultural by-products like wheat bran.

Many kinds of feed materials may be used as supplementary feeds for your fish such as:

- Terrestrial plants: grasses, leaves (e.g. cassava)and seeds of leguminous shrubs and trees vegetables;
- Aquatic plants: water hyacinth, water lettuce, duckweed;
- Small terrestrial animals: earthworms, termites, snails;
- Aquatic animals: trash fish;
- Rice: broken, bran, hulls;
- Wheat: middling, bran;
- Maize: gluten feed, gluten meal;

- Oil/cakes after extraction of oil from seeds of mustard, coconut, groundnut, cotton, sunflower, soybean;
- Cottonseeds;
- Brewers wastes and yeast;
- Slaughterhouse wastes: offal, blood, rumen contents;
- Manure: chicken droppings, pig manure

Supplementary feeds are available in two forms

i). **Dry feedstuffs** such as cereals and cakes with about 10% moisture. These are easier to transport, store, and to distribute to the fish.

ii). **Wet feedstuffs** such as blood, rumen contents, molasses and brewery wastes with 30 to 50% moisture. Moist feeds do not keep well, and only small quantities should be prepared at a time. These feeds require special treatment, for example mixing with dry feedstuffs to absorb part of the moisture or drying to improve storage life before feeding.

3. **Complete feeds** are made from a mixture of carefully selected ingredients to provide all the nutrients necessary for the fish to grow. They are made in a form which the fish find easy to eat and digest. These feeds are difficult to make on the farm and are usually expensive to buy. Under intensive systems, feed provided to the fish must meet all their dietary requirements. The fish rely wholly on exogenous feeds. The feeds must be complete in terms of nutrients supply.

Fish Dietary Nutrient Requirements

Protein

- Important tissue building component
- Also important in repairing worn out tissues
- Important to juveniles for growth.
- Fish requires much more protein levels in feeds compared to most domestic animals

In semi-intensive production, protein comes from the algae (resulting from proper pond water fertilization) and exogenous feeding with supplemental feed. However in intensive production of tilapia, the diets should have 28-32% protein.

Carbohydrates:
Provides energy needed by the fish to carry out its physiological activities like respiration. Any excess is converted and stored as lipids

Fats
They are utilized to supply energy like the carbohydrates. They also provide structural support and act as precursors to physiological chemical processes. Excess of fats reduce the marketability of fish. Diets for adult fish should not have high amounts of lipids because it accumulates and reduce flesh quality. Trout is

able to utilize fats much more effectively and can ingest considerable amounts with their diet.

Deficiency in essential fatty acids result in reduced growth, de-pigmentation, erosion of fins, fatty liver and even shock.

Vitamins
Vitamins are required in very small quantities but play a major role in the chemical processes within fish body. Deficiency results in poor health and deformities.

In artificially produced feeds, a balanced mix of vitamins and minerals (premixes) can be obtained from specialized feed manufacturers. They should be used in proportions that meet the nutritional needs of the fish under culture.

Minerals
These are inorganic elements needed for various metabolic functions. Fish can obtain some of them through the gill surfaces into their bodies. Some important minerals include calcium, potassium, sodium and magnesium.
Other feed additives
Some feed additives that could be used in fish feeds includes attractants, binders, dyes and medicinal agents like vaccines.

Feed Conversion Ratio (FCR)

- Feed conversion ratio (FCR) is calculated from the kilos of feed that are used to produce one kilo of whole fish
- It tell a farmer the amount of fish feed needed to produce one kilo of fish
- It can be used to estimate the quantity of feed needed in a production season for a given crop of fish
- For example, if the estimated FCR for a feed is 3:1, it means that a farmer needs 3kg of that feed to produce 1kg of fish.

It is important to note that:

i). Small fish need more food than larger ones.
ii). Where there is plenty of natural food, less supplementary feed should be used
iii). Where low stocking densities are used, less supplementary feeds are used
iv). The better the quality of the feed (low FCR), the less the quantity needed to feed the fish
v). More food is required in warm water than in cooler water.
vi). It is therefore recommended for producers to constantly adjust the feeding throughout the production cycle for better results.
vii). FCR will be affected by Overfeeding, poor feeds, poor pond fertilisation for semi intensive production and poor fish health.

FISH FEEDING
It is normally not easy to estimate the amount of feed to provide to each pond. However, the following should be avoided:

- Under feeding, will lead to loss in fish production;
- Over feeding, uneconomical (higher production costs) and may also result in poor water quality

A producer must at all times know approximately how many fish and how big they are in each pond to be able to estimate the amount of feed to give.

How to feed:
For most fish, feeding twice a day is sufficient – at about 10 AM and 4 PM. Earlier than 10 am in the morning, the water is a bit cold and oxygen levels are low so this is not a good time t feed the fish.

If you feed at close to the same time and at the same place in the pond every day, the fish will learn to come for the feed.

Recommended feeding rates for tilapia or tilapia/clarias polyculture

Approx month after stocking	Assumed size of fish	Amount of wheat bran per day	Pelleted diet (26% protein)
1-2	5-20g	1 g/fish	1 g/fish
2-3	20-50g	1-3 g/fish	1-2 g/fish
3-5	50-100g	3 g/fish	2 g/fish
5-8	100-200g	4 g/fish	3 g/fish
8 or more	Over 200g	5 g/fish	3-4 g/fish

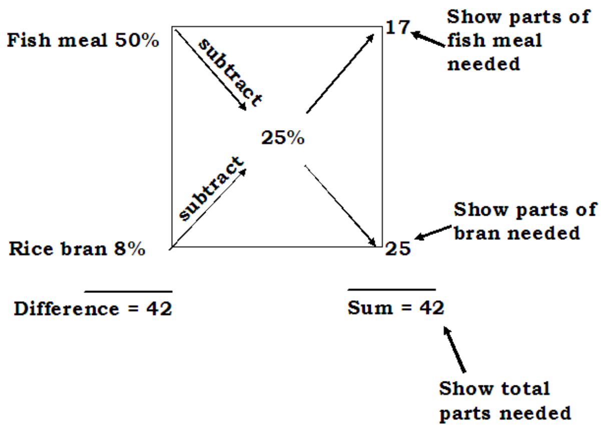
FEED FORMULATION

The purpose of feed formulation is to ensure that the aquaculture diets meet the nutritional needs of the fish under culture during it various stages of growth. Therefore, for one to be able to formulate a specific feed for a particular fish, they need to know the following nutritional needs as regards the fish:

- Crude protein
- Crude fibre
- Energy
- Specific amino acids and
- Ash

The most common and simplest method of formulation fish feeds in Kenya is the square method.

For example, if the desired feed should contain 25% protein, and there are two ingredients to use (fish meal with 50% protein and rice bran with 8%)



i). The desired protein level is inserted at the centre
ii). The two ingredients with their protein levels are place at each corner on the left hand side of the square
iii). The differences between the centre and each feed ingredient are place at each corner on the right side diagonally opposite the ingredient (ignoring the plus or minus signs)
iv). The upper right hand corner in this example indicate the proportion of fish meal needed and the lower one that of rice bran
v). This can be expressed as
    a. Ratio i.e. fish meal:rice bran 17:25
    b. Percentage 17/42 = 40.5% for fish meals and, 25/42 = 59.5% for rice bran.

10 RECOD KEEPING IN AQUACULTURE

Introduction

One of the main drawbacks on the economic operation of aquaculture investment in Kenya is lack of deliberately kept economic records of production operations. Investors who operate without records are likely to make wrong decisions due to lack of information of what is happening in their farms.

The best sources of information needed to advice on proper running of aquaculture investments are properly designed and kept farm records.

What Is Record?

Record is information that has been systematically and carefully collected and appropriately stored for intended use. To be able to run any business successfully, carefully thought out, properly collected and kept records are a must. For the purpose of keeping track and decision making in any business, comprehensive and well kept records must be kept.

Just as in any other enterprise, properly collected and kept records are important in fish farming enterprises.

The records will:

- Be used in Determining profitability of various techniques of production or systems
- Be used to compare the efficiency of use of inputs, such as land, labour and capital, with that of alternative production activities
- Help the investor in improving the efficiency of farm's operations
- Be used to preserve institutional memory of the enterprise for future reference

Good records will, for example;

- Be useful in projection of expected production
- Be useful in determining the amount of inputs requirements for specific ponds at various stages of production
- Be useful determine the expected harvesting time
- Determine the financial health of the enterprise

Some important aquaculture records parameters in include:

- Capital investment costs e.g. cost of constructing ponds, hatchery etc
- Total area under culture
- Individual pond identity
- Individual pond treatments
- Stocking densities and time of stocking
- Species stocked
- Kinds, quantities and cost of inputs used
- Pond productions in amounts and values
- Other productions and values
- Daily occurrences

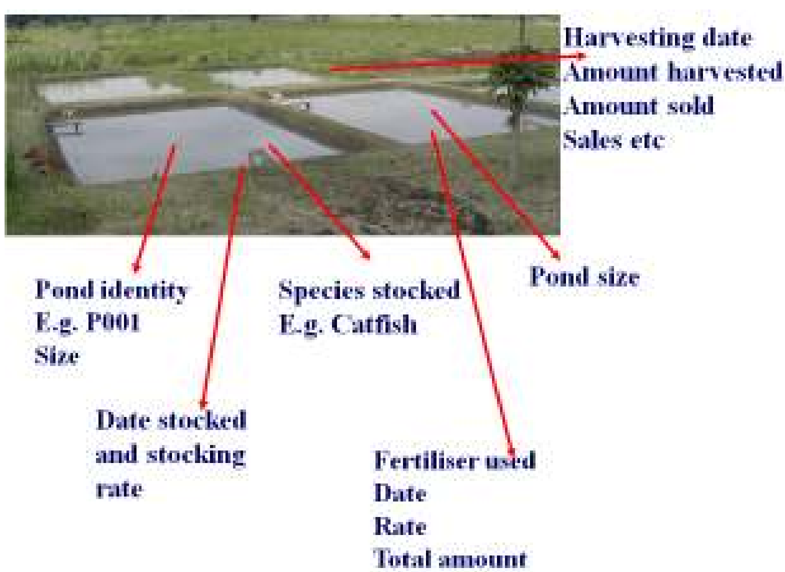


Fig. 1. Some important parameters in aquaculture records (MbuguaHM)

Classification of aquaculture records

Aquaculture records can be classified into:

- Daily records kept for input usage like feeds, fertilisers, labour and daily occurrence
- Occasional record which are kept for events that do not happen on daily basis. Such records would include:
  - Specific pond production (Quantity and values) by species
  - Costs of acquisition of inputs
  - Cost incurred in new constructions or repairs
  - Salaries (both in cash and in kind)

Level of record keeping

How much and how comprehensive kept records are, is dependent on:

- Level of investment; Complex investments require complex records
- Motivation of investor; Serious investors will have more comprehensive records
- Level of aquaculture management: Intensive operations will have more complex records as compared to semi intensive operations
- Skills of the investor (Or manager); Well trained managers will keep better records

As the management levels rises, culture systems become more complex and so is the record keeping. This is the reason the farmer must think very carefully of what he needs to record.

Examples of aquaculture records

- Fish farming biological management records
- Financial management records

  Purchase of inputs
  Sales records
  Salary records
  Inventory of equipment
  Records on payment of rents and hire of equipment, machinery, services etc
- Occurrence book

It is very important for individual farmers to clearly know what they need recorded and the intended use of this. This will assist them in preparing the most effective way of capturing the needed information.

Some examples of simple aquaculture records would include (but not limited to) the following:

Pond management records

Pond Identity:						
Date	Type of input	Rate of usage	Total usage	Unit cost	Total cost	Remarks

Stocking records

Date	Pond Identity	Size (m^2)	Species	Source	Stocking rate	Average Weight	Total number /weight	Unit cost	Total Cost

Harvesting/sales records

Pond ID	Date	Harvest		Amount sold			Amount consumed on farm		Amount given away		Payment in kind		Total value of produce
		Species	Quantity Kg	Quantity Kg	Unit Price Ksh/ kg	Total value Kshs	Quantity Kg	Value Kshs	Quantity Kg	Value Kshs	Quantity Kg	Value Kshs	

Please note that all produce that is lost through spoilage, being undesirable to the market etc, should be captured in the records

Cash flow records

Cash inflow				Cash outflow			
Date	Source	Amount	Comments	Date	Activity	Amount	Comments

Other records to consider include

- Salary records
- Farm inventory records
- Records on payment of rents and hire of equipment, machinery, services etc
- Pond sampling records

11 SOME IMPORTANT COMMERCIAL AQUACULTURE SPECIES OF KENYA:

NILE TILAPIA (*Oreochromis niloticus*) *Mbugua h. m.*

- Tilapia are indigenous to Africa, but have been introduced in many parts around the world.
- They are disease-resistant
- They are prolific breeders and reproduce easily under culture conditions
- Feed on a wide variety of foods and tolerate poor water quality with low dissolved oxygen levels.
- Can grow in brackish water and some will adapt to sea water
- Mainly grow under semi intensive systems as monoculture, males only monoculture or polyculture with African catfish
- Optimum temperature range 27-30^{0}C
- Very popular in Kenya and have a good market in world
- Fillets yield is from 30% to 37%, depending on fillet size and final trim

AFRICAN CATFISH (*Clarias gariepinus*)
Mbugua h. m.

- Indigenous to Africa.
- Can be described as omnivorous eating vegetable matter, zooplankton, insects, snails, tadpoles, leeches, small fish etc
- Very hardy and can survive in low oxygen waters
- Can grow in brackish water in salinities of 10ppm
- Has ability to breath atmospheric oxygen
- Do not breed in captivity and artificial spawning is used
- Grows very quickly if adequate high protein feed is available.
- Few bones; has higher fillet percentage than tilapia
- Mainly grown in semi intensive polyculture systems with tilapia
- Optimum temperature range 25-27^{0}C
- A good candidate for rural aquaculture in developing countries

Mbugua h. m.

RAINBOW TROUT (*Oncorhyncus mykiss)*

- Native of North America but has been introduced and farmed all over the world
- A carnivorous fish which in natural waters consumes insects, crustacean and other small animals
- Grows well in cool fast flowing waters, 10-18°C, with high oxygen content
- Under culture conditions, require a water flow rate of 1 L/min/kg without aeration
- Trout will not spawn naturally in aquaculture systems and artificial spawning is used
- Produced in intensive systems in tanks and raceways
- Restricted to highland areas in tropical regions where favourable conditions allow
- Requires high quality feed, >40% protein.
- High market price, especially when fresh
- Fine bones; high fillet percentage and excellent when smoked

COMMON CARP **(*Cyprinus carpio*)**

- An exotic species that has established itself in natural water bodies in Kenya
- An omnivore feeding on both plant and animal matter
- Its habit of feeding on organisms at in mud at pond bottom, maes the pond water muddy
- Eats a variety of supplementary foods including brans
- Very limited aquaculture production in Kenya where they are grown under semi intensive systems
- Attains a large size and does not usually overpopulate a pond
- Optimum temperature range, 23-26 ^{0}C
- Poor market in Kenya due to intramuscular bones but popular in Asia

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